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Biotechnological Cultivation and Landscape Application of Ornamental Plants in Landscape Architecture: A Review

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Abstract
The improvement and innovation of their morphology, function, and quality are essential for enhancing the beauty, ecological value, and cultural significance of landscapes. Biotechnology, employing biological principles and methods to modify and utilize organisms, holds vast potential in the cultivation and application of ornamental plants in landscape architecture. This review aims to summarize the research progress in biotechnological cultivation and landscape application of ornamental plants, analyzing their advantages, limitations, challenges, and future directions. Using a systematic literature review approach, relevant literature from domestic and international databases over the past five years was retrieved and classified based on different biotechnological cultivation methods and landscape application types. The review outlines the principles, characteristics, and application scopes of biotechnological cultivation methods such as tissue culture, genetic transformation, molecular markers, and gene editing, as well as their landscape application types and effects including improving ornamental features, enhancing adaptability, increasing functionality, and creating new varieties. It highlights the innovative and prospective nature of biotechnological cultivation and landscape application of ornamental plants, offering new insights and means for the beautification, ecological sustainability, and cultural enrichment of landscapes. However, it also identifies technical, economic, ethical, legal, and ecological challenges and risks that require strengthened research and regulation to ensure safety and sustainability.

Keywords: *ornamental plants; biotechnological cultivation; landscape application; literature review*

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I. INTRODUCTION

Scenic gardens represent a harmonious blend of human creativity with nature, serving to fulfill diverse needs such as aesthetic appreciation, leisure, education, and environmental conservation while fostering social harmony and sustainable development [1]. Among the constituents of scenic gardens, plants play a pivotal and dynamic role, offering not only visual and olfactory stimuli through diverse colors, forms, textures, and fragrances but also regulating climate, purifying air, maintaining soil and water, enhancing biodiversity, reducing noise, and conveying cultural, historical, and traditional information, thereby enriching the essence and allure of scenic gardens [2].

The selection and arrangement of plants are crucial aspects of scenic garden design, necessitating considerations of plant morphology, functions, quality, as well as their relationship and adaptability to the environment and humans. To meet various design purposes and requirements, the improvement and innovation of scenic garden plants are indispensable, employing traditional breeding and propagation techniques alongside modern biotechnology [3]. Biotechnology, leveraging biological principles and methods to manipulate and utilize organisms, holds vast potential and prospects for the cultivation and application of scenic garden plants. It enables breakthroughs beyond traditional breeding and propagation techniques, facilitating rapid propagation, trait improvement, novel variety creation, stress tolerance enhancement, and functionality augmentation, thereby providing new pathways and means for enhancing the diversity, quantity, quality, and efficacy of scenic garden plants.

In recent years, with the advancement of biotechnology, research on the biotechnological cultivation and landscape application of scenic garden plants has yielded some achievements and progress while facing challenges and issues. To better understand and grasp the current status and trends of research on the biotechnological cultivation and landscape application of scenic garden plants, this review adopts a systematic literature review approach, retrieving relevant literature from domestic and international databases over the past five years, categorized and analyzed based on different biotechnological cultivation methods and landscape application types. The purpose of this review is to summarize the research progress in the biotechnological cultivation and landscape application of scenic garden plants, analyze their advantages, limitations, challenges, and future directions. The structure of this review is as follows: The second section introduces the principles, characteristics, and application scope of biotechnological cultivation methods for scenic garden plants, such as tissue culture, genetic transformation, molecular markers, and gene editing; the third section introduces the types and effects of biotechnological cultivation and landscape application of scenic garden plants, such as improving ornamental value, enhancing adaptability, increasing functionality, and creating new varieties; the fourth section summarizes and discusses the advantages and prospects of biotechnological cultivation and landscape application of scenic garden plants, as well as the existing issues and risks, proposing some development directions and suggestions; the fifth section is the conclusion, reviewing the main contents and conclusions of this review, pointing out its contributions and limitations, as well as future research directions and suggestions.

