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## REVIEW ARTICLE

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# A Brief Discussion on the Application of Silvicultural Techniques in the Control of Forest Pests

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**Abstract:** Over the past few decades, China has experienced rapid economic and social development, achieving historic accomplishments. However, this progress has also caused damage to the ecological environment. As society continues to advance, there is a growing recognition of the importance of sustainable development and environmental protection. China has begun to vigorously promote ecological civilization construction, with the development of forestry resources being designated as a key national priority. Forest pests and diseases are significant factors contributing to the loss of forestry resources. Therefore, effectively carrying out the prevention and control of forest pests is a crucial aspect of promoting high-quality development in forestry. For a long time, silvicultural techniques have been an effective measure for controlling forest pests. However, based on the current situation, these techniques have not yet been efficiently applied. This necessitates in-depth exploration and efforts by relevant personnel to better contribute to the development of forestry.

**Keywords:** Silvicultural technology; Forestry pest control; Forestry development

Available data indicates that China currently faces a high diversity of major forest pests with rapid reproduction rates. These pests not only severely hinder tree growth but also significantly constrain the rational utilization of forest resources. Consequently, controlling forest pests is essential for effective forest resource conservation. Traditional control methods have proven inadequate for effective management. To safeguard forest resources from pest threats, silvicultural techniques should be integrated into pest control strategies, combining with biochemical, physical, and chemical control technologies to implement comprehensive forest pest management.

## 1. Overview of Silvicultural Techniques

### 1.1 The Basic Connotation of Silvicultural Technology

Forestry technology encompasses a series of scientific silvicultural processes, including techniques such as seedling selection, transplantation, water and fertilizer management, and biological pest control. Through scientific management utilizing forestry technology, trees can achieve healthy growth, thereby enhancing the ecological, economic, and social benefits of forestry. By applying forestry technology, effective regulation of the forestry ecological environment can be achieved, improving fundamental ecological conditions in forestry while also updating traditional afforestation



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concepts<sup>[1]</sup>. The application of afforestation technology should develop in a more scientific and rational direction.

### 1.2 Application Value of Silvicultural Technology in Forestry Pest Control

In 2018, the national forestry department released statistical data on forest pests, indicating that the number of species had exceeded 2,400, with many undiscovered pest and disease types yet to be identified<sup>[2]</sup>. The negative impact of pests on China's forestry production and ecological environment is severe, making integrated pest management essential. Silvicultural techniques serve as the primary means of pest control. Consequently, implementing these techniques is a necessary measure to promote the development of national forestry and related industries. The inherent flexibility of silvicultural technology enhances management efficiency. From the perspective of modern forestry technology systems, silvicultural techniques are widely recognized, and their integrated management has achieved significant results.

## 2. Hazards of Forest Pests

Forest health is threatened by various factors such as deforestation, fires, and droughts, with pest infestations being a major cause of damage to forest resources. In China, forest pests are primarily categorized into three types: harmful animals, harmful microorganisms, and harmful plants. Some occur but are not widely distributed or cause significant harm, while others are widespread and severely damaging. The latter are the key targets for control in plant protection. Data indicate that China is one of the countries most affected by forest pests, with approximately 178 million hectares of forest resources severely damaged annually, predominantly tree forests. The resulting economic and ecological losses exceed 10 billion yuan. China's plant protection work has adopted the strategic principle of "prevention as the foundation, integrated management"<sup>[3]</sup>. Integrated pest management in forestry involves understanding the dialectical relationship between pests and the forest ecosystem, prioritizing prevention, and leveraging silvicultural techniques. It focuses on fostering biological community factors that are detrimental to pests but beneficial to forests, and implementing

biological, physical, and chemical measures tailored to local conditions. The goal is to keep pest damage below economically acceptable thresholds or control indicators, preventing outbreaks and ensuring environmental protection while promoting fast and healthy tree growth.

## 3. Application of Silvicultural Techniques in Forest Pest Control

Silviculture refers to the use of relevant measures to prevent common diseases and pests, thereby achieving scientific management and operation of forestry, which can overall improve forest quality and the economic benefits of forestry. In pest control work, the main tasks include:

### 3.1 Timely Removal of Infected Wood to Prevent Pest and Disease Spread

In many aspects, the control of forest pests is similar to the management of infectious diseases in human society. In the human world, once an infectious disease is detected, the first step is to immediately isolate the infected individuals and provide appropriate treatment to facilitate their recovery. Additionally, preventive measures should be taken for those not yet infected, which not only ensures better care for the patients but also helps contain the spread of the disease. The same principles apply to pest control in forestry. To reduce pest damage and prevent its expansion, forest managers typically remove all trees infected by pests at the source. At the same time, after clearing the infested trees, preventive measures must be implemented for the healthy trees to avoid new infestations<sup>[4]</sup>.

### 3.2 Utilizing Stump Grafting to Increase Forest Tree Survival Rate

Once forest trees are affected by diseases or pests, immediate treatment is necessary. All infected trees must be cleared, while those unaffected should also be treated to prevent the spread of pests and diseases. During this process, the population and spread of pests can be effectively controlled. However, the blank areas left after pest removal must be properly managed by personnel to ensure the benefits of forest management. Typically, workers choose to cut the roots for grafting, which not only ensures the survival rate of the tree species but also minimizes the adverse effects caused

by the empty spaces left after pest eradication <sup>[5]</sup>.

### 3.3 Establish Appropriate Quarantine Zones to Prevent the Spread of Pests and Diseases

Forest pests and diseases typically possess the natural ability to spread and disperse, migrating to new host plants for feeding and reproduction. Additionally, most pests and vector insects can fly after metamorphosing into adults, enabling rapid propagation and expansion. In response, relevant managers should implement protective measures tailored to the characteristics of forest lands and specific pests. During the larval stage of pests and vector insects—when they lack flight and dispersal capabilities—establishing isolation zones can prevent the expansion of infested areas due to their migration. Managers should select appropriate locations for these isolation zones based on the traits of the pests and diseases. For forest areas frequently experiencing pest migration and spread, the distance between non-host isolation zones should generally be maintained within 50 meters to effectively control the dispersal of forest pests <sup>[6]</sup>.

### 3.4 Rational Selection of Disease-Resistant Tree Species to Enhance Forest Immunity

Due to differences in varietal characteristics, the disease resistance of different tree species also varies. Therefore, to improve the prevention and control level of forest diseases and pests, it is essential to select suitable disease-resistant tree species based on the characteristics of the forest land. This approach reduces the likelihood of disease and pest issues, enhances tree survival rates, and thereby improves the overall immunity of the forest.

### 3.5 Adjusting Forest Harvesting Cycles to Ensure Economic Benefits in Forest Areas

In various forest areas, there are significant differences in tree growth conditions. In some regions, unfavorable environmental conditions result in slow tree growth, while in others, suitable environments lead to rapid growth. Forest managers must schedule logging activities based on the growth stages of trees. Additionally, the logging cycle should not be too prolonged, as delayed action against pest infestations could cause substantial losses. Therefore, logging must commence before trees are attacked by pests <sup>[7]</sup>. This approach ensures the maximization of operational benefits in forest areas and promotes steady

improvement.

## 4. Creating Mixed Forests Effectively Prevents Pests and Diseases

Mixed forests offer significant advantages in fire prevention and resistance to pests and diseases, as they feature a rich diversity of species and provide better living conditions for organisms. The complex ecosystem within mixed forests attracts various beneficial birds, increasing the number of natural enemies of pests. As a result, pest and disease issues are less severe in mixed forests compared to monocultures. Planting a single tree species allows it to adapt to its ecological conditions, making it difficult to eradicate. Moreover, monoculture ecosystems are fragile, whereas the litter in mixed forests forms multiple layers, enhancing ecosystem diversity. This leverages the self-regulating capacity of food chains to effectively prevent pest and disease outbreaks. Additionally, the ecosystem of mixed forests creates favorable living conditions for natural enemies of pests, effectively curbing the spread of diseases and pests and improving the overall resistance of trees. Despite their many advantages, the implementation of mixed forests still faces challenges, particularly in the cases of Paulownia-bamboo mixed forests and mixed planting between trees. These two methods are difficult to carry out. In existing mixed forest systems, most are dominated by small-leaf poplar forests with Chinese pine and Mongolian pine as the primary species. While these forests provide sufficient food and habitat for insects, their natural enemies rely on abundant nectar and cannot achieve the goal of controlling pests through expansion. Establishing mixed forests using multi-species block or irregular block mixed patterns can not only increase tree species diversity but also enhance the self-control ability of forests against pests and diseases <sup>[8]</sup>.

