Ecological Scaffolds

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Architectural Infrastructures Informed by Root Morphologies and Growth Patterns

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ABSTRACT

Over the past 15 years, the integration of 3D printing and plant science has evolved from creating structures for plants to incorporating plant materials directly into the printing process. This shift highlights a growing relationship between additive manufacturing and botanical applications, driven by advancements in technology and interdisciplinary collaboration among plant biology, materials science, and engineering. In architecture, these advancements promote circular economy principles by using biodegradable structures and indoor planting to sequester carbon dioxide, potentially resulting in carbon-neutral buildings. However, their success depends on understanding the relationship between plants and their environments, especially concerning root morphology and growth space. Commercial practices employ modular designs that replace entire plants or modules to maintain green walls. This modularity addresses issues of confined growth space, where plants that become root-bound are replaced. In systems like GSky's potted rack, root confinement may occur within 8-12 months (Burchell), while Semper Greenwalls see less than 5% replacement annually (Sempergreen, 2023). Despite manufacturers' efforts to improve automation and support, the fundamental issue of root growth remains unresolved, leading to increased operational energy and carbon emissions due to replacement. Designing living systems for interior environments presents global challenges. The global market for green systems was valued at approximately $2.4 billion in 2022 and is projected to grow to $5.3 billion by 2031 (Straits, 2023). To bring these numbers into a smaller scale, for a 500-square-foot live green wall, annual plant replacement costs reach $2,250 (Green, 2022). Extrapolating this to the projected 30-40 million square feet of greenwalls by 2031,

1 Detailed view of root growth in Gradient Density Matrix Prototype #4, 3D Printed Prototype Using Formlabs Fuse 1+ 30W SLS Printer, Printed with Nylon 12 Material, Size: 1.5" x 3" x 4", Growth study of Salvia hispanica, May 2021.

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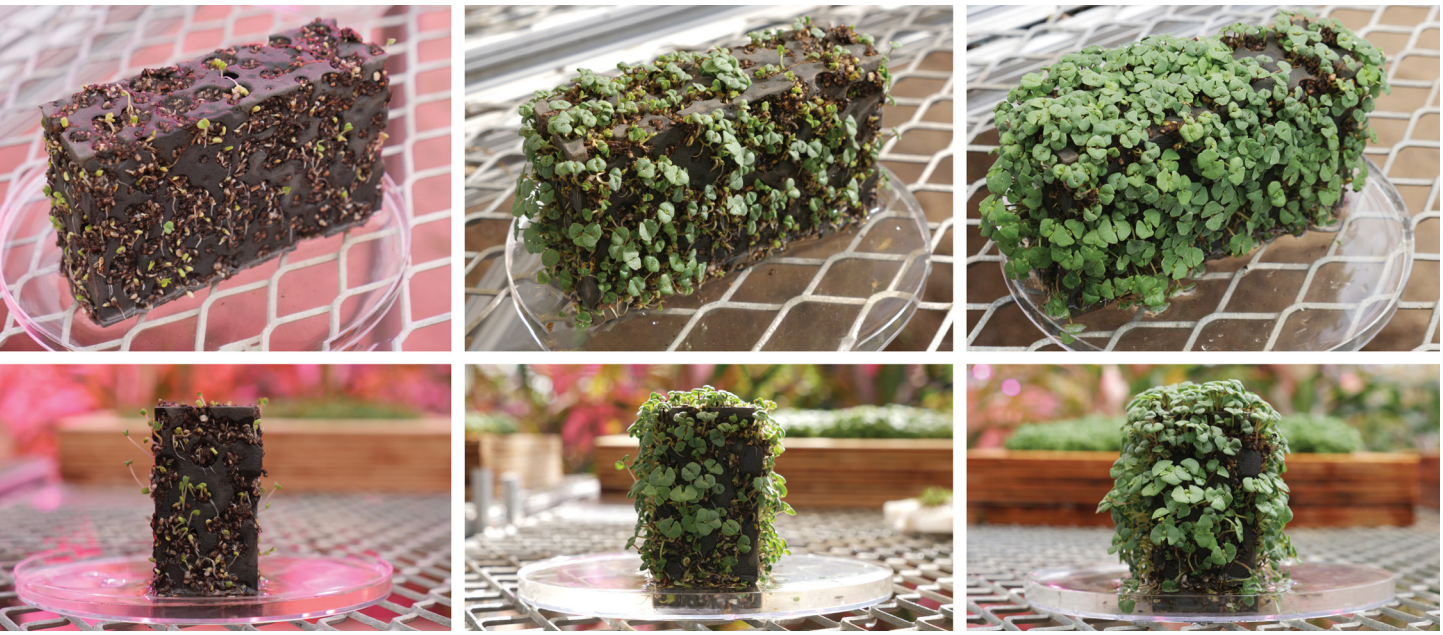

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implies replacing 750 million to 1 billion plants annually, costing between $135 to $180 million. Given these challenges and projections, it is essential to reassess the sustainability of current design practices for living systems. Research should focus on developing resilient, low-maintenance solutions that minimize financial and environmental costs while addressing root growth issues critical to plant health. Our labs research on root morphology explores three main areas to address these concerns. Materials that support growth, both synthetic and natural, testing for pH, plant physiology to assess water uptake, nutrient absorption, and root respiration. Forms for root growth: Understanding root performance in various spatial arrangements including digital and analog fabrication, using advanced imaging techniques for non-destructive analysis and computational design for simulation growth and geometric form-finding. Environmental factors impacting root health: This encompasses light quality, humidity, CO2 exchange, and practical horticultural areas such as pruning and pest management. In this category species are also considered and research of plants with the proper root systems for growth indoors. Collaborators include Gail Langellotto (Professor of Horticulture at Oregon State University, OSU), Devin Roach (Assistant Professor in Mechanical Engineering at OSU), Paul Dalton (Associate Professor at the University of Oregon, Advanced Biomaterials), Kelly O'Neill (Bioengineering PhD candidate), and Taite McLoughlin (PhD candidate at Queensland University of Technology). This approach seeks to redesign the incorporation of living systems in built environments while minimizing environmental impact from frequent plant replacements and informing future research.

2 Timelapse study of root growth on Gradient Density Matrix Prototype #4, 3D Printed Prototype Using Formlabs Fuse 1+ 30W SLS Printer, Printed with Nylon 12 Material, Size: 1.5" x 3" x 4", Growth study of Salvia hispanica, May 2021.