II. LITERATURE SYNTHESIS

The results obtained are as discussed below

2.1 Biotechnological Cultivation Methods

The biotechnological cultivation methods for scenic garden plants mainly include tissue culture, genetic transformation, molecular markers, and gene editing [4], [5], with their principles, characteristics, and application scope as follows:

2.1.1 Tissue Culture

It is a technique that involves the in vitro cultivation of plant cells, tissues, or organs under aseptic conditions on synthetically formulated media, aiming to achieve rapid propagation, trait improvement, and novel variety creation by inducing plant differentiation, proliferation, and regeneration processes [6], [7]. Tissue culture technology finds extensive applications in the cultivation of scenic garden plants, such as detoxification, preservation, propagation, mutagenesis, and breeding. The advantages of tissue culture technology include overcoming the limitations of traditional propagation methods, such as seasonality, low quantity, susceptibility to pests and diseases, while improving plant quality, uniformity, shortening the propagation cycle, and saving space and resources. The disadvantages of tissue culture technology lie in the requirement of high technical expertise and equipment, as well as susceptibility to issues such as improper media formulation, contamination, variation, and poor adaptability.

2.1.2 Genetic Transformation

It is a technique involving the introduction of exogenous genes into recipient cells to enable their expression and heredity, aiming to achieve trait improvement, functionality enhancement, and stress tolerance through altering the plant's genetic composition [8]. Genetic transformation technology plays a crucial role in the cultivation of scenic garden plants, such as improving ornamental value, increasing resistance to pests and diseases, enhancing salt and alkali tolerance, and strengthening cold resistance. The advantages of genetic transformation technology lie in its ability to overcome interspecific genetic isolation, achieve gene exchange between different species precisely control gene expression and function, creating new traits and varieties. The disadvantages of genetic transformation technology lie in the requirement of high technical expertise and safety, as well as susceptibility to issues such as genetic instability, interaction, loss, societal controversies, and opposition.

2.1.3 Molecular Markers

It is a technique utilizing molecular biology methods to detect and analyze plant genes or genomes, aiming to achieve plant classification, identification, and breeding by identifying genetic variations in plants [9]. Molecular marker technology plays a crucial role in the cultivation of scenic garden plants, such as parental determination, hybrid assessment, assisted selection, and variety identification. The advantages of molecular marker technology lie in its rapid, accurate, and efficient detection of plant genetic information, unaffected by environmental and developmental stages, thus enhancing breeding efficiency and quality [10]. The disadvantages of molecular marker technology lie in the requirement of high technical expertise and equipment, as well as susceptibility to issues such as cost, time, and marker-trait association.

2.1.4 Gene Editing:

It is a technique utilizing genome engineering tools to precisely modify plant genes or genomes, aiming to achieve targeted gene mutation, insertion, deletion, or replacement, thereby creating new traits and varieties with improved performance and functionality (Puchta, 2005). Gene editing technology plays a crucial role in the cultivation of scenic garden plants, such as disease resistance improvement, pest control, quality enhancement, and stress tolerance. The advantages of gene editing technology lie in its precision, efficiency, specificity, and versatility, enabling targeted modifications at the nucleotide level, without introducing foreign DNA or disrupting endogenous genes, thus minimizing off-target effects and regulatory concerns[11]. The disadvantages of gene editing technology lie in the requirement of high technical expertise, safety, and regulation, as well as susceptibility to issues such as ethical, legal, and societal controversies.

2.2 LANDSCAPE APPLICATION TYPES

The landscape application types of biotechnological cultivation of scenic garden plants mainly include improving ornamental value, enhancing adaptability, increasing functionality, and creating new varieties[12], with their characteristics, effects, and examples as follows:

2.2.1 Improving Ornamental Value

It involves the use of biotechnological methods to enhance the aesthetic appeal, visual interest, and sensory pleasure of scenic garden plants, such as altering flower color, size, shape, fragrance, foliage texture, and growth habit, thereby creating novel and attractive varieties. For example, tissue culture technology has been employed to induce somaclonal variation and chimera formation in begonias, geraniums, and chrysanthemums, resulting in new flower colors, patterns, and forms. Genetic transformation technology has been utilized to introduce exogenous pigment biosynthesis genes into petunias, roses, and carnations, leading to flower color modification. Molecular marker technology has been applied to identify and select superior parental lines and hybrid combinations with desired ornamental traits, such as flower size, shape, and longevity. Gene editing technology has been exploited to knock out or knock in key genes involved in flower development, pigment biosynthesis, and hormone metabolism, thereby altering flower color, fragrance, and longevity. These efforts have resulted in the creation of new varieties of roses with blue, black, and multicolored flowers, lilies with fragrant flowers, orchids with novel flower shapes, and petunias with patterned flowers.

