



Photosynthetic Characteristics of Landscape Plants, Environmental Quality, and Their Applications in Ecological Landscape Construction

Nanyang Chen*, Hanzhen Long

College of Tourism and Landscape Architecture, Guilin University of Technology, Guangxi
Zhuang Autonomous Region, Guilin, 541006, China

*704541976@qq.com

Abstract. The relationship between the photosynthetic characteristics of landscape plants and environmental quality plays a critical role in ecological landscape construction. Through a systematic literature review, this study examines the biochemical mechanisms of photosynthesis, analyzes the effects of key environmental factors on photosynthetic efficiency, and explores the applications of photosynthetic principles in ecological landscape design. Results indicate that light reactions and the Calvin cycle are highly sensitive to environmental stressors: heavy metal pollution inhibits chlorophyll synthesis, while particulate matter deposition reduces the maximum quantum yield (F_v/F_m) from ~ 0.83 to below 0.75. Well-maintained urban green spaces can store up to 5.2 kg C/m^2 , while a single mature tree can lower local temperatures by $1\text{--}3^\circ\text{C}$ through transpiration. These findings highlight the importance of selecting plants with high photosynthetic efficiency and integrating photosynthetic principles into landscape planning to achieve both ecological and social benefits in urban greening.

Keywords: Landscape plants; photosynthetic characteristics; environmental quality; ecological landscape construction; plant configuration; ecosystem stability; sustainable development

1 Introduction

As human demands for environmental quality continue to rise, we have begun to re-examine the mysteries of nature — particularly the factors closely linked to environmental quality. Among these, photosynthetic characteristics, as a key factor in plant photosynthesis, are undoubtedly one of our primary areas of focus [1]. They not only affect plant growth but are also intimately related to environmental quality. The state of environmental quality directly influences the growth and reproduction of living organisms. Plants, as one of the most important organisms on Earth, have a particularly close relationship between their photosynthetic characteristics and environmental quality [2]. Plants convert light energy into chemical energy through photosynthesis to produce the organic matter they need — a process that demands very high environmental

quality. Therefore, understanding the relationship between the photosynthetic characteristics of plants and environmental quality is of great significance for protecting the ecological environment and improving environmental quality [3].

2 Literature Review

2.1 Basic Principles of Photosynthesis

The basic principle of plant photosynthesis is the process by which plants use pigments in chloroplasts to absorb light energy and convert carbon dioxide and water into organic matter and oxygen. As shown in Fig. 1, This process can be divided into two stages: the light reactions and the dark reactions [4].

In the light reactions, plants use chlorophyll and other pigments to absorb light energy from sunlight and convert it into chemical energy. This process occurs on the thylakoid membranes of the chloroplasts. At the molecular level, when a photon strikes a chlorophyll molecule in Photosystem II (PSII), it excites an electron to a higher energy state. This electron is passed along the electron transport chain — through plastoquinone, the cytochrome b6f complex, and plastocyanin — to Photosystem I (PSI), driving the pumping of protons across the thylakoid membrane and generating a proton gradient. This gradient powers ATP synthase to produce ATP. Meanwhile, PSI reduces NADP^+ to NADPH using the re-energized electrons. The oxygen released as a byproduct derives from the photolytic splitting of water molecules ($2\text{H}_2\text{O} \rightarrow 4\text{H}^+ + 4\text{e}^- + \text{O}_2$) [5].

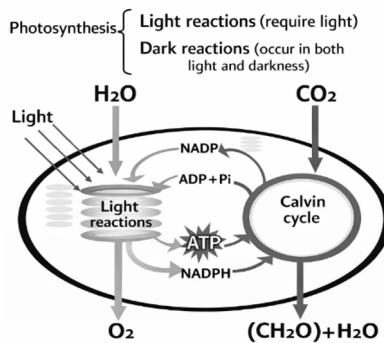


Fig. 1. Light and dark reactions of photosynthesis

The dark reactions (Calvin cycle) occur in the stroma of the chloroplasts and are driven by the ATP and NADPH generated in the light reactions. The cycle proceeds through three biochemical stages: (1) Carbon fixation — the enzyme ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO) catalyzes the attachment of CO_2 to the five-carbon molecule ribulose biphosphate (RuBP), forming two molecules of 3-phosphoglycerate (3-PGA); (2) Reduction — ATP and NADPH are used to reduce 3-PGA

to glyceraldehyde-3-phosphate (G3P), the primary carbohydrate product; (3) Regeneration of RuBP — most G3P molecules are used to regenerate RuBP, consuming additional ATP, ensuring the cycle can continue. Notably, RuBisCO is a rate-limiting enzyme, fixing only 3–10 CO₂ molecules per second under normal conditions, which makes its activity highly sensitive to temperature, CO₂ concentration, and cellular redox state [6].

Plant photosynthesis is a complex biochemical reaction that requires the participation of various enzymes, coenzymes, and other biochemical substances. Its principle can be simply summarized as the conversion of light energy into chemical energy — one of the main pathways for plant energy acquisition. Photosynthesis not only serves as an energy conversion process but also regulates the concentrations of carbon dioxide and oxygen in the atmosphere. Through photosynthesis, plants absorb large amounts of carbon dioxide while releasing oxygen, a process of great significance for maintaining the Earth's ecological balance.

