A “Flight Manual” for Air Plants

The green fabric that clothes the earth is fraying. Sadly, through overuse, the garment we depend upon is wearing out. The construction of buildings and urban infrastructure like roads and car parks become “dead pixels” in the living image of the planet. Repairing the old garment by stitching plants into the structures of our cities is a vital option. Incorporating plants into tall building design is an important aspect of this restoration project. This paper describes the successful installation of plants on the exterior of Melbourne’s iconic Eureka Tower (see Figure 1) and provides an example of a selective vertical gardening system with a high Environmentally Sustainable Development (ESD) factor, which eliminates the requirement for plant growth substrate.

The Importance of Vertical Gardens

From simple organisms, evolving through millions of years to complex biological systems, vegetation has obeyed its innate compulsion to cover the planet with a living green membrane that supports all other life. Plants have waxed and waned in their flight to cover geological surface since the Cenozoic era (45 million years ago), and as we progress through our current era, the Anthropocene, it is evident that human actions are the primary determinant for the survival or extinction of species. The exponential rate at which our cities have expanded demands that we now plan and act to integrate our urban centers into the biosphere of the planet. The combined surface of high-rise buildings and other urban infrastructure can provide significant areas to support plants, and weave back the threads of green fabric.

Integrating plants into the built environment improves air quality, moderates temperatures (Saadatan et al. 2013), improves human well-being, lifts the spirit (Townsend & Weinarsurya 2010), and can provide habitat for other species (Obermiller et al. 2007). In March 2015, it was promising to see a law passed in France, which mandates that rooftops on new buildings built in commercial zones must either be partially covered in plants or solar panels. This mandate draws a line, whereby inspiring contemporary architecture will be measured by the successful integration of living green texture into the fabric and form of the structure. Imagination and experimentation have driven a welcome expansion of roof and vertical gardens in recent years. The urban tall buildings we now see may quickly become historic symbols of a past age, when architecture was less connected to nature.

Vertical Garden Systems

Utilizing living plants as an effective façade poses many problems. Unlike metal, glass and concrete, which are inert, plants require nurturing. Concerns over increased maintenance costs (Zhang et al. 2012), damage to façades, and increased loading on structural systems (Wood et al. 2014) are barriers to the implementation of green roofs and walls. Zhang et al. provide a succinct definition of “intensive” and “extensive” green roof systems.

Intensive green roof systems are characterized by deep (greater than 15 centimeters) growing media, opportunities for a diverse plant palate on the rooftop, and high maintenance requirements. In many cases, intensive green roofs are being replaced by extensive green roofs, which have a much thinner, lighter media (thus fewer structural requirements) and offer fewer, but potentially more practical plant choices.

Building on Zhang’s categorization of green roofs, the authors propose that incorporating vertical gardens into a building’s design can employ two systems, which are adaptive or selective.

Adaptive systems

Analogous to intensive green roofs, adaptive vertical gardens require the environment to be
adapted to support the plants' biological demands, which will vary depending on the ecophysiological characteristics of the selected species. This condition is met by mesh-mounted plant growth substrate, irrigation and fertilization. The benefit of adaptive systems is that they allow a greater selection of species; however, they have limitations, including the cost of installing and maintaining structures to support plant growth substrates (Pérez et al. 2011).

Selective systems
Akin to extensive green roofs, selective systems use critical species selection to identify plants that naturally grow in environments similar to those encompassing an existing building’s façade. They have the advantage of reducing or eliminating the requirement for plant growth substrate and associated installation and maintenance costs. The limitation of selective systems is a reduced plant palette.

Drought tolerance
Bromeliads minimize transpirational water losses by utilizing the cassisulenan acid metabolism (CAM) cycle, in which the stomata are closed in the heat of the day and open to uptake CO₂ at night, releasing oxygen during darkness (Benzing 1990). Moisture and nutrient uptake occur through specialized trichome cells, further reducing transpirational water losses; these adaptations make Tillandsia very drought-tolerant.

No requirement for soil
One adaptation of Tillandsias to the epiphytic life-mode is the modification of the role of the roots from that of moisture and nutrient absorption to that of “hold fasts” that function only to attach the plant to the substrate (Benzing 1990). The leaves of the plant replace the role of the roots and sequester moisture and nutrients directly from the atmosphere.

Absorption of airborne pollutants
The trichomes of Tillandsia have a high absorptive capacity, which allows them to absorb air pollutants rapidly (Li et al. 2015). The installation of large Tillandsia screens on tall buildings has the potential to act as an air filter for the building and surroundings.

Minimal weight
Based on previous installations, the weight of a Tillandsia screen is estimated to be 3 kg/m², which is minimal in comparison to adaptive systems that require plant growth substrates and supporting structures. The light weight of Tillandsia means they are perfectly suited for use on screens (Pérez 2011) and can be placed in arbitrary shapes on the building.