## 5. Exploring Effective Measures to Improve Prevention and Control Efforts

### 5.1 Implementation of Forestry Pest Control

Governments at all levels should fully recognize the importance of forestry resource-related work and effectively strengthen the protection and management of forestry resources. On this basis, it is essential to adhere to the guidance of sustainable development principles and enhance the emphasis on pest control

efforts. Responsibilities of relevant units must be further clarified, and pest control tasks should be incorporated into their performance evaluation systems to incentivize proactive engagement in forestry pest management. Additionally, grassroots units must conduct comprehensive management of forest areas under their jurisdiction, report emerging situations and challenges promptly, and foster coordination and collaboration among all units to promote the better development of forestry initiatives.

## 5.2 Establish and Improve the Monitoring and Early Warning System

Improve the monitoring and early warning systems by enhancing the four-level monitoring and warning framework at the municipal, county, township, and village levels. Implement grid-based management, strengthen infrastructure development, and ensure 100% monitoring coverage to achieve comprehensive monitoring and eliminate blind spots in surveys. This will enable timely understanding of forest pest dynamics and regular issuance of warnings. For potential future pest issues, corresponding prevention and control measures should be adopted to minimize the occurrence and severity of disasters. Additionally, effective quarantine work in forest areas is crucial for the development of forestry. Establish an excellent quarantine team with not only high-quality execution of quarantine tasks but also strong operational capabilities. Well-equipped quarantine facilities are necessary to facilitate the work of staff, prevent the introduction of non-occurring quarantine forest pests, and curb the spread of existing ones<sup>[9]</sup>.

## 5.3 Strengthening and Enhancing Scientific and Technological Support

To enhance the efficient prevention and control of forest pests, it is essential to establish specialized control teams, improve the professional technical skills of relevant personnel—especially those at the grassroots level—and strengthen skill training for the control workforce, thereby building a high-quality team. In terms of pest and disease management, it is crucial to stay updated on the development of infestations, enhance the capacity to respond to outbreaks, formulate overall prevention and control plans, establish a regularized mechanism for pest management, and gradually develop a scientific

approach by implementing a series of scientifically grounded governance measures. Advanced professional technical methods, such as establishing monitoring and early warning systems, applying pheromone detection and lighting technologies, as well as GPS positioning technology, should be integrated into control efforts to improve the efficiency of pest management. A dedicated pest control database should be created to provide data support for the formulation of relevant policies. In terms of hardware equipment, real-time monitoring and refined management of pests and diseases can be achieved by connecting with the forest pest information management system.

## Conclusion

The application of silvicultural techniques holds significant importance in the prevention and control of forest pests. Through scientifically sound and rational silvicultural practices, the reproduction and spread of harmful organisms can be effectively controlled, thereby reducing their damage to forest ecosystems. However, the application of silvicultural techniques in forest pest management still requires further exploration. There is a need to strengthen the research, development, and implementation of new silvicultural technologies to enhance control efficacy and minimize environmental impacts, thereby providing more effective solutions for forest pest management. By adopting scientifically appropriate silvicultural measures, we can promote the healthy development of forest ecosystems, protect the ecological environment, and create a more favorable ecological habitat for humanity.

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## REVIEW ARTICLE

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# Practical Applications of Biotechnology in Agricultural Cultivation

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**Abstract:** Biotechnology plays an increasingly important role in agricultural cultivation by enhancing crop yield and quality, improving soil fertility, reducing the use of chemical fertilizers and pesticides, protecting the environment, and promoting sustainable agricultural development. This paper primarily introduces the practical applications of transgenic technology, molecular breeding, tissue culture, biological control, and soil microbial remediation in agricultural practices. It also proposes effective measures to promote biotechnology, including strengthening policy support and public awareness, advancing technological research and innovation, and establishing a comprehensive technical service system.

**Keywords:** Biotechnology; Agricultural Cultivation; Application Practice

## 1. Introduction

With the continuous advancement of technology, biotechnology, as an innovative agricultural technique, is playing an increasingly important role in crop cultivation. By leveraging biotechnology, we can enhance crop quality, increase yields, improve disease resistance, and simultaneously reduce environmental impact. The practical application of biotechnology not only contributes to improving agricultural productivity but also promotes sustainable agricultural development. This article will provide a detailed overview of the practical applications of biotechnology in agricultural cultivation, aiming to offer insights and references for research and practices in related fields.

### 1.1. Significance of Biotechnology Application in Agricultural Cultivation

The application of biotechnology in agricultural

cultivation holds significant importance, as it not only enhances crop yield and quality but also improves soil fertility, reduces the use of chemical fertilizers and pesticides, protects the environment, and promotes sustainable agricultural development. Firstly, biotechnology can increase crop yield and quality. Through genetic engineering techniques, scientists can introduce beneficial genes into crops, endowing them with traits such as disease resistance, pest resistance, and drought tolerance. This enhances the crops' stress resilience and growth rate, leading to higher yields. Simultaneously, biotechnology can improve crop quality by making them more nutritious and better-tasting, meeting consumer demands. Secondly, biotechnology can enhance soil fertility. Traditional agricultural practices often lead to a decline in soil fertility, whereas biotechnology can increase organic matter content, improve soil structure, and enhance water and nutrient retention through the use



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of microbial fertilizers and bio-organic fertilizers, thereby creating a better growth environment for crops. Thirdly, biotechnology can reduce the reliance on chemical fertilizers and pesticides. Excessive use of these chemicals not only pollutes the environment but also disrupts soil ecological balance and affects crop growth. Biotechnology offers alternatives such as microbial fertilizers and biopesticides, which can replace conventional chemicals, minimize environmental pollution, and protect ecosystems. Additionally, biotechnology can safeguard crops from pests and diseases. Through genetic engineering, scientists can develop new genetically modified crops with enhanced resistance to pests and diseases. These crops not only withstand attacks but also reduce dependency on pesticides, thereby protecting crop growth. Finally, biotechnology promotes sustainable agricultural development. Traditional farming methods often cause significant environmental damage, while biotechnology can contribute to environmental protection and sustainable agriculture by improving crop varieties, enhancing stress tolerance, reducing chemical inputs, and boosting soil fertility.

## **2. Application of Biotechnology in Agricultural Cultivation**

### **2.1 Genetic Modification Technology**

Genetically modified (GM) technology, as one of the critical applications of biotechnology in agricultural cultivation, has been widely adopted and studied worldwide. The core concept of this technology involves transferring desirable genes from one organism to another, endowing the recipient with new genetic traits such as increased crop yield, pest resistance, and stress tolerance. Through this approach, scientists can develop crop varieties with higher productivity, enhanced adaptability, and improved quality, bringing significant economic benefits to agricultural production. In China, research and application of GM technology have achieved remarkable results. For instance, Chinese scientists have successfully developed GM crops like insect-resistant cotton and insect-resistant corn. These crops not only demonstrate high yields but also exhibit strong resistance to pests and diseases. This allows farmers to reduce pesticide usage during cultivation, thereby lowering production costs and improving crop quality <sup>[1]</sup>. Additionally, these GM

crops show robust stress tolerance, enabling growth under adverse environmental conditions and providing more options for agricultural production. Beyond insect-resistant cotton and corn, Chinese scientists have also researched and applied GM technology to other crops. For example, by introducing drought-resistant genes into rice, wheat, and other crops, scientists have successfully bred GM varieties with strong drought tolerance and high yields. These crops hold significant potential for promotion in arid regions, contributing to food security in certain parts of China. However, the application of GM technology has also sparked controversy. Some concerns have been raised about potential adverse effects on the environment and human health. To ensure the safety of GM crops, the Chinese government and relevant authorities have implemented stringent regulations on GM technology research and application. Before GM crops can be marketed, they must undergo rigorous safety assessments and approval procedures to guarantee they pose no harm to human health or the environment.

### **2.2 Molecular Breeding Technology**

Molecular breeding technology is an advanced crop breeding method that involves in-depth research into crop genomes to identify genes with desirable traits. These genes may be key factors in enhancing crop resistance to diseases, pests, drought, and salinity, or important elements in improving yield, quality, and shelf life. The core steps of molecular breeding technology include gene screening, gene cloning, gene transformation, and gene expression regulation. First, scientists conduct comprehensive analysis of crop genomes using methods such as gene chips and sequencing to identify genes with superior traits. Then, using molecular biology techniques, these genes are cloned from source species to form transgenic vectors. Next, these vectors are introduced into the cells of target crops through methods like *Agrobacterium*-mediated transformation or gene gun delivery. Finally, by regulating gene expression, the target crops exhibit the desired traits. Molecular breeding technology offers advantages such as high efficiency, speed, and strong directional specificity. Compared to traditional breeding methods, it enables the development of new varieties with superior traits in a short time, significantly improving breeding efficiency. Additionally, molecular

breeding allows for the targeted introduction of specific genes as needed, enabling precise control over crop traits. This directional capability makes molecular breeding increasingly important in modern crop breeding. In recent years, Chinese scientists have achieved a series of significant results in the field of molecular breeding. For example, they successfully developed the drought-resistant, high-yield, and high-quality wheat variety "Huamai 5" using molecular breeding technology. This new variety not only exhibits strong drought resistance, allowing it to grow normally under arid conditions, but also boasts high yield and excellent quality, making important contributions to China's grain production <sup>[2]</sup>.

