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Enlightenments from potted landscapes (Bonsai and Penjing) for urban revegetation in the built environment

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Highlights

- Impervious surfaces in modern cities can be used for revegetation.
- Bonsai (Penjing) is an ancient art that has relevant lessons for urban revegetation.
- Limited substrate and pot sizes are key challenges in bonsai and revegetation.
- There is a correlation between root size and shoot size.
- Control of growth vigour is critical.

Abstract

Impervious surfaces in modern cities can be used for revegetation. However, the ecological quality of belowground ecosystem components and constrained soil space are crucial factors that limit habitat restoration. The long-term development of Bonsai (Penjing) trees has resulted in mature theories and techniques that suggest optimal root-canopy ratios. Considering the similarities with constrained pot landscapes, some “enlightenments”, or key findings, derived from Bonsai theory can also be applied to urban special revegetation (USR). In this study, we analyzed the root-shoot correlations of the different styles of Bonsai trees and provide an assessment on the relationships between Bonsai theory and USR. Using an on-site survey and biomass experiment, nine “enlightenments” from Bonsai theory are proposed: positive root-canopy correlation, environmental stress increasing the root-shoot ratio, connectivity of the tree bark “water line”, rebalancing after disruption of the root-canopy balance, precise root and canopy design, artificial auxiliary fixation of the root, control of growth, horticultural reshaping skills, and plant diversity. In particular, for the successful establishment of urban rebuilt environments, it is essential to understand the mechanisms of root-canopy correlations. Therefore, we suggest that the four main types of USR (green roofs, vertical greening, container gardening, and street trees) should follow the core principle based on the root-shoot balance to effectively design both the root and canopy.

Introduction

Ongoing urbanization has resulted in a series of ecological and environmental problems that have affected cities worldwide. Most existing buildings and grey infrastructure have substantial, impermeable surfaces that directly affect the urban microclimate, negatively impacting urban sustainable development and resilience. Urban special revegetation (USR), i.e., the installation of green roofs, vertical greening of buildings, container gardening, and street trees, is essential to rebuild habitats on these artificial impermeable surfaces. The term USR emphasizes the differences between the general “greening” of the earth and the particularities of the built environment, which is somewhat isolated from natural ecosystems. This results in a constrained root growth space with limited substrate volume and nutrients, and a low buffer capacity. Therefore, precise maintenance technologies are necessary to restore such urban habitats.

Different USR types exist within the built environment, and thus further studies should focus on the relationships between plants and their habitats, the balance between the belowground and aboveground portions of ecosystems, and active interactions between the tree roots and canopies. The extended development of specialized horticultural cultivation methods should be supported by mature theories that can provide recommendations for

the four revegetation types used in modern cities, given the similarities in the belowground soil ecosystems (which are both isolated from the ground soil). In this regard, Bonsai trees offer a suitable model with mature theories and practices that can be applied to USR. Penjing is an artform that originated in China to manipulate Bonsai trees, which was developed as a tradition for thousands of years prior to its spread into Japan and then to the western world.

Forming a Bonsai (Penjing) involves wiring the plant with palm fibers, followed by cutting the roots and branches. The variations in the local natural scenery and diversity of plants used for Bonsai have resulted in the formation of different styles of Penjing art across China (Table 1). The bent and compacted tree form controls the mass growth. The most problematic factor for plant growth is the tiny container and shallow substrate used, which are not conducive to root growth and development and therefore directly limit the growth of the tree; the tree can nevertheless maintain health under these conditions (Manda, 2015). Root cutting has an obvious effect on the fine roots, but not on the tap root, which is a result of self-adaptation by the plant to the limited container volume. This container effect has a positive impact on tree survival. Furthermore, the fine root mass is suitable for transplantation, and results in a higher survival rate than that of plants directly transplanted from the ground.

Based on these “enlightenments” obtained from this long history, we sought to apply these insights from Bonsai to develop effective countermeasures for urban trees. Accordingly, the aim of the present study was to apply Bonsai theory to urban tree plantation and maintenance.

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Section snippets

Study site and tree species

The study was conducted in the Shanghai Botanical Garden in the metropolis of Shanghai (30°40′–31°55′N and 120°50′–121°55′E), located in the middle of the east coast of China,

which belongs to the northern subtropical humid monsoon climate belt with abundant rainfall and heat resources. The average annual temperature is 17.7 °C and the average annual precipitation is 1388.8 mm (SMBS (Shanghai Municipal Bureau of Statistics), 2018). The typical zonal and semi-natural vegetation is an evergreen...

Relationship between bonsai and USR

Bonsai and USR are both artificial methods of gardening within a built environment, and they have similar restrictions in terms of a small and constrained root-growing space (Fig. 3). As shown in Fig. 4, the Bonsai tree *PP* exhibited a decreasing RSR with increasing tree height, which is similar to urban forest trees (Johnson and Gerhold, 2003).

The key differences between Bonsai and USR are related to focus, microclimate, value, and cost (Table 2). In addition, Bonsai can be repotted every few...

Conclusions

Based on its long history of cultivation and development, Bonsai theory should be a model for scientific induction that is supported by experimental results. This study confirms the key findings from Bonsai practice, including the positive root-canopy correlation, container effect of small leaves and short internodes, higher RSR, and others, based on the results of an on-site survey and biomass experiment. These “enlightenments” derived from Bonsai theory are highly relevant for USR. One of the ...

Declaration of Competing Interest

The authors have no conflicts of interest to declare....

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...These studies have also found that reclaimed idle spaces reduced residents' stress and increased their physical exercise levels (Jackson and Kochtitzky, 2001; Wells, 2000). In a study conducted in Philadelphia, residents living near idle spaces reclaimed under a greening project were found to have a lower heart rate than residents living in the vicinity of empty and abandoned spaces (Branas et al.,

2011; South et al., 2015; Wang et al., 2020). A few studies have specifically investigated the effect of urban regeneration projects on the health of local residents....

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