Phytotechnology & Design for Vertical Greening Systems.Light requirements for indoor applications and low-cost solutions for fostering their diffusion.

Doctoral Dissertation
Doctoral Program in Management, Production & Design (33rd Cycle)

Phytotechnology & Design for Vertical Greening Systems.

Light requirements for indoor applications and low-cost solutions for fostering their diffusion.

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Politecnico di Torino
2021

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Summary

The ongoing intensification of urbanisation led to a strong change of people lifestyle inducing to spend almost 80-90% of daily time in indoor spaces with negative consequences on physical and mental health. Urban green areas play a pivotal role to the improvement of cities' environmental quality producing regulating and cultural ecosystem services, and generating positive psychological effects on citizens. However, urbanization and land-use changes put public green areas under increasing pressure inducing to undertake alternative strategies for greening built environment. Vertical greening systems, also known as green walls and living walls, are included in the set of urban green infrastructures that refer to the network of multifunctional traditional and technological green spaces covered by vegetation that apply nature-based and phytotechnology solution in order to increase sustainability in urban environment.

Recently, living walls are increasingly adopted as useful ornamental and multi-functional design elements for improving the quality of interior spaces. Interior design practice has always considered ornamental indoor plants as partners to re-introduce natural elements in interiors, and the first part of dissertation focuses on exploring past and current motivation and dynamics that led to the integration of plants and living organisms in the interior design practice. The exploratory investigation outlines the historical dynamics and material culture framework which led to the transition of vertical greening systems from outdoor towards indoor environment. Besides the ornamental value, indoor living walls are installed to improve indoor air quality that often is worse than ambient air due to the high concentration of airborne pollutants. Long-term exposure to indoor air pollutants may affect the comfort, learning ability, attention, health and productivity of buildings' occupants. Laboratory experiments conducted on air phytoremediation ability of indoor foliage plants demonstrated interesting

opportunities to naturally reduce the concentration of some common pollutants, such as carbon dioxide and volatile organic compounds. However, *In situ* application presents some limiting factors that cannot be easily managed as in controlled lab environment. Modular living wall are often installed in public spaces such as school, offices and meeting rooms where sunlight provision is lacking as well as indication for artificial lighting design. Lack of adequate light provision may affect plants growth and could negatively influence the long-term successful of indoor vertical greening systems, decrease aesthetic appeal and increase the need of extraordinary maintenance. The second part of the dissertation focuses on investigating optimal light requirements for indoor living wall in order to optimise plant phytoremediation ability. The study is performed collecting data through *In-situ* measurements on indoor living walls installed in commercial building, measuring illuminance across vegetated surface, and two sets of sealed chamber experiments that perform plant's CO_2 drawdown ability under several lighting setups (light intensities and directionalities and exposure period). Findings obtained by field measurements report that ~87 % of indoor living walls' surface is exposed to low light intensity (< 49 $\mu mol \cdot m^{-2} \cdot s^{-1}$), while lab experiments confirm that plants perform better if exposed to higher light intensities (> 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$). The study also highlights that light directionality influences plant's CO_2 removal ability and morphology. Results indicate that current lighting systems are inadequate for healthy plant photosynthesis and CO_2 removal and data are discussed through statistical analysis in order to provide baseline indications for further studies.

At the end, the last part of the dissertation focuses on investigating bottom-up approach to vertical greening systems through the engagement of community garden's stakeholders. The investigation aims to explore users and stakeholders perspective providing user-friendly information in order to *democratize* vertical greening and to encourage *in situ* small-scale application that require ordinary maintenance by non-expert users. Although previous studies focused on technical features to improve ornamental and functional role, the last part of the dissertation focuses on design guideline for individuals and communities who want to install low-budget or small-scale vertical greening systems, considering solutions adopted for both indoor and outdoor environment. It also discusses opportunities provided by vertical greening systems in organising environmental education activities involving student in order to promote the *ecological literacy* and the importance of nature-based solutions at local-scale for human health and well-being.