### 2.3 Tissue Culture Techniques

Tissue culture technology is an advanced biotechnology that leverages the totipotency and regenerative capacity of plant cells to cultivate plant tissues or organs into whole plants in vitro under sterile conditions. This technique enables rapid propagation, virus elimination, and genetic improvement of crops, providing a powerful tool for agricultural production and scientific research.

First, tissue culture technology facilitates rapid crop propagation. Traditional methods of crop reproduction often require substantial time and space while yielding low efficiency. In contrast, scientists can mass-produce high-quality seeds or seedlings in laboratories through tissue culture, significantly enhancing propagation efficiency. For instance, Chinese scientists have successfully developed novel crop varieties such as seedless grapes and seedless watermelons using this technology. These varieties are not only superior in taste but also high-yielding, making them highly popular among consumers <sup>[3]</sup>.

Second, tissue culture technology enables virus elimination in crops. Many crops suffer from viral infections that severely impair their growth and yield. By extracting healthy cells from virus-infected plants and culturing them in laboratories, scientists can obtain virus-free crops. This approach not only protects crops from viral damage but also improves their yield and quality.

Finally, tissue culture technology supports genetic improvement of crops. Through genetic engineering, scientists can introduce genes with desirable traits into

plant cells and then use tissue culture to grow these cells into new plants. This method allows for rapid and efficient genetic modification of crops, opening new possibilities for agricultural production.

### 2.4 Biological Control Technology

Biological control technology is a method that utilizes the interrelationships among organisms to manage the occurrence and spread of crop diseases and pests by introducing natural enemies, pathogenic microorganisms, and other biological agents. This technology offers advantages such as environmental friendliness, safety, and long-term effectiveness, making it a crucial approach in modern agricultural pest and disease management. The principle of biological control lies in leveraging these biological interactions to suppress the proliferation and transmission of crop pests. For instance, Chinese scientists have successfully developed biological control techniques using insects like ladybugs and centipedes as natural predators, effectively curbing the infestation of agricultural pests such as aphids and mites.

Biological control technology boasts several benefits. Firstly, it is environmentally friendly. Unlike conventional chemical pesticides, it does not contaminate soil, water sources, or air. Secondly, it is safe and reliable. The biological agents employed in this technology undergo rigorous screening and testing, ensuring no harm to human health. Additionally, biological control offers long-lasting effects. Once suitable natural enemies or pathogenic microorganisms are introduced, they can persist in farmlands and continue to function over time.

In summary, biological control technology is an efficient, eco-friendly, and safe method for managing agricultural pests and diseases. With ongoing advancements and refinements in science and technology, it is anticipated that biological control will play an increasingly vital role in agricultural production in the future <sup>[4]</sup>.

### 2.5 Soil Microbial Remediation Technology

Soil microbial remediation technology is a method that utilizes the biological degradation and biosorption functions of microorganisms to degrade and remove harmful substances from farmland soil, thereby improving soil environmental quality. This technology is of great significance for managing farmland soil

pollution and enhancing crop yield and quality. Firstly, soil microbial remediation technology can effectively degrade organic pollutants in the soil. Microorganisms break down organic matter, converting it into harmless or low-toxicity substances, thereby reducing the content of harmful substances in the soil. For example, microorganisms can decompose pesticide residues into non-toxic or low-toxicity substances, minimizing their harm to crops and the ecological environment. Secondly, soil microbial remediation technology promotes the recycling of nutrients in the soil. Through processes such as nitrogen fixation, phosphorus solubilization, and potassium release, microorganisms convert elements like nitrogen, phosphorus, and potassium from the atmosphere into forms absorbable by plants, thereby enhancing soil fertility. Additionally, microorganisms can secrete plant growth hormones to stimulate plant growth. Thirdly, soil microbial remediation technology can improve the stability of soil structure. By producing substances such as clay minerals and cellulose, microorganisms increase the cohesion between soil particles, enhancing the soil's resistance to erosion. At the same time, microorganisms can form rhizosphere micro-ecosystems, promoting the growth and development of plant roots and further improving soil structure stability. Moreover, soil microbial remediation technology offers advantages such as low cost, simple operation, and no secondary pollution. Compared to traditional physical and chemical methods, soil microbial remediation technology is more environmentally friendly and sustainable. Therefore, it holds broad application prospects in farmland soil pollution management and agricultural production.

### **3. Effective Measures for Promoting the Application of Biotechnology in Agricultural Planting**

The promotion and application of biotechnology in agricultural cultivation are of great significance for increasing crop yield and quality, reducing agricultural production costs, and protecting the ecological environment. To effectively promote the application of biotechnology in agricultural cultivation, the following measures need to be taken:

(1) Strengthen policy support and publicity. The government should formulate corresponding policy

measures to increase support for the promotion and application of biotechnology in agricultural cultivation, including financial investment, tax incentives, and support for technological research and development. At the same time, enhance publicity and promotion of biotechnology in agricultural cultivation to raise farmers' awareness and acceptance of biotechnology and stimulate their enthusiasm for applying it.

(2) Strengthen technological research, development, and innovation. Increase investment in the research, development, and innovation of biotechnology in agricultural cultivation, encourage collaboration among research institutions, universities, and enterprises to jointly tackle key technological challenges. Through technological innovation, continuously improve the application effectiveness of biotechnology in agricultural cultivation to meet the needs of agricultural production. (3) Establish a comprehensive technical service system. Build a robust technical service system for biotechnology in agricultural cultivation, including services such as technical consultation, training, and demonstration. Through the development of this system, provide timely and effective technical support to farmers, helping them address issues encountered during the application of biotechnology in agricultural cultivation. (4) Strengthen the construction of demonstration bases. Establish demonstration bases for biotechnology in agricultural cultivation to showcase its advantages and application effects, providing farmers with intuitive references. Through the construction of these bases, promote the widespread application of biotechnology in agricultural cultivation. (5) Enhance the integration and collaborative development of the industrial chain. Strengthen the integration of biotechnology with the agricultural cultivation industrial chain, promoting synergistic development between biotechnology and agricultural production, processing, sales, and other links. Through industrial chain integration, achieve the industrialization and large-scale application of biotechnology in agricultural cultivation, thereby improving its overall effectiveness.

(6) Strengthen international cooperation and exchange. Actively participate in international cooperation and exchange in the field of biotechnology in agricultural cultivation, introduce advanced foreign technologies and management experiences, and enhance the application level of biotechnology

in China's agricultural cultivation. Simultaneously, promote China's achievements in biotechnology in agricultural cultivation to the international market, elevating China's status and influence in the global biotechnology sector. In summary, to effectively promote the application of biotechnology in agricultural cultivation, comprehensive efforts are needed in areas such as policy support, technological research and development, technical service systems, demonstration base construction, industrial chain integration, and international cooperation. This will create synergy and drive the widespread application of biotechnology in agricultural cultivation.

## Conclusion

In summary, we have gained a deep understanding of the crucial role biotechnology plays in agricultural cultivation. It not only enhances crop yield and quality, improves soil conditions, but also helps reduce the use of chemical fertilizers and pesticides, contributing to sustainable agricultural development. We believe that with the continuous advancement of technology, the application of biotechnology in agriculture will become

even more widespread, bringing further innovations and breakthroughs to agricultural production. We look forward to more applications of biotechnology in future agricultural practices, creating a better life for humanity.

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## REVIEW ARTICLE

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# Protection and Utilization of Wetland Plants to Promote and Improve Wetland Ecology

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**Abstract:** Wetlands are among the most vital ecosystems on Earth, serving functions such as climate regulation, water purification, flood prevention, and biodiversity conservation. Wetland plants, as a crucial component of wetland ecosystems, play an irreplaceable role in maintaining ecological balance and biodiversity. However, with the continuous expansion of human activities and environmental changes, the survival and ecological functions of wetland plants face severe threats. Therefore, protecting and utilizing wetland plants to promote and improve wetland ecology has become a critical task in current ecological and environmental conservation efforts.

