

Simultaneously, establishing asexual propagation systems (such as cuttings, tissue culture) to ensure the stable inheritance of excellent traits is a crucial step in variety industrialization (Lin et al., 2022). Cutting propagation is simple and low-cost, but some maple varieties have difficulty rooting, resulting in unstable survival rates; although tissue culture is technically demanding, it allows rapid propagation of superior seedlings while maintaining the excellent traits of the mother plant. Currently, tissue culture techniques for important ornamental maples like Japanese maple and red maple have matured, providing a foundation for the large-scale production of superior varieties. Furthermore, during the promotion process, cultivation technical guidance needs to be strengthened, including proper water and fertilizer management, shaping and pruning, and pest and disease control, to ensure that new varieties display their optimal ornamental effects in different regions. By establishing a comprehensive superior variety propagation and promotion system, the application of excellent maple varieties in urban greening can be accelerated, enhancing the overall quality of autumn landscapes.

7 Challenges and Future Trends in Maple Landscape Design

7.1 Impacts of urban environment on maple growth and leaf color expression

The urban environment presents specific challenges such as high temperatures, drought, soil compaction, and air pollution, which impact maple growth and leaf color expression. Research indicates that the urban heat island effect can delay autumn phenology, shorten the red leaf period, and even affect anthocyanin synthesis (Liu et al., 2019). Nighttime temperatures in city centers are significantly higher than in suburban areas, disrupting the temperature signals plants use to perceive seasonal changes, leading to delayed or insufficient leaf coloration. Additionally, air pollutants like sulfur dioxide and ozone can directly damage leaf tissue, accelerate leaf senescence, and cause leaves to fall before displaying their full red color, severely impacting the landscape effect.

Soil compaction and poor aeration limit root system development, subsequently affecting nutrient absorption and leaf pigment metabolism. Soil in urban roadsides and squares often becomes compacted due to construction traffic, reducing porosity and restricting root growth, leading to weakened tree vigor and dull leaf color. Simultaneously, the large area of impermeable pavement hinders rainwater infiltration, causing unstable soil moisture supply and frequent drought stress (Lu and Wang, 2025). Therefore, in landscape design, it is necessary to select adaptable varieties, such as Norway maple and silver maple, which tolerate urban conditions, and adopt cultivation measures like soil improvement, supplemental irrigation, and the use of mulches to maintain good leaf color effects. Furthermore, rationally configuring tree species and avoiding planting maples in severely polluted or poorly lit areas can maximize their ornamental value. Technical measures such as soil improvement in planting pits, permeable pavement around tree pits, and regular deep aeration can significantly improve the growing conditions for maples.

7.2 Challenges of climate change and maple phenological shifts for landscape design

Global climate change leads to increased temperature fluctuations and frequent extreme weather events, directly affecting the timing and duration of maple leaf coloration. For example, autumn warming can delay color transition, while early frosts may cause leaves to fall before changing color, diminishing the landscape effect (Mattila and Tyystjärvi, 2023). Over the past few decades, the peak autumn foliage period in famous maple-viewing areas like Kyoto, Japan, has shown a trend of delay and increased interannual variability, posing challenges for tourism organization and landscape management. Furthermore, changes in precipitation patterns can affect anthocyanin accumulation and leaf senescence processes; in drought years, red leaves may fall prematurely, while in rainy years, insufficient light may lead to duller leaf colors.

This requires landscape designers to consider climate change factors during planning, select varieties with stable phenological responses, and employ diverse tree species combinations to buffer the impact of climate anomalies on autumn color landscapes. For instance, combining maple varieties with different coloration periods can extend the red-leaf viewing period from 2-3 weeks for a single species to over a month; introducing other autumn color tree species like ginkgo and tulip tree creates composite landscapes with interwoven yellow, orange, and red hues, maintaining overall landscape quality even if one species performs poorly. Simultaneously, establishing long-term phenological monitoring networks, combined with meteorological data to predict leaf color change trends,