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Original Paper

Research and Application of Biological Control Technologies for Forest Pests and Diseases

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Abstract

This article focuses on the application of biological control technologies in forest pest and disease management. Firstly, it provides an overview of biological control technologies, highlighting their use of organisms or their metabolic products to control pests and diseases, with advantages such as environmental friendliness and sustainability. Subsequently, it analyzes the characteristics of forest pest and disease occurrences, including a wide variety of species, sudden outbreaks, large affected areas, and rapid spread, as well as exploring causes such as the increase in artificial forest areas, significant climate change, and over-reliance on chemical control. Finally, it emphasizes the application strategies of biological control technologies, including the use of natural enemies of pests and diseases, fungal control, avian control, and biological enzyme technologies. These strategies can effectively reduce the use of chemical pesticides, protect the ecological environment, maintain forest ecological balance, and provide a scientific, green, and sustainable approach to forest pest and disease management, which is of great significance for safeguarding forest resource health and ecological security.

Keywords

Biological control technologies, Forest pest and disease management, Application strategies

1. Introduction

Forests, as the core component of terrestrial ecosystems, are akin to the green lungs of the Earth, playing an irreplaceable and vital role in maintaining ecological balance and providing a rich variety of ecological services. They not only regulate the climate, conserve water sources, and preserve soil and water but also serve as habitats for numerous wild animals and plants to thrive and reproduce, making them important repositories of biodiversity.

However, in recent years, the issue of forest pests and diseases has taken on an increasingly severe form, akin to an invisible "war" that seriously threatens the health of forests and the normal functioning

of their ecological functions. Traditionally, chemical control has been the primary means of addressing forest pests and diseases, as it can, to a certain extent, swiftly curb the spread of pests and diseases and safeguard the short-term security of forest resources. However, the long-term and large-scale use of chemical pesticides has also brought about a series of drawbacks that cannot be overlooked. Pesticide residues can contaminate soil and water sources, disrupting the balance of ecosystems; pests gradually develop resistance in the long-term "struggle for survival," significantly reducing the effectiveness of chemical control and even necessitating a continuous increase in dosage, creating a vicious cycle.

Against this severe backdrop, biological control technology stands out with its unique advantages, becoming a research hotspot and practical direction in the field of forest pest and disease control. Biological control technology mainly utilizes the mutual restrictive relationships among organisms in nature to control pest populations by introducing or protecting natural enemies of pests, pathogenic microorganisms, and so on. It is environmentally friendly and highly sustainable, causing no pollution to the ecological environment and not leading to pest resistance, thus fundamentally maintaining the stability and health of forest ecosystems.

This paper aims to delve into the specific applications of biological control technology in forest pest and disease control, analyzing its applicability and effectiveness across different forest types and pest and disease species. Through systematic research and practical case analyses, it summarizes the successful experiences and existing problems of biological control technology, providing solid theoretical support and practical references for enhancing the level of forest pest and disease control in China and facilitating the sustainable development of forest resources.

2. Overview of Biological Control Technologies

Biological control technologies are green prevention and control methods that utilize organisms or their metabolic products to control harmful organism populations, thereby maintaining ecological balance and ensuring the healthy development of agriculture, forestry, and other industries. Based on the interrelationships among organisms in ecosystems and following natural regulatory laws, they possess significant advantages such as environmental friendliness and strong sustainability.

There are various types of biological control technologies. Among them, using insects to control insects involves utilizing natural enemy insects of pests to suppress pest populations. For example, Trichogramma spp. can parasitize the eggs of various Lepidoptera pests, effectively reducing pest hatching rates. Fungal control employs pathogenic microorganisms, such as Beauveria bassiana, which can infect various insects and cause them to die from illness. Avian control utilizes the pest-eating characteristics of birds; many bird species are natural enemies of forest pests and can consume large numbers of pests, reducing their harm to forests. Additionally, biological enzyme technologies involve extracting specific biological enzymes to interfere with the physiological and metabolic processes of pests, achieving control purposes.

Compared with chemical control, biological control does not cause environmental pollution or

pesticide residues, can protect other beneficial organisms in ecosystems, and maintain biodiversity. Moreover, harmful organisms are less likely to develop resistance to biological control factors, facilitating long-term control of harmful organisms. With increasing emphasis on ecological environmental protection, biological control technologies are being increasingly widely applied in agriculture, forestry, and other fields, becoming important technical support for achieving green prevention and control, ensuring ecological security, and the quality and safety of agricultural products, with broad development prospects.

3. Characteristics and Causes of Forest Pest and Disease Occurrences

3.1 Characteristics of Forest Pest and Disease Occurrences

3.1.1 Wide Variety of Species

The forest ecosystem is complex and diverse, providing habitats for numerous organisms, which also results in an extremely rich variety of forest pests and diseases. In terms of insect pests, there are Lepidoptera pests such as pine caterpillars and gypsy moths, and Coleoptera pests such as longhorn beetles and bark beetles, which infest trees in different ways, some feeding on leaves and others boring into branches and trunks, seriously affecting tree growth and development. Disease species are equally diverse, including fungal diseases such as pine blight and poplar canker, as well as various diseases caused by viruses and bacteria, which can damage tree tissue structures and reduce tree resistance. Different types of pests and diseases have varying biological characteristics and occurrence patterns, greatly increasing the difficulty of control efforts.