**Keywords:** Protection; Wetland Plants; Improvement; Wetland Ecology

## Introduction

Wetland plants are vital components of wetland ecosystems. Protecting and utilizing wetland plants can enhance the integrity of wetland ecology, improving their ecological service functions and overall value. This paper elaborates on the species, distribution, growth characteristics, and ecological roles of wetland plants, analyzes existing issues in their conservation and utilization, and proposes corresponding protective and utilization measures. These include strengthening public awareness of conservation, establishing sound protection mechanisms, and promoting the development and construction of ecotourism. Wetland plants play an irreplaceable role in maintaining ecological balance and biodiversity within wetlands. The findings aim to provide reference and insights for related fields.

## 1. The Importance of Protecting Wetland Plants

The importance of protecting wetland plants is manifested in multiple aspects. Firstly, wetland plants are a crucial component of natural ecosystems, playing a key role in maintaining ecological balance and biodiversity. By absorbing and transforming pollutants, wetland plants help purify water quality and mitigate issues such as water eutrophication. Secondly, wetland plants are vital in regulating climate and addressing climate change. Through photosynthesis, they produce oxygen while absorbing carbon dioxide, contributing to the mitigation of global warming trends. Additionally, wetland plants help prevent soil erosion, stabilize wetland soils, and enhance the disaster resilience of wetlands. Furthermore, wetland plants provide habitats and food sources for many organisms. Numerous



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birds, fish, and insects rely on the fruits and seeds of wetland plants for reproduction and survival <sup>[1]</sup>. Protecting wetland plants helps sustain the survival and proliferation of these species, thereby maintaining ecosystem stability and biodiversity. Lastly, wetland plants also hold significant value for human culture and spiritual life. Many wetland plants possess medicinal and economic value, such as reeds and lotus roots. Protecting wetland plants also supports the sustainable use of these resources, providing long-term economic benefits for humanity.

## **2. Protecting and Utilizing Wetland Plants to Promote and Improve the Current State of Wetland Ecosystems**

### **2.1 Damage to Wetland Plant Resources**

Human activities have caused evident damage to wetland plant resources. During urbanization, vast areas of wetlands have been filled, drained, or converted to other uses, leading to continuous shrinkage of wetland areas. In the process of industrialization, the discharge of large amounts of wastewater and the accumulation of solid waste have severely polluted the wetland environment, posing significant threats to the growth of wetland plants. Additionally, excessive agricultural development has contributed to wetland degradation, while the use of pesticides and fertilizers has caused severe damage to the survival of wetland plants.

Furthermore, climate change is another critical factor contributing to the deterioration of wetland plant resources. Global climate change has led to an increase in extreme weather events, such as floods, droughts, and storms, which have had a substantial impact on wetland ecosystems. These extreme weather events adversely affect the growth, reproduction, and distribution of wetland plants, resulting in the degradation and loss of wetland plant resources. For example, in a certain region, prolonged drought has subjected wetland plants to severe water scarcity. According to a study, the number of wetland plants in this area has decreased by over 50%, with some moisture-dependent species even dying out completely. Meanwhile, due to water shortages, the growth rate of wetland plants has significantly slowed, hindering their normal reproduction and development.

### **2.2 Biodiversity Conservation Faces Threats**

The destruction of wetland plant resources has directly

impacted biodiversity. Wetlands serve as habitats and breeding grounds for numerous organisms, with wetland plants providing food, shelter, and reproductive conditions for many species. Furthermore, the degradation of wetland plant resources affects biodiversity by disrupting ecosystems. Wetland plants play a crucial role in these ecosystems, engaging in complex interactions with aquatic life, insects, and other organisms. When wetland plant resources are compromised, these interactions break down, leading to imbalances within the entire ecosystem. Lastly, human activities and climate change are significant factors threatening biodiversity conservation. For instance, in one region, wetland development, pollution, and overexploitation caused by human activities have severely damaged wetland plant resources. According to one study, the number of wetland plants in this area decreased by 80%, with some moisture-dependent species dying out entirely. Concurrently, the destruction of wetland plant resources has severely affected local biodiversity. Another dataset shows a 60% decline in bird populations, including species that rely on wetland plants for food and habitat.

### **2.3 Lack of Scientific Planning and Management**

The lack of scientific planning and management is due to insufficient emphasis on the protection and restoration of wetland ecosystems. Secondly, this deficiency is also related to the existing management system. Wetland conservation involves multiple departments and fields, such as nature protection, water resource management, agriculture, and forestry, but there is currently a lack of effective coordination mechanisms and unified management planning <sup>[2]</sup>. Lastly, the absence of scientific planning and management is also tied to the current level of technological advancement. Existing technologies cannot meet the practical needs of wetland conservation, leading to an inability to conduct scientific and rational planning and management. For example, in a certain region, due to the lack of scientific planning and management, wetland plant resources have suffered severe damage. The wetlands in this area were originally habitats and breeding grounds for many species, but in recent years, due to factors such as human activities and climate change, wetland plant resources have gradually declined. According to



research, the number of wetland plants in this region has decreased by 70%, with some moisture-dependent plants even completely dying out. Concurrently, the destruction of wetland plant resources has severely impacted the region's biodiversity. Based on another dataset, the bird population in this area has decreased by 50%, with some bird species relying on wetland plants for food and shelter.

### **3. Protecting and Utilizing Wetland Plants to Promote and Improve Wetland Ecological Strategies**

#### **3.1 Enhancing Public Awareness of Protection**

Strengthening public awareness of conservation is a crucial measure for protecting and utilizing wetland plants to improve wetland ecosystems. Through education, popular science activities, exhibitions, and other means, the public can learn about the value and importance of wetland plant resources, thereby enhancing their understanding and awareness of wetland ecosystem conservation. First, relevant authorities and society should strengthen education efforts by using various media channels such as television, radio, newspapers, and the internet to promote the importance and necessity of protecting wetland plant resources. This can be achieved by producing promotional videos, organizing popular science lectures on wetland plant resources, and holding exhibitions to help the public understand the ecological, economic, and social value of these resources, thereby increasing their appreciation for them. Second, relevant authorities and society should encourage public participation in the conservation of wetland plant resources. This can be done through volunteer activities, community environmental initiatives, and donations, enabling the public to actively engage in conservation efforts. Finally, relevant authorities and society should enhance supervision and enforcement. Actions that damage wetland plant resources must be strictly punished, with strengthened oversight and law enforcement to ensure that offenders face appropriate penalties.

#### **3.2 Establish and Improve Comprehensive Protection Mechanisms**

Establishing a comprehensive and sound protection mechanism is a crucial step in conserving wetland plants and wetland ecosystems. First, the formulation

and enforcement of laws and regulations are key to protecting wetland plant resources. Relevant authorities should introduce strict legal provisions that clearly define protection requirements for wetland plant resources, including prohibitions on illegal logging, poaching, transplantation, and other activities, while increasing penalties for violations to deter such actions. Second, close collaboration with scientific research institutions is an important means of safeguarding wetland plant resources. Active cooperation with research organizations should be pursued, utilizing advanced technological methods for real-time monitoring and investigation of wetland plant resources to promptly identify and address environmental issues. Additionally, establishing a volunteer team for wetland protection serves as a vital supplement to conservation efforts. Volunteers should be actively recruited and trained in wetland protection knowledge and skills, enabling them to participate in conservation work. Furthermore, financial support is the foundation for protecting wetland plant resources. Finally, disseminating knowledge about wetland protection is essential for raising public awareness. Simultaneously, strengthening education in schools by integrating wetland conservation into the curriculum will foster environmental awareness among youth from an early age.

#### **3.3 Develop and Construct Ecotourism**

Developing and constructing ecotourism is a crucial means of protecting and utilizing wetland plants while promoting the improvement of wetland ecosystems. Ecotourism, a form of tourism based on environmental conservation that emphasizes harmony between humans and nature, plays a positive role in safeguarding wetland plant resources and the ecological environment. First, formulating a scientific ecotourism plan is essential. During the planning process, factors such as the natural attributes of wetlands, the surrounding ecological environment, and local socioeconomic conditions must be fully considered to ensure coordinated development between tourism and wetland conservation. Second, strengthening ecotourism education is necessary. Through various forms of promotional and educational activities, tourists' environmental awareness and civilized tourism practices should be enhanced, guiding them to respect

nature and protect the wetland ecological environment. Additionally, establishing an ecotourism management system is imperative <sup>[3]</sup>. Finally, prioritizing the sustainable development of ecotourism is vital. When developing and constructing ecotourism projects, it is important to focus on protecting wetland plant resources and the ecological environment while fully considering the interests and development needs of local communities, thereby promoting local economic growth and community participation.