“The leaves of the Tillandsia sequester moisture and nutrients directly from the atmosphere, removing the requirement for a plant growth substrate to be installed on the building façade.”

Figure 1. Eureka Tower, Melbourne. © John Gollings

Figure 2. Tillandsia, the “air plants” chosen for the experiment.
exterior (Wang et al. 2011). Plant screens have demonstrated effectiveness as passive energy-saving systems (Pérez 2011).

Methods

The project team installed eight Tillandsia plants in wire cages in groups of two, affixed to secure points at four locations on the Eureka Tower. Plant cages were installed at Levels 56, 65, 91, and 92 (see Figure 3). The aspect of the building at which the plants were placed was determined by the location of available balconies and cage attachment points. Plants were photographed and labeled prior to placement in the cages.

Plants were inspected four times in the period between June 17, 2014 and May 20, 2015, and health categories were recorded for each specimen (see Table 1 and Figure 4). The proportion of living foliage was used to evaluate plant health (Costello 2005) and observations were assigned to one of six ordinal health categories: These were dead (<10% live growth), very poor (<25% live growth), poor (<50% live growth), fair (50% live growth), good (>75% live growth), and excellent (>90% live growth). Plant health was assessed by visual observation of each leaf of the subject plant. When an individual leaf was in a state of decline (>35% dead tissue) this was categorized as dead. The relative proportion of live and dead leaves was used to assign a health category to each plant. No supplementary irrigation or fertilization was provided to the plants during the installation period.

Weather records were obtained from the Eureka Tower meteorological station, and periods of low rainfall and high temperatures were identified during the survey period.

Results

During the October 16, 2014 inspection session, some leaf die-back at locations farthest from the growing tip was observed. This is attributed to the acclimatization of the plants to the new environment. All of the plants maintained high levels of health, with the exception of one on Level 91. This plant was located in the most sheltered position, an external stairway niche receiving the least rain and sunlight.

During the February 25, 2015 inspection, this plant was observed to be the only plant to have flowered during the experiment period and to have formed new “pups” (vegetatively produced new plantlets). During the May 20, 2015 inspection, plants on Levels 56 and 65 were also observed to be forming pups.

Discussion

The trial results indicate that Tillandsias are able to survive on the exteriors of tall buildings without supplementary irrigation. At approximately 300 meters above grade, the Level 92 installation is the world’s highest plant installation on a building and a proof of concept for selective vertical garden systems.

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Table 1. Tillandsia installation results over time.
plant installation on a building and a proof of concept for selective vertical garden systems.

Buildings within the urban environment are essentially pieces of refined geography, so when endeavouring to integrate plants into high-rise buildings, one must first observe plants that inhabit similar hostile environments in nature. Basically, buildings are high vertical cliffs of rock with no humus, often no water retention, and extreme temperature changes, which is the type of environment to which some species of Tillandsia have adapted and thrive in. Plants on tall buildings are subjected to high wind speeds and limited soil volumes, which places great pressure on irrigation systems to provide water to counteract transpirational losses. Such demanding ecophysiological environments mean that, for some plant species, no matter how much water is provided to the root system, they are simply not able to uptake water at the rate of transpiration. For adaptive systems the functioning of the irrigation is critical, and there have been high-profile cases of green walls dramatically failing (Klettner 2009). The advantage of selective systems is that they are insulated from this threat.

The CH2 building experiment
In 2011, the opportunity arose to stage a demonstration of the Tillandsia in a vertical urban condition. Collaborating with Ralph Webster, senior architect of the Melbourne City Council, the opportunity came to experiment with a few air plants in a demanding location on the new CH2 building located at 240 Little Collins Street (see Figures 5, 6, and 7). Existing climbing plants had struggled to thrive along the north wall, which is subject to very hot, dry winds, with the wind tunnel effect of a narrow alley exacerbating the dehydration. After 18 months, the Tillandsias proved that, while they grew slowly, they could thrive solely on their adaptive biological systems, requiring no soil or reticulated (pressurized) watering system, whereas the climbing plants originally installed continued to struggle. By February 2015, the climbing plants were still in place, but covered much less of the netting than in 2011, suggesting the effort to replant and maintain them had exceeded the environmental reward. The simple experiment offered a model for a larger project with City of Melbourne – Airborne.

The Airborne project
Supported through a City of Melbourne Arts Grant in 2013, the Airborne project presented eight air plant sculptures, which were installed for 13 months in central Melbourne with no soil or auxiliary watering system in a demanding location: Les Edel Plaza, Northbank, Melbourne, adjacent to a busy rail corridor at Flinders Street Station. Despite prolonged periods of dryness, including record heat (with five consecutive days over 41°C), the plants grew and even flowered.