2.2.2 Enhancing Adaptability

It involves the use of biotechnological methods to improve the environmental tolerance, stress resistance, and growth vigor of scenic garden plants, such as enhancing drought, heat, cold, salt, alkali, and disease resistance, thereby expanding the range of plant adaptation and application. For example, tissue culture technology has been applied to induce somaclonal variation and mutation in potatoes, tomatoes, and peppers, resulting in new germplasms with improved resistance to late blight, wilt, and virus. Genetic transformation technology has been employed to introduce exogenous stress-responsive genes into rice, wheat, and maize, leading to enhanced tolerance to drought, salt, and cold. Molecular marker technology has been utilized to identify and select superior parental lines and hybrid combinations with desirable stress-resistant traits, such as deep roots, thick cuticles, and osmotic regulation. Gene editing technology has been exploited to knock out or knock in key genes involved in stress perception, signal transduction, and metabolic regulation, thereby enhancing stress tolerance and resilience. These efforts have resulted in the creation of new varieties of soybeans with drought tolerance, strawberries with cold tolerance, and turfgrasses with salt tolerance.

2.2.3 Increasing Functionality

It involves the use of biotechnological methods to improve the nutritional value, medicinal efficacy, and functional properties of scenic garden plants, such as enhancing the content of vitamins, minerals, proteins, antioxidants, and secondary metabolites, thereby promoting human health and well-being. For example, tissue culture technology has been applied to induce somaclonal variation and mutation in carrots, cabbages, and lettuces, resulting in new germplasms with increased content of carotenoids, flavonoids, and glucosinolates. Genetic transformation technology has been employed to introduce exogenous biosynthesis genes into bananas, apples, and strawberries, leading to enhanced accumulation of vitamins, minerals, and antioxidants. Molecular marker technology has been utilized to identify and select superior parental lines and hybrid combinations with desirable functional traits, such as high protein content, low sugar content, and balanced fatty acids. Gene editing technology has been exploited to knock out or knock in key genes involved in metabolic pathways, regulatory networks, and biosynthesis pathways, thereby enhancing the production and accumulation of functional compounds. These efforts have resulted in the creation of new varieties of tomatoes with high lycopene content, potatoes with high anthocyanin content, and soybeans with high protein content.

2.2.4 Creating New Varieties

It involves the use of biotechnological methods to generate novel genotypes, phenotypes, and combinations of scenic garden plants, such as developing hybrids, polyploids, and recombinants with improved performance, adaptability, and functionality, thereby enriching plant diversity and utility. For example, tissue culture technology has been applied to induce somaclonal variation and polyploidization in irises, lilies, and daylilies, resulting in new germplasms with increased flower size, color range, and bloom period. Genetic transformation technology has been employed to introduce exogenous fertility restoration genes into cytoplasmic male-sterile lines of rice, wheat, and maize, leading to the development of hybrid varieties with increased yield potential and heterosis. Molecular marker technology has been utilized to identify and select superior parental lines and hybrid combinations with desirable genetic backgrounds, such as disease resistance, adaptation, and quality. Gene editing technology has been exploited to knock out or knock in key genes involved in reproductive development, meiotic division, and gametophyte formation, thereby altering fertility, sterility, and seed set. These efforts have resulted in the creation of new varieties of corn with high yield potential, soybeans with high oil content, and turfgrasses with low mowing requirements. It involves the use of biotechnological methods to generate novel genotypes, phenotypes, and combinations of scenic garden plants, such as developing hybrids, polyploids, and recombinants with improved performance, adaptability, and functionality, thereby enriching plant diversity and utility. For example, tissue culture technology has been applied to induce somaclonal variation and polyploidization in irises, lilies, and daylilies, resulting in new germplasms with increased flower size, color range, and bloom period. Genetic transformation technology has been employed to introduce exogenous fertility restoration genes into cytoplasmic male-sterile lines of rice, wheat, and maize, leading to the development of hybrid varieties with increased yield potential and heterosis. Molecular marker technology has been utilized to identify and select superior parental lines and hybrid combinations with desirable genetic backgrounds, such as disease resistance, adaptation, and quality. Gene editing technology has been exploited to knock out or knock in key genes involved in reproductive development, meiotic division, and gametophyte formation, thereby altering fertility, sterility, and seed set. These efforts have resulted in the creation of new varieties of corn with high yield potential, soybeans with high oil content, and turfgrasses with low mowing requirements.

2.3 DISCUSSION

This section summarizes and discusses the advantages and prospects of biotechnological cultivation and landscape application of scenic garden plants, as well as the existing issues and risks, proposing some development directions and suggestions.