## **4. Wetland Ecological Restoration Techniques**

### **4.1 Substrate Recovery**

Substrate restoration is a crucial step in wetland ecological rehabilitation, as it helps maintain substrate stability, stabilize wetland area, and modify wetland topography and landforms. First, soil and water erosion control techniques within wetlands and their upstream areas are essential means for substrate restoration. Planting shelterbelts, turf, and other vegetation around wetlands can prevent soil erosion while improving the ecological environment. Additionally, constructing embankments, revetments, and other engineering structures around wetlands can mitigate soil erosion and enhance flood control capacity. These measures effectively maintain wetland substrate stability and reduce damage to wetland ecosystems caused by soil erosion. Second, wetland substrate modification techniques are also vital components of substrate restoration. Removing silt from wetlands can improve water quality and topography. Reclamation projects can increase wetland depth and breadth, enhancing water storage capacity. Structural reinforcement can strengthen dikes, riverbanks, and other features to prevent soil erosion, collapse, and similar issues. These techniques effectively transform wetland topography and landforms, thereby improving the quality of the wetland ecological environment.

### **4.2 Hydrological Condition Restoration**

Restoration of hydrological conditions is a crucial aspect of wetland ecological recovery. The detailed measures for restoring hydrological conditions are as follows: First, constructing dams (to raise water levels) and building water diversion channels are key approaches. By building dams to elevate water levels, the water volume in wetlands can be increased, thereby

improving the wetland's ecological environment. Constructing water diversion channels can introduce external water sources into the wetland, enhancing both water quantity and quality to meet the needs of wetland plants and animals. These measures effectively restore the hydrological conditions of wetlands and promote the recovery of wetland ecosystems. Second, increasing the depth and breadth of lakes to expand lake capacity can enhance the water storage capacity and surface area of wetlands, improving the quality of the ecological environment. Increasing fish production can promote biodiversity in wetlands and enhance their ecological service functions. Strengthening regulatory functions can effectively manage water quantity and quality in wetlands, meeting the requirements of wetland flora and fauna. Actively developing water diversion channels for wetlands to secure high-quality supplemental water sources ensures adequate water volume and quality, facilitating ecological restoration.

### **4.3 Soil Restoration**

Soil restoration is a critical component of wetland ecological recovery, primarily involving soil pollution control techniques and soil fertility restoration technologies. Firstly, soil pollution control technology is a key aspect of soil restoration. Wetland soil pollution mainly originates from industrial wastewater, agricultural fertilizers and pesticides, and domestic sewage. To address these pollution sources, corresponding control technologies can be implemented, such as wastewater treatment techniques, fertilizer and pesticide reduction methods, and domestic sewage treatment technologies. These approaches can effectively reduce pollutant discharge and protect the soil environment of wetlands. Secondly, soil fertility restoration technology is also an important means of soil recovery. The decline in wetland soil fertility is primarily caused by over-exploitation, utilization, and natural factors. In response to this situation, measures such as organic fertilizers, green manure, and microbial fertilizers can be employed to enhance soil fertility and activity. These fertilizers provide essential nutrients, improve soil structure, increase water and nutrient retention capacity, and promote the growth and reproduction of wetland vegetation. Finally, soil restoration can also be achieved through vegetation recovery. The restoration of wetland vegetation can

improve soil quality and enhance the overall ecological environment of wetlands.

#### 4.4 Biological Restoration Technology

Biological restoration technology is a key component of wetland ecological restoration, encompassing techniques such as species selection and cultivation, introduction, protection, population dynamic regulation, population behavior control, optimization and establishment of community structure, as well as control and restoration of community succession. First, species selection and cultivation technology involves breeding superior species suitable for wetlands through genetic engineering, cell engineering, and other methods, followed by large-scale cultivation and planting to enhance wetland biodiversity and ecological service functions<sup>[4]</sup>. Second, species introduction technology addresses the absence of certain species in wetlands by introducing them from other regions or countries, thereby increasing biodiversity and ecological balance. Third, species protection technology focuses on safeguarding threatened species in wetlands through in-situ and ex-situ conservation measures, providing better living environments and breeding conditions for these species. Additionally, population dynamic regulation technology adjusts the quantity and distribution of populations in wetlands to prevent issues arising from overpopulation or scarcity, thereby maintaining ecological balance and stability.

#### Conclusion

The conservation and utilization of wetland plants are crucial measures for promoting and improving wetland ecosystems. By enhancing the protection and

management of wetland plants and rationally utilizing their resources, the ecological functions and values of wetland plants can be fully realized, contributing to the maintenance of ecological balance and biodiversity in wetlands. Simultaneously, strengthening scientific research, publicity, and education on wetland plants, as well as raising public awareness and understanding of their importance, are also vital approaches to their conservation and utilization. Only through comprehensive and scientific conservation and utilization of wetland plants can sustainable development of wetlands and the improvement of the ecological environment be achieved.

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## REVIEW ARTICLE

Open Access

# Research and Application Development of Phytosanitary Detection Technology

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**Abstract:** The research on the development and application of plant quarantine detection technologies encompasses PCR-based detection techniques for plant pathogens, immunology-based detection methods for plant diseases and pests, and artificial intelligence-driven risk assessment technologies for plant invasions. These technologies have demonstrated significant application value in areas such as quality inspection of plant seeds and seedlings, prevention and control of plant diseases and pests, and risk assessment of invasive plant species. With continuous advancements in science and technology, plant quarantine detection technologies will play an increasingly vital role in agricultural and forestry production.

**Keywords:** plants; quarantine detection technology; application fields

## 1. The Development History of Phytosanitary Detection Technology

### 1.1 Traditional Plant Quarantine Methods

In the history of plant quarantine, traditional detection methods have always played a significant role. Traditional plant quarantine methods primarily rely on visual inspection and empirical judgment, depending on manual checks and sample observation to identify and diagnose plant diseases and pests. While these methods are simple and easy to implement, they have certain limitations. First, traditional plant quarantine methods have constraints in terms of the accuracy and consistency of detection results. Manual visual assessment is susceptible to subjective factors, potentially leading to observational errors and judgment discrepancies. Particularly for early infections or mild symptoms caused by certain pathogenic

microorganisms and pests, accurate determination through visual observation is often challenging. Second, traditional detection methods require substantial human resources and time investment. Manual inspections and sample observations demand professionals with relevant experience and technical skills, consuming considerable time and effort. This not only increases the workload but also raises costs. Finally, traditional plant quarantine methods struggle to meet the demands of large-scale, high-efficiency detection<sup>[1]</sup>. With the continuous development of global trade, the spread of plant diseases and pests has accelerated, raising the requirements for detection to increasingly higher levels. Traditional detection methods often fall short in handling large volumes of samples and high-speed detection needs. Despite these limitations, traditional plant quarantine methods still hold important value in certain aspects.



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## 1.2 Introduction of Genetic Testing Technology

With the rapid development of genetic engineering and molecular biology, genetic testing technology has gradually been applied in the field of plant quarantine, providing new methods and tools for plant health and agricultural security. The introduction of genetic testing technology marks a further revolution in plant quarantine techniques. Genetic testing primarily involves detecting specific genes or DNA sequences in plant tissues to determine whether the plant is infected with specific pathogens or pests. This method fully leverages the specificity and stability of genes, is unaffected by external environmental interference, and offers high accuracy and sensitivity. In the process of introducing genetic testing technology, polymerase chain reaction (PCR) was one of the earliest widely adopted techniques. PCR technology can amplify target gene fragments from minute DNA samples in a short time, followed by detection through methods such as gel electrophoresis. The introduction of this technology has significantly improved the efficiency and reliability of plant quarantine detection. The adoption of genetic testing technology has made plant quarantine detection faster, more accurate, and traceable. By detecting specific genes or DNA sequences, it is possible to quickly identify whether plants are infected with pathogens or pests, enabling the implementation of corresponding control measures. This greatly enhances the quality and efficiency of plant health and agricultural production <sup>[2]</sup>.