3.1.2 Sudden Outbreaks

Forest pests and diseases often erupt suddenly when people are least prepared. Many pests and diseases have inconspicuous symptoms during the latent period and are difficult to detect in a timely manner. Once environmental conditions are favorable, such as rising temperatures and increased humidity, pests and diseases can rapidly reproduce and spread, causing large-scale harm in a short period. For example, certain leaf-eating pests may hide inside tree canopies during the larval stage and are not easily noticeable. When they enter the feeding frenzy stage, they can devour all the leaves in an entire forest in a few days, causing devastating damage to the forest. This suddenness often leaves control efforts in a passive state, making it difficult to take effective measures at the optimal time.

3.1.3 Large Affected Areas

Once forest pests and diseases occur, they often spread rapidly and continuously expand the affected area. Due to the strong connectivity of forests, pests and diseases can spread through various means such as wind, water flow, and animal transportation. Some major pest and disease outbreaks can cross regional boundaries in a short period and affect large forest areas. For instance, pine wilt disease, known as the "cancer of pine trees," has spread to multiple provinces in China since its introduction, causing the death of a large number of pine trees and seriously damaging local forest resources and ecological balance.

3.1.4 Rapid Spread

The convenience of modern transportation and global climate change have provided favorable conditions for the spread of forest pests and diseases. Some alien pests and diseases can quickly spread to new areas through cargo transportation and seedling transfer. At the same time, climate change-induced temperature increases and altered precipitation patterns have expanded the distribution ranges of pests and diseases and accelerated their spread. For example, the red turpentine beetle, originally mainly distributed in North America, has been introduced to China through international trade and has caused severe harm in some areas.

3.2 Causes of Forest Pest and Disease Occurrences

3.2.1 Rapid Increase in Artificial Forest Areas

With the growing social demand for timber and other forest products, the area of artificial forests has rapidly expanded. However, artificial forests often have relatively simple tree species selections, mostly consisting of pure forests. This single ecosystem structure reduces biodiversity and weakens the stability of the ecosystem. Compared with natural forests, artificial forests lack the mutual restraint and balance mechanisms among multiple organisms. Once a certain pest or disease occurs, it can easily spread and expand rapidly due to the lack of natural enemy control. For example, large areas of pure Chinese fir forests, when attacked by pine caterpillars and other pests, can experience rapid pest reproduction and severe harm due to the lack of 阻挡 (this Chinese character seems out of place and may be a typo; if it means "blocking" by other tree species or natural enemies, it can be translated as "blocking by other tree species or natural enemies") by other tree species or predation by natural enemies.

3.2.2 Significant Natural Climate Change

Natural climate change has a significant impact on the occurrence of forest pests and diseases. In recent years, the trend of global warming has been evident, with frequent occurrences of climate anomalies such as rising temperatures and altered precipitation patterns. Warm climate conditions are conducive to the overwintering and reproduction of pests and diseases, enabling some pests and diseases that were originally difficult to survive in cold areas to survive and spread. At the same time, climate warming has also changed the species distribution and ecological relationships in forest ecosystems, allowing some alien pests and diseases to enter new areas and pose threats to local forests. In addition, extreme climate events such as heavy rain, drought, and typhoons can weaken tree resistance to pests and diseases, making trees more susceptible to infestation.

3.2.3 Over-reliance on Chemical Control

For a long time in the past, chemical control was the main method for forest pest and disease management. Chemical pesticides have advantages such as quick effectiveness and convenient use but also have many drawbacks. Long-term overuse of chemical pesticides not only pollutes soil, water sources, and air and damages the ecological environment but also causes pests and diseases to develop

resistance. As resistance increases, the control effectiveness of chemical pesticides gradually declines, requiring continuous increases in dosage and frequency of use, forming a vicious cycle. Moreover, chemical pesticides, while killing pests, also kill a large number of natural enemies of pests, disrupting the natural balance of forest ecosystems and further exacerbating pest and disease occurrences.