2.3.1 Advantages And Prospects

The biotechnological cultivation and landscape application of scenic garden plants offer several advantages and prospects:

- Enhanced efficiency: Biotechnological methods enable rapid propagation, trait improvement, and novel variety creation of scenic garden plants, overcoming the limitations of traditional breeding and propagation techniques, such as seasonality, low quantity, susceptibility to pests and diseases, while improving plant quality, uniformity, shortening the propagation cycle, and saving space and resources.
- Expanded scope: Biotechnological methods enable the modification and manipulation of plant genes and genomes, creating new traits and varieties with improved performance, adaptability, and functionality, thereby expanding the range of plant adaptation and application in diverse environments and purposes.
- Improved quality: Biotechnological methods enable the precise control and regulation of plant gene expression and metabolism, enhancing the nutritional value, medicinal efficacy, and functional properties of scenic garden plants, thereby promoting human health and well-being.
- Enriched diversity: Biotechnological methods enable the generation and selection of novel genotypes, phenotypes, and combinations of scenic garden plants, enriching plant diversity and utility, preserving endangered species, and restoring degraded ecosystems.

2.3.2 Issues And Risks

However, there are several issues and risks associated with biotechnological cultivation and landscape application of scenic garden plants:

- Regulatory concerns: Biotechnological methods raise various regulatory concerns and challenges, such as biosafety, bioethics, and biodiversity, regarding the release and commercialization of genetically modified organisms (GMOs), intellectual property rights (IPRs), and environmental risks.
- Ethical controversies: Biotechnological methods raise various ethical controversies and debates, such as animal welfare, human health, and food safety, regarding the use of animals and humans in research, the consumption of GMOs, and the labeling of GM products.
- Societal perceptions: Biotechnological methods raise various societal perceptions and attitudes, such as public awareness, acceptance, and engagement, regarding the benefits and risks of GMOs, the role of science and technology in agriculture, and the responsibility of stakeholders.

• Environmental impacts: Biotechnological methods raise various environmental impacts and consequences, such as ecological disruption, gene flow, and ecosystem services, regarding the unintended effects of GM crops on non-target organisms, soil microorganisms, and biodiversity.

2.3.3 Development Directions And Suggestions

To address these issues and risks, some development directions and suggestions are proposed for the biotechnological cultivation and landscape application of scenic garden plants:

• Regulatory frameworks: Develop and implement science-based regulatory frameworks for the assessment and management of biotechnological products and processes, considering their potential risks and benefits, while ensuring transparency, accountability, and stakeholder participation.

• Ethical guidelines: Establish and enforce ethical guidelines and standards for the responsible conduct of biotechnological research and innovation, considering the welfare of animals and humans, the safety of food and environment, and the rights of consumers and producers.

• Societal dialogues: Foster open and inclusive dialogues and deliberations among scientists, policymakers, industry representatives, consumers, and civil society organizations, regarding the ethical, social, and cultural dimensions of biotechnological applications and implications.

• Environmental safeguards: Implement environmental safeguards and monitoring mechanisms to prevent, mitigate, and remediate the environmental impacts of biotechnological activities and products, considering the conservation of biodiversity, the protection of ecosystems, and the sustainability of agriculture.

III. CONCLUSION

This part summarizes and summarizes the contents of literature synthesis and discussion, summarizes the main characteristics and development trends of biotechnology cultivation and landscape application of landscape plants, points out the existing problems and deficiencies, and puts forward measures and suggestions for improvement and perfection.

• The biotechnology cultivation and landscape application of landscape plants is a new, efficient and innovative technical means, which has broad application prospects and great development potential, and provides new support and impetus for the construction and development of landscape architecture.

• The biotechnology cultivation and landscape application of landscape plants also face some challenges and difficulties, such as the complexity and instability of technology, the safety and adaptability of plants, the recognition and acceptance of society, and the standardization and perfection of law. Further research and exploration are needed to improve the maturity and reliability of technology, ensure the health and ecology of plants, increase the trust and support of society, and improve the system and guarantee of law.

• The biotechnology cultivation and landscape application of landscape plants should follow the scientific, reasonable and sustainable principles, adhere to the people-oriented, ecological first, innovation as the key, coordination as the basis, benefit as the purpose, standard as the standard, service as the purpose, development as the driving force, and the mission of building beautiful China and beautiful landscape architecture.

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