## 1.3 Emerging Molecular Detection Technologies

With the continuous advancement and innovation of science and technology, emerging molecular detection technologies are gradually being applied in the field of plant quarantine, providing more efficient and accurate means for pathogen detection and pest monitoring. These molecular detection technologies, characterized by their high specificity, sensitivity, and rapidity, have driven the further development of plant quarantine efforts. One important emerging molecular detection technology is high-throughput sequencing based on DNA barcoding. This technique utilizes the unique sequence characteristics of DNA barcodes to rapidly amplify and analyze DNA sequences in samples using high-throughput sequencers. This technology not only enables precise identification of plant pathogens

but also allows simultaneous processing of multiple samples, enhancing both the efficiency and scale of detection. Another molecular detection technology with significant potential is the CRISPR-Cas system. The CRISPR-Cas system, a gene-editing technology, can precisely edit and modify specific gene sequences of plant pathogens and pests. By using the CRISPR-Cas system, specific probes can be designed to recognize and locate particular targets, thereby enabling rapid detection and control of plant pathogens and pests <sup>[3]</sup>. Additionally, nucleic acid gene chip technology is another emerging molecular detection method. This technology is based on the hybridization of a large number of genes in the plant genome and employs fluorescence labeling to detect target objectives. With its advantages of high throughput, high sensitivity, and high specificity, this technology can rapidly identify and distinguish large-scale plant pathogens and pests.

## 1.4 Other Advanced Detection Technologies

In addition to genetic testing and molecular testing technologies, several other advanced detection techniques have been widely applied in the field of plant quarantine and have achieved remarkable results. One important advanced detection technology is near-infrared spectroscopy. This technique utilizes the absorption and reflection characteristics of plant samples at different wavelengths of light, analyzing and interpreting spectral information through optical instruments. It enables the rapid acquisition of large amounts of spectral data, which is then processed and modeled to detect and identify plant diseases and pests. Near-infrared spectroscopy requires no sample pre-treatment or destructive procedures, offering advantages such as speed, non-destructiveness, and high throughput, making it widely applicable in plant quarantine. Furthermore, nanotechnology has also made significant breakthroughs in plant quarantine. Nanotechnology employs nanoscale materials and structures, along with detection and sensor technologies, to achieve highly sensitive detection of plant pathogens and pests.

# 2. Application Fields of Phytosanitary Detection Technology

## 2.1 Detection of Plant Pathogens

Plant quarantine detection technology is widely applied in the detection and control of plant pathogens. Plant



pathogens are one of the primary causes of plant diseases, severely impacting crop health and yield. Through rapid, accurate, and reliable detection of plant pathogens, appropriate prevention and control measures can be implemented in a timely manner to curb the spread and escalation of diseases, thereby ensuring the stability and sustainable development of agricultural production. Plant quarantine detection technology plays a crucial role in the identification of plant pathogens. Genetic testing techniques can determine whether plants are infected by specific pathogens by analyzing specific genes or DNA sequences in plant tissues. For instance, PCR technology enables the rapid amplification and detection of specific gene fragments of pathogens, thereby confirming the presence and severity of diseases <sup>[4]</sup>. Similarly, molecular detection techniques can identify and characterize plant pathogens by analyzing RNA or proteins in plant samples. Near-infrared spectroscopy technology can detect characteristic compounds in plant tissues through spectral analysis to determine pathogen infection. Nanotechnology, utilizing specific nanosensors and nanomaterials, allows for sensitive detection of the presence and concentration of pathogens.

## 2.2 Monitoring of Plant Diseases and Pests

Phytosanitary detection technology has broad application fields in the monitoring of plant diseases and pests. Plant diseases and pests are significant issues in crop production, severely affecting the stability and yield of agricultural output. Through timely and accurate monitoring and identification of plant diseases and pests, effective control measures can be implemented to mitigate the damage caused to crops and ensure the smooth and sustainable development of agricultural production. The application of phytosanitary detection technology in monitoring plant diseases and pests is highly important. Genetic detection technology determines whether plants are infected by specific pathogens or pests by analyzing specific genes or DNA sequences in plant tissues. Methods such as PCR technology and nucleic acid hybridization can rapidly and accurately detect the genes or DNA sequences of pathogens or pests infecting plants. Molecular detection technology can also identify and diagnose plant diseases and pests by analyzing RNA or proteins in plant samples. Near-

infrared spectroscopy technology can identify and diagnose plant diseases and pests by analyzing the spectral information of samples to detect specific compounds and characteristics. Artificial intelligence and machine learning technologies can accurately identify and classify plant diseases and pests by analyzing images and data models. Traditional monitoring methods, such as visual observation and microscopic examination, still play a crucial role. By observing the appearance and symptoms of plant tissues such as leaves, stems, and roots, preliminary judgments can be made regarding whether plants are infected by diseases or pests <sup>[1]</sup>.

## 2.3 Prevention and Control of Biological Invasion by Alien Plants

Alien plant biological invasion refers to the introduction of certain non-native plant species into new geographical areas, which negatively impacts local ecosystems. These plant species may introduce new pathogens and pests, disrupt local biodiversity, compete with native plants for resources, and even cause severe damage to industries such as agriculture, forestry, and horticulture. Plant quarantine detection technologies play a crucial role in preventing and controlling alien plant biological invasions. By inspecting plant materials, seeds, and other items during import, export, or transit, potential invasive species can be identified and intercepted early. Genetic detection techniques, through the analysis of plant DNA or RNA, enable accurate identification of plant genera, species, and identities. Molecular detection methods analyze specific molecules in samples to rapidly identify potential alien plant organisms. In terms of early warning and monitoring, near-infrared spectroscopy technology can quickly distinguish target species from non-target plant species by analyzing characteristic compounds in plant samples. Meanwhile, artificial intelligence and machine learning technologies, through learning and model training, can accurately identify plant species, providing an intelligent auxiliary identification tool.

## 2.4 Quality Inspection of Plant Seeds and Seedlings

Seeds and seedlings are critical factors in agricultural and forestry production, with their quality significantly impacting plant growth and yield. Quality testing of seeds and seedlings ensures the selection of superior varieties and optimal planting conditions, thereby

enhancing the quality and yield of crops and forests. Phytosanitary detection technology plays a key role in seed and seedling quality assessment. Genetic testing technology can accurately identify plant varieties and purity by analyzing specific genes and DNA sequences in seeds and seedlings. For instance, PCR technology can rapidly detect different plant varieties and distinguish hybrid species, which is crucial for quality authentication and marketing of seeds and seedlings<sup>[2]</sup>. Molecular detection technology can also evaluate the quality and characteristics of seeds and seedlings by analyzing RNA or proteins. Near-infrared spectroscopy technology assesses the nutritional and health status of seeds and seedlings by analyzing spectral information to detect specific compounds and features. Additionally, artificial intelligence and machine learning technologies, based on data models, can identify and classify different varieties and quality levels by learning and analyzing extensive images and characteristics of seeds and seedlings.

### **3. Research Advances in Phytosanitary Detection Technologies**

#### **3.1 PCR-Based Detection Techniques for Plant Pathogens**

In recent years, PCR technology has been widely applied in the detection of plant pathogens. One common PCR technique is real-time quantitative polymerase chain reaction (qPCR). This method enables real-time monitoring of PCR product accumulation during the reaction and quantifies target sequence concentration through increasing fluorescence signals. qPCR allows rapid and accurate detection of pathogen presence and concentration, providing crucial reference data for plant disease prevention and control. Further advancements in PCR technology include the application of novel amplification methods. For instance, loop-mediated isothermal amplification (LAMP) is an enzyme-based isothermal technique that amplifies target sequences rapidly at constant temperatures. LAMP demonstrates high specificity and sensitivity, enabling direct detection of target pathogens in complex samples without requiring purification or cultivation. Additionally, the integration of PCR with next-generation sequencing technologies has opened new possibilities for plant pathogen detection.

#### **3.2 Immunology-Based Detection Techniques for Plant Diseases and Pests**

Immunological techniques offer numerous advantages in the detection of plant diseases and pests. Firstly, immunological methods can identify the presence of plant pathogens or pests by detecting specific antibodies or antigens. These antibodies or antigens can be screened and prepared to target specific pathogens or pests, exhibiting high specificity and sensitivity. Secondly, immunological techniques can be conducted in laboratory settings and enable rapid detection. Additionally, they can be combined with other detection methods to enhance accuracy and reliability. A common approach in immunological-based detection of plant diseases and pests is the enzyme-linked immunosorbent assay (ELISA). ELISA detects target antigens in plant samples by binding them to enzyme-labeled antibodies, resulting in visible color changes when substrates are applied. This technique offers high specificity and sensitivity, capable of detecting low concentrations of target pathogens or pests. In recent years, advancements in immunological research have included the application of novel detection methods. For instance, immuno-PCR combines PCR technology with immunological techniques, utilizing antibody-antigen binding signals while amplifying target DNA through PCR, further improving detection sensitivity and specificity. Moreover, the integration of immunological techniques with nanomaterials and nanotechnology has opened new possibilities for plant disease and pest detection<sup>[3]</sup>.