4. Application Strategies of Biological Control Technologies in Forest Pest and Disease Management

4.1 Natural Enemies of Pests and Diseases

Utilizing natural enemies of pests and diseases is one of the core strategies of biological control. In forest ecosystems, there are numerous natural enemy insects that feed on pests, such as parasitoid wasps, predatory ladybugs, and lacewings. Parasitoid wasps can lay their eggs inside or on the surface of pests, and their larvae develop inside the pests, ultimately causing the pests to die. For example, Trichogramma spp. can parasitize the eggs of various Lepidoptera pests, and by mass-releasing Trichogramma, the population sizes of pests such as pine caterpillars and corn borers can be effectively controlled. Predatory ladybugs feed on aphids, scale insects, etc., and a single ladybug can consume a large number of pests in its lifetime. Introducing or protecting these natural enemy insects in forests can establish natural pest control mechanisms. To better leverage the role of natural enemy insects, it is necessary to create environments suitable for their survival and reproduction. Planting nectar-source plants in forests can provide food sources for natural enemy insects, prolonging their lifespans and reproductive cycles. At the same time, reducing the use of chemical pesticides can avoid harming natural enemy insects. In addition, artificial breeding and release of natural enemy insects can increase their population sizes in forests and improve control effectiveness.

4.2 Fungal Control Technologies

Fungal control involves using microorganisms pathogenic to pests to control pest populations. Commonly used fungi include bacteria, fungi, and viruses. Bacillus thuringiensis is a widely used bacterial insecticide that can produce parasporal crystals and toxins. When pests ingest them, their midgut cells are damaged, leading to pest death. Bacillus thuringiensis has good control effects on various Lepidoptera, Coleoptera, and Diptera pests and is safe for humans and livestock and does not pollute the environment. Beauveria bassiana is a fungal insecticide that can infect various insects. Its spores germinate and invade the pest's body, absorbing the pest's nutrients and causing it to die. Beauveria bassiana has significant control effects on forest pests such as pine caterpillars and longhorn beetles. During the control process, fungal agents can be applied to forests through spraying or dusting, enabling pests to come into contact with and become infected by the pathogens. Insect viruses are also important resources for fungal control. Nuclear polyhedrosis viruses have strong host specificity and only infect specific pest species, posing no harm to other organisms. For example, the pine caterpillar nuclear polyhedrosis virus can effectively control pine caterpillars. By releasing virus preparations in forests, pine caterpillars can be infected and develop diseases, thereby controlling their population

sizes.

4.3 Avian Control Technologies

Birds are important components of forest ecosystems, and many bird species feed on pests, playing a significant role in forest pest and disease management. Woodpeckers, known as "forest doctors," can capture longhorn beetles, jewel beetles, and other boring pests in tree trunks, protecting tree health. Tits and cuckoos mainly feed on small pests such as leafhoppers and aphids. To attract birds to enter and inhabit forests for a long time, a series of measures can be taken. Setting up artificial bird nests in forests can provide breeding and habitat sites for birds. Selecting appropriate nest materials and shapes based on the habits of different bird species can improve the attractiveness and utilization rates of the nests. At the same time, protecting natural water sources and food resources in forests can create a good living environment for birds. In addition, through publicity and education, public awareness of bird protection can be raised, reducing interference and damage to birds.

4.4 Biological Enzyme Technologies

Biological enzyme technologies are newly developed biological control technologies in recent years. Biological enzymes are proteins with catalytic effects produced in organisms, which can interfere with the physiological and metabolic processes of pests, achieving pest control purposes. For example, chitinase can decompose the exoskeletons of pests, leaving them unprotected and vulnerable to external environmental influences and predation by natural enemies. Proteases can decompose proteins inside pests, disrupting their normal physiological functions. Biological enzyme technologies have advantages such as high efficiency, environmental friendliness, and safety. Compared with chemical pesticides, biological enzymes have less impact on non-target organisms and do not cause environmental pollution or pesticide residues. When applying biological enzyme technologies, biological enzyme preparations can be made and applied to forests through spraying or injection. At the same time, combining modern biotechnological means to modify and optimize biological enzymes can improve their stability and control effectiveness.

Biological control technologies have broad application prospects in forest pest and disease management. By reasonably utilizing strategies such as natural enemies of pests and diseases, fungal control, avian control, and biological enzyme technologies, the occurrence and spread of forest pests and diseases can be effectively controlled, protecting the health and stability of forest ecosystems and achieving sustainable utilization of forest resources. In future work, further research and promotion of biological control technologies should be strengthened, and the biological control system should be continuously improved to provide more scientific and effective technical support for forest pest and disease management.

5. Conclusion and Outlook

Biological control technologies demonstrate tremendous potential and advantages in forest pest and disease management. By utilizing strategies such as natural enemies of pests and diseases, fungal

control, avian control, and biological enzyme technologies, the use of chemical pesticides can be effectively reduced, environmental pollution can be lowered, and forest ecosystem balance can be protected. Although biological control technologies have achieved certain results, they still face issues such as insufficient research on the action mechanisms of biological control factors and limited application ranges. In the future, basic research should be strengthened to deeply explore the interaction mechanisms between biological control factors and pests and diseases, improving control effectiveness. Technical promotion efforts should be increased to expand the application ranges of biological control technologies. At the same time, combining modern information technologies can achieve precise and intelligent biological control. It is believed that with in-depth research and technological development, biological control technologies will play a greater role in forest pest and disease management, safeguarding forest health and ecological security.

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