2.2 Effects of Environmental Factors on Plant Photosynthetic Characteristics

Environmental factors influence plant photosynthetic characteristics through specific biochemical pathways. As shown in Fig. 2, light intensity controls the rate of electron excitation in PSII and the consequent production of ATP and NADPH; beyond the light saturation point, excess excitation energy causes photoinhibition, damaging the D1 protein of PSII and reducing overall photosynthetic capacity. Temperature directly modulates the activity of key enzymes including RuBisCO, ATP synthase, and the enzymes of the Calvin cycle — most landscape plants show optimal enzyme activity between 25–35°C, with activity declining sharply outside this range due to protein denaturation. CO₂ concentration determines the substrate availability for RuBisCO; under elevated CO₂, carboxylation is favored over oxygenation, reducing photorespiration and increasing net photosynthetic efficiency. Water stress induces stomatal closure, which simultaneously limits CO₂ entry and reduces transpiration-driven cooling. Soil nutrient availability, particularly nitrogen and magnesium, directly affects chlorophyll biosynthesis, as both elements are essential components of the chlorophyll molecule [7].

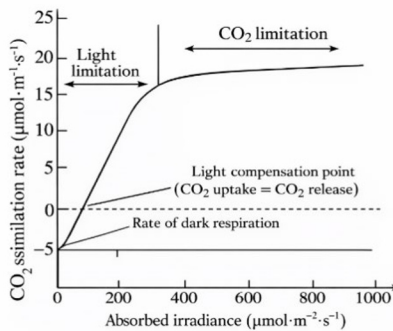


Fig. 2. Relationship curve between photosynthetic rate and light radiation intensity in C₃ plants

3 Methods

This study adopts a qualitative literature review and analytical approach. The analysis focused on three dimensions:

(1) Photosynthetic mechanisms examining the molecular and biochemical mechanisms of light reactions and the Calvin cycle, including the roles of PSII, PSI, the electron transport chain, RuBisCO, ATP, and NADPH.

(2) Environmental factor analysis evaluating the effects of light intensity, temperature, humidity, CO₂ concentration, and soil nutrition on plant photosynthetic characteristics, supported by empirical case study data.

(3) Application assessment analyzing case studies and design principles related to plant selection, environmental optimization, and ecological function in landscape construction.

By comprehensively analyzing data and research findings, this study aims to clarify the key relationships between photosynthetic characteristics and environmental quality, and thereby provide evidence-based recommendations for ecological landscape design and implementation.

4 Results

4.1 Photosynthetic Characteristics and Environmental Quality

Photosynthesis is the foundation of plant growth and development, while photosynthetic characteristics determine how plants perform under different environmental conditions. In ecological landscape construction, leveraging photosynthetic characteristics can optimize plant configuration and improve the overall ecological and landscape benefits of the garden. Priority should be given to plant species with high photosynthetic efficiency — plants that can rapidly photosynthesize under sufficient light, produce more organic matter, accelerate growth, and increase biomass[8]. For example, evergreen trees such as pine and cypress maintain high photosynthetic efficiency throughout the year and are preferred for ecological landscaping. Banyan trees are also important evergreen species in tropical and subtropical regions, with lush canopies and strong root systems capable of year-round photosynthesis, providing shade and ecological support [9].

Plant photosynthetic characteristics are closely related to environmental adaptability. Therefore, when selecting plants, local environmental conditions must be carefully considered, choosing species with strong adaptability and high photosynthetic efficiency under specific conditions. In arid regions, drought-tolerant plants such as poplars should be selected, as they can adapt to dry soil and climate while maintaining relatively high photosynthetic efficiency. In humid regions, moisture-loving plants such as ferns and mosses should be chosen, as they can photosynthesize under low-light and humid conditions, providing stable ecological services [10].

In addition to photosynthetic efficiency and environmental adaptability, ornamental value is also an important factor in plant selection. By choosing plants with beautiful

forms, rich flower colors, and distinctive fruits, attractive and unique landscape scenery can be created. Such plants can also attract visitors and enhance the appeal of the ecological garden [11].

4.2 Environmental Quality and Ecosystem Stability

Environmental pollution disrupts ecosystem stability at multiple levels. Heavy metals such as cadmium and lead inhibit chlorophyll synthesis and key photosynthetic enzymes, while SO₂ exposure disrupts thylakoid membrane potential. At the ecosystem scale, well-maintained urban green spaces store approximately 126.88 Gg C with a carbon density of 5.2 kg C/m² — a capacity directly dependent on sustained high photosynthetic efficiency. When pollution reduces species diversity, the ecosystem's carbon fixation capacity weakens, further destabilizing energy flow and material cycling[12-14].

5 Discussion

5.1 Environmental Optimization

High-photosynthesis plants significantly improve the garden environment. A single mature tree transpires 100–400 liters of water per day, lowering local temperatures by 1-3°C and mitigating the urban heat island effect. Plants also improve soil quality through nitrogen fixation and enhance biodiversity, further strengthening ecosystem stability and service functions.

5.2 Limitations

Current research is mainly concentrated on specific plant species and regions. Future studies should broaden geographic and species scope, improve measurement methodologies, and strengthen long-term research to better support ecological garden planning.

6 Conclusion

This study confirms that photosynthetic characteristics are closely linked to environmental quality, with significant implications for ecological landscape construction [1-3]. The integrity of the electron transport chain and RuBisCO activity make photosynthetic performance a reliable indicator of ecosystem health. Through rational plant selection and community configuration, ecological gardens can achieve enhanced carbon sequestration, microclimate regulation, and strengthened ecological services. Integrating photosynthetic principles into landscape planning is essential for sustainable urban greening [15-16].

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