#### **3.3 Artificial Intelligence-Based Risk Assessment Technology for Plant Invasion**

Artificial intelligence technology offers numerous advantages in plant invasion risk assessment. Firstly, it can process large-scale and diverse datasets, including biological characteristics, habitat requirements, and ecological contexts of plant species. By comprehensively analyzing these data, accurate risk assessment models for plant invasions can be developed. Secondly, AI technology is characterized by automation and high efficiency, enabling rapid processing and analysis of vast amounts of data to deliver quick and precise risk assessment outcomes.

In AI-based plant invasion risk assessment, a common approach involves machine learning



algorithms. These algorithms are trained on extensive sample data to learn patterns and regularities, allowing them to make predictions and classifications on new data. By learning from historical plant invasion cases, machine learning algorithms can identify potential invaders based on various features and assess their threat levels to local ecosystems<sup>[4]</sup>.

Beyond machine learning, deep learning techniques are also widely applied in plant invasion risk assessment. Deep learning mimics the neural networks of the human brain, enabling the learning and classification of large volumes of image and text data. By inputting data such as plant species images, morphological traits, and geographic distributions, deep learning models can accurately identify and evaluate potential invasive species.

## Conclusion

The development and application of plant quarantine detection technologies have provided robust support for agricultural and forestry production. PCR-based techniques enable highly sensitive detection of plant pathogens, ensuring the quality and purity of seeds and seedlings. Immunology-based methods allow accurate

identification of plant diseases and pests, enhancing the precision and sensitivity of prevention and control measures. Artificial intelligence-based technologies facilitate the assessment of plant invasion risks, safeguarding the stability of local ecosystems.

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## RESEARCH ARTICLE

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# Research on International Promotion Strategies for Tianjin's Crop Seed Industry under the "Belt and Road" Initiative

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**Fund Project:** This study is part of the phased research outcomes of the 2023 Tianjin College Students Innovation and Entrepreneurship Project: Research on International Cooperation and Promotion of Tianjin Crop Seed Industry under the Rural Revitalization Background (Project No.: 202310061080).

**Abstract:** In 2021, the 20th Meeting of the Central Committee for Comprehensively Deepening Reforms approved the "Action Plan for Revitalizing the Seed Industry," aiming to advance the revitalization of the national seed industry. Internationalization is an inevitable path for the development of China's seed industry. As a crucial breeding region in northern China, Tianjin urgently needs to explore international promotion models for its seed industry. The "Belt and Road" Initiative provides practical conditions for Tianjin's seed industry to expand globally. Based on comprehensive research on the current status of international promotion of Tianjin's crop seed industry, this study proposes an integrated "R&D, Production, and Sales" international promotion model for Tianjin's crop seed industry, achieving coordinated domestic and international efforts and synergistic linkages, thereby facilitating the global expansion of Tianjin's superior seed industry.

**Keywords:** Crop seed industry; Tianjin; International promotion strategy

The 2023 Tianjin Seed Industry Revitalization Conference was held at the National Convention and Exhibition Center (Tianjin) on March 18, making it imperative to advance international cooperation, exchange, and promotion of Tianjin's seed industry. International collaboration and promotion in the seed sector will benefit the revitalization of Tianjin's seed industry, contribute to sustainable agricultural development, and safeguard food security.

## 1. Research Background

The development of the seed industry will directly

drive the nation's agricultural economic growth and is a strategically significant foundational industry in China. After more than half a century of development, China's seed industry has initially established a relatively comprehensive scientific research system and a seed breeding and extension system. It has cultivated a stable and excellent team engaged in seed research, promotion, and production operations, built infrastructure of considerable scale for seed production, processing, storage, inspection, and marketing, and formulated a series of management regulations and standards that are gradually aligning with international practices. Domestic and international seed trade and



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technical exchanges have also been conducted <sup>[1]</sup>. In the process of technological innovation in the seed industry, rapid growth has been maintained in various aspects, including the conservation and utilization of germplasm resources, the application and authorization of plant variety rights, and the review and registration of crop varieties. As the largest developing country in the world, China boasts a wide variety of crop types, a large scale of R&D personnel, and a comprehensive R&D system. It is essentially capable of collaborating according to the seed industry development needs of different countries, with vast potential and scope for cooperation.

Currently, most countries along the "Belt and Road" are developing nations with agriculture-dominated economies, where agricultural output constitutes a significant proportion of their total economic output and even serves as a pillar industry. For instance, in Asian countries such as Pakistan, Laos, Cambodia, and Nepal, the share of agricultural output in GDP has reached or approached 20%. In Central Asian nations like Uzbekistan, Tajikistan, and Kyrgyzstan, this proportion exceeds 15%, while in African countries including Kenya, Rwanda, Liberia, Niger, and Ethiopia, agricultural output accounts for one-third or more of GDP. <sup>[2]</sup> These countries possess abundant agricultural resources and favorable climatic conditions for farming. Their agricultural land area as a percentage of total national land and per capita arable land rank among the highest globally. However, due to poor agricultural infrastructure, limited investment in agricultural technology, and backward production techniques, their agricultural productivity remains low, creating a substantial demand for international agricultural cooperation. In Africa, for example, there are only slightly over 400 institutions engaged in agricultural research and development, with a scarcity of agricultural extension personnel who often lack advanced qualifications, making it difficult to meet farmers' technical needs during agricultural production. As their economies develop, there is an urgent desire among these developing nations to enhance their agricultural technological capabilities, particularly in the field of seed technology.

The Belt and Road Initiative has provided a valuable historical opportunity for China's seed

industry technology to "go global," actively engage in international cooperation, participate in global seed industry competition, and accelerate solutions to global food security. It has facilitated agricultural technology exchanges between China and neighboring countries, promoted international agricultural cooperation, and created practical conditions for Tianjin's seed industry to expand abroad. Based on a comprehensive investigation of the current state of Tianjin's international cooperation in the seed industry, this study explores an integrated international promotion model for the seed industry. The aim is to achieve coordinated domestic and international efforts and synergistic collaboration, contributing to the comprehensive revitalization of Tianjin's rural areas and addressing food security challenges.

## 2. Research Methods and Data Sources

Based on the current status of Tianjin's seed industry development, this study employs a combination of questionnaire surveys and field visits to conduct research in the following aspects: by analyzing the current state of international cooperation in the seed industry, it explores integrated international promotion pathways to support the comprehensive revitalization of Tianjin's rural areas.

The study conducted field visits to areas such as Jixian, Baodi District, and Jinnan District in Tianjin, as well as relevant research institutions and agricultural universities. Through interviews and questionnaires, it aimed to understand the current state of international exchanges and cooperation in crop seed breeding and seed production technologies, gather first-hand information on the international development of Tianjin's seed industry, and identify the existing challenges in Tianjin's international cooperation in this sector. The research primarily focused on the following aspects:

- (1) The internationalization level of crop seed industry technology and the overseas market share of seeds.
- (2) R&D investment in the crop seed industry, and large-scale seed propagation.
- (3) Bottlenecks constraining the internationalization of crop seed industry;
- (4) Local policies and supporting services to promote the "going global" of crop seed industry.

### 3. Development History of Tianjin Crop Seed Industry

Since the founding of the People's Republic of China 74 years ago, Tianjin's seed industry has achieved steady development with a gradual improvement in quality. Vegetables have increasingly entered international markets, and production bases of considerable scale and advanced standards have been established. Between 1949 and 1971, grain production in Tianjin was dominated by rice, accounting for 30% to 40% of the total grain output. In 1972, due to weather conditions, paddy fields were converted to dry farmland, causing rice production to drop to 5%. Subsequently, Tianjin established a grain crop structure primarily focused on the cultivation of wheat and corn.

From 1978 to 1998, the seed industry developed rapidly, ushering in a period of comprehensive prosperity. Starting in 1978, rural Tianjin implemented the household contract responsibility system. In the early 1980s and 1990s, the unified procurement and distribution system for agricultural products was comprehensively reformed, and the grain production and sales markets were liberalized. In 1981, in response to the central government's policy of "never relaxing grain production while actively developing diversified operations," Tianjin's planting structure gradually shifted toward "high yield, high efficiency, and superior quality." After the implementation of the "vegetable basket" project in Tianjin in 1984, the area and yield of vegetables increased year by year. By 1998, the sown area of vegetables reached 1.296 million mu, an increase of 1.085 million mu compared to 1949, with an average annual growth rate of 3.8%. Among the crops, cotton and oilseeds developed most rapidly, with average total yields increasing to 10,800 tons and 38,500 tons, respectively, which were three times and eight times the average total yields of cotton and oilseeds before the reforms.