After 13 months, the growth habit of the plants had changed. They were more compact in structure, with shorter, harder leaves, and more silver in color due to increased levels of trichomes. However, pup production was more prolific, with seven or eight per plant, many more than in a less stressful location, where pup production
might normally be two or three. The authors attribute the increased production to the plants’ biological “insurance” – if one or more pups die, then the plant has more reserve shoots from which to prosper. Also, a clump of plants creates greater shade, protecting other plants in the colony. Of several thousand individual Tillandia used on the eight sculptures, only two plants died during the 13-month installation.

Rotating on swivels, the air plant sculptures dissipated energy instead of becoming excited, as a fixed sail might. During this period, a storm with winds of up to 115 kph rippled a large sculpture from its mounts only a few hundred meters away, and tragically brought down a brick wall that killed three people – but it had little effect on the living sculptures. While vertical and rooftop gardens occupy surfaces, the Airborne project proved that air gardens can successfully step beyond earthly confines to suspend between structures in open space, providing living overhead screenings (see Figure 8).

**Biological Insurance**

The Eureka air plant experiment strongly suggests that Tillandia plants can be grown with no soil or auxiliary watering system on the tallest of buildings in a city like Melbourne, and opens a portal for installing plants in a creative but effective and environmentally beneficial manner on high-rise buildings. The management of the Eureka Tower was very supportive of the experiment, and there is potential for a larger project in the future.

The authors continue to believe that “air plants” provide a significant advantage over plants that need to be supported by active watering and fertilization systems, not least because of the probability of “extreme events” that could rob the plant of its water and/or nutrients.

With a reticulated watering system, an extreme event might be:

- a pump failure, blocked pipe or drain
- a weather event like wind, cold, heat, or drought
- tracking, a condition where the liquid drips from the wall down a leaf surface, and falls onto the ground below, which denies water to the plants below the point.

Vertical and roof gardens most often fail because these factors are not considered or maintained. Because Tillandia has no need of soil medium or a reticulated watering system, the risk factors are reduced. Importantly, there is also no risk of water ingress to undesired aspect of a building, nor is there risk of roots penetrating and damaging the façade or structure.

Therefore, even if such an experiment should prove a “failure” with widespread plant deaths, the lightweight characteristics of the Tillandia would not pose the same kinds of issues as hard-tissue plants like vines, such as scarring on and penetrations in the façade, if at any time they were detached from the building.

**The Future: A “Flight Manual” for Air Plants**

Buildings are statements; architects define surfaces and geometries within the overall structure through the use of metals, glass, concrete, and synthetics. However, responsible architecture in the 21st century not only considers the advantages of plants within the urban environment and simply “acks” a vertical garden onto a wall, but draws from the diverse array of possible living textures of green, juxtaposing them against existing materials and textures, into the overall visual design of the structure at the concept stage. The addition of this new living material offers an exciting potential for the future, where imagination can soar to greater heights.

Imagine tidal gardens with multiple screens that move independently at various rates up and down a building’s façade. Imagine whole façades of plants that shimmer on the wind and move from aspect to aspect on a building. Imagine a modular system, where Tillandia are suspended across an open public space like a plaza during summer, creating dappled shade, and then simply moved onto a building’s façade for the cooler winter months when the sun is welcome. Imagine roof gardens with suspended Tillandia screens designed to create modulated shade patterns to complement other, less stress-tolerant plants that might grow on the roof surface below.
Tillandsia screens (see Figures 9 and 10) could be:

- moved horizontally or vertically in parallel from the building’s façade across a window
- rotated on a curved axis, so while they can be set to block direct sunlight, they can also allow a clear view out the window
- set on a swivel off the building and rotated
- positioned horizontally out from the building for shading, or hinged upward.

Because there is no need for reticulated liquid screens of Tillandsia can defy gravity in ways that are restrictive for other vertical garden systems. They can be mounted on façades that overhang or have complex, intricate geometric or organically curved surfaces. For future green architecture, they offer a flexible living texture which, with little maintenance, can be juxtaposed against glass, steel, or concrete. In fact it is possible to create living façades that alter their shape and form during the day.

As bromelids grow asexually over time they can be harvested to provide a biosource to create new material. A significant advantage of integrating Tillandsias into a green building design is that a “living wall” can be completed in sections, along which, over time, the plants are harvested and assigned to the next section of a wall. High-rise façades might be completed several levels at a time. Unlike current vertical gardens, there is no operating cost of water, pumps, and no need for replacement plants.

The results of these experiments with Tillandsia over the past few years have shown that designers can act with the knowledge and confidence that these systems work. Air gardens break new ground, offering fresh dimensions by incorporating plants in our cities for high environmental benefit. They write a “flight manual” for plants to escape their earthy confines in the urban habitat and occupy new and existing space within our cities.

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References