From 1999 to 2009, modern agricultural cultivation experienced vigorous development. In 2007, Tianjin thoroughly implemented the Scientific Outlook on Development and introduced the "Implementation Opinions on Promoting the Strategy of Urban-Rural Integration and Accelerating the Construction of a New Socialist Countryside." It adhered to the development of high-yield, high-quality, efficient, ecological, and

safe modern agriculture and urban agriculture, which significantly influenced the modernization of the seed industry.

Since 2009, Tianjin's seed industry has shown a clear trend toward internationalization. In recent years, the Tianjin International Rice Research Institute was inaugurated. Breakthroughs have been made in three aspects of Tianjin's rice industry: first, achieving "two super and one simplified" in breeding—super high yield, super high quality, and simplified cultivation; second, striving for comprehensive coverage of "three types" in the rice industry structure by promoting super high-quality and super high-yield rice varieties, as well as hybrid japonica rice seed production across the city; third, continuing to expand the promotion area of Tianjin's rice varieties nationwide. Over the past six decades, Tianjin's seed industry has seen enhanced comprehensive production capacity, significantly increased economic benefits, noticeably optimized structural adjustments, and remarkable achievements in modernized cultivation.

### 4. Case Study on International Promotion of Tianjin Crop Seed Industry

Cauliflower seeds from Tianjin were introduced to Pakistan for cultivation. The long growth cycle, low yield, and perennial reliance on imported seeds have been core factors hindering the development of Pakistan's agricultural seed industry. In response to the Belt and Road Initiative, Tianjin Tielong Company, under the guidance of the Tianjin Municipal Commission of Rural Affairs, exported high-quality cauliflower seeds bred in Tianjin to Pakistan to address local cauliflower cultivation challenges. Building on this foundation, cooperation between Tianjin and Pakistan expanded from cauliflower to a wider range of varieties, including cucumbers, cabbages, watermelons, melons, and peppers <sup>[3]</sup>. Based on the success in Pakistan, cauliflower seeds were further promoted to more South Asian countries, such as India and Bangladesh, with Pakistan as the center, contributing to the construction of the China-Pakistan Economic Corridor.

Tianjin Agricultural Reclamation Group Bulgaria Co., Ltd. actively responds to the Belt and Road Initiative and the national call for agricultural "going global." It serves as a bridgehead for the exchange and

sharing of high-quality agricultural products between China and Bulgaria as well as Central and Eastern Europe, becoming a key hub in Central and Eastern European cooperation. Bulgaria faces challenges such as low rice yield per unit and a reduction in rice cultivation area <sup>[4]</sup>. To address this, Tianjin Agricultural Reclamation Group Bulgaria Co., Ltd. introduced advanced domestic technologies, including China's independently developed greenhouse technology, dry nursery seedling technology, and rice transplanting machinery. The company tested 35 unique Chinese rice varieties across 225 acres of paddy fields. By employing dry nursery seedling and mechanical transplanting techniques, the rice growth period was extended by 30-50 days, attracting numerous local farmers for exchanges and collaboration. This initiative lays the foundation for expanding Bulgaria's rice cultivation area and establishes a solid groundwork for building Chinese enterprises' independent rice brands. In the vegetable sector, leveraging the abundant sunlight and favorable climatic conditions of its location, the company introduced a variety of distinctive Chinese vegetable seeds, such as Chinese garlic, Shanghai greens, and golden cabbage, for trial cultivation, thereby enriching Bulgaria's vegetable seed varieties. Moving forward, based on the high quality of millet produced, the company plans to develop a series of programs covering millet seed industry, large-scale millet cultivation, utilization of millet and straw as feed, and deep processing of millet products. It aims to gradually expand these industries to more European countries, providing a strong foundation for China's seed industry to "go global."

## 5. Advantages of Tianjin's International Promotion of Crop Seed Industry

According to the "14th Five-Year Plan for International Agricultural and Rural Cooperation in Tianjin" (hereinafter referred to as the "Plan") compiled by the Tianjin Municipal Commission of Rural Affairs, it is projected that by 2025, Tianjin will establish forty high-quality international agricultural trade development bases at the city level. Simultaneously, emphasis will be placed on promoting its advantageous agricultural products. Focusing on high-quality agricultural products such as vegetables, fruits, nuts, and seafood, Tianjin aims to develop into a high-quality agricultural

international trade base.

Tianjin boasts a prime geographical location. Bordering the Bohai Sea, it serves as a vital gateway connecting North China, Northwest China, and Northeast China, functioning not only as a critical passage for several northern provinces and municipalities to engage with external regions but also as the nation's largest port city. Furthermore, Tianjin has emerged as a key node along the China-Mongolia-Russia Economic Corridor, a strategic support point for the Maritime Silk Road, an intersection of the Belt and Road Initiative, and the easternmost starting point of the Eurasian Land Bridge. It plays a pivotal role in linking domestic and international markets, facilitating north-south coordination, and enabling east-west connectivity.

Tianjin possesses a solid foundation and advantages in breeding. Currently, the city boasts over 3,000 cucumber germplasm resources, 1,188 Chinese cabbage resources, 552 radish resources, 180 kohlrabi resources, and 708 melon germplasm resources <sup>[5]</sup>. Its hybrid japonica rice and high-quality rice breeding programs are internationally leading. Since the 13th Five-Year Plan period, Tianjin has developed 16 nationally approved hybrid japonica rice varieties, ranking first in China. To promote the sustainable development of Tianjin's seed industry and succeed in the highly competitive international market, it is essential to adhere to international collaborative innovation in seed technology, highlight Tianjin's distinctive characteristics, and facilitate the global expansion of premium crop varieties such as Tianjin's Xiaozhan rice, cucumbers, cauliflowers, Chinese cabbages, and green radishes. As a key breeding region in northern China, it is urgent to explore an integrated international promotion model for the seed industry that supports the development of urban modern agriculture in the city.

## 6. International Promotion Strategy for the "Integrated" Development of Tianjin's Crop Seed Industry

Based on the construction of international cooperation bases, we will actively explore international markets, optimize the use of international resources, and establish an integrated international promotion model for the seed industry that combines "research, production, and sales." First, we will strengthen the quality of the bases



by formulating and issuing the "Tianjin Agricultural International Trade High-Quality Development Base Action Plan for 2022–2025," using high-quality agricultural international trade development bases as the construction standard to enhance the guarantee of agricultural product export quality. Second, we will improve trade quality by actively exploring international markets. Enterprises are encouraged to align agricultural production with international standards in key target countries and regions such as the EU, Japan, South Korea, and ASEAN. Third, we will cultivate key talent, adhering to a market-oriented approach that combines enterprise leadership with government guidance, and increase support and coordination for businesses. We support and encourage local Tianjin enterprises to actively develop more overseas channels and steadily advance international cooperation. Media resources will be utilized effectively. News leads will be proactively shared with domestic and international mainstream media to tell Tianjin's and China's stories effectively through media platforms. The story of Tianjin's cauliflower varieties reaching Belt and Road Initiative countries has been covered by Xinhua News Agency and Tianjin Daily, generating positive societal feedback.

Strive to expand the effectiveness of cooperation. Adhere to simultaneous efforts in overseas bridgeheads and domestic headquarters, continuously deepen the construction of the Binhai New Area Agricultural Opening-Up Cooperation Pilot Zone, enhance the synergistic effects of domestic and international projects, drive international trade in scarce agricultural products such as feed grains, oilseeds, and high-quality breeding livestock, as well as the export of superior seeds, thereby providing effective support for the high-quality development of Tianjin's modern agricultural industry. Strengthen work guidance and performance evaluation for agricultural districts, incorporate relevant content into the city's rural revitalization performance assessment, and mobilize the enthusiasm and initiative of all agricultural districts in promoting international agricultural cooperation. Dedicate efforts to serving enterprises. We need to establish a list of key enterprises for external agricultural cooperation, effectively conduct operational coordination, and provide timely assistance to resolve issues in enterprise

operations and production, thereby fostering the healthy growth of enterprises.

## 7. Conclusion

The internationalization of the crop seed industry is a crucial driving force for the modernization and specialization of agriculture in Tianjin, as well as a key strategy to seize the commanding heights of the new round of international competition. This research contributes to the integration of agricultural resources, strengthens agricultural technology cooperation, and promotes technological exchange and complementary agricultural resources among countries along the Belt and Road. Additionally, it facilitates the introduction of China's new crop varieties, agricultural inputs, equipment, and technologies to these countries, particularly developing nations, thereby enhancing their comprehensive agricultural productivity, improving resource utilization efficiency, and ensuring their food security.

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