



Review

Application of microbioccontrol technology in the cultivation of traditional Chinese medicine

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Abstract

Plant diseases affect the cultivation of Chinese herbal medicines, while traditional chemical pesticides have many drawbacks such as environmental pollution, health risks and disruption of ecological balance. Microbiocontrol has gradually appeared in public view, and its application has become increasingly extensive. This paper reviews the disease-causing species of medicinal plants, including fungal, bacterial, nematode, viral and parasitic pests, and reviews the diseases caused by microorganisms in traditional Chinese medicine planting and their biological control by consulting Sciencedirect databases and Web of Science databases. 4667 related articles were found, of which 552 were related to microbioccontrol technology and cultivation of traditional Chinese medicines. This review provides a reference for the green planting technology of traditional Chinese medicine.

Keywords: microbial control technology; traditional Chinese medicine; application

1 Introduction

In the cultivation of modern traditional Chinese medicine, plant diseases have a great influence on the survival rate and efficacy of the medicine. Plant diseases encompass various pathological changes in plant physiology, cellular structure, and organization caused by biological aggression and abiotic factors, resulting in symptoms such as yield loss, quality deterioration, and the production of toxic metabolites. For instance, shellfish rot

is a major threat to shellfish production, with a potential loss of up to 20% in the Hubei region and sometimes even up to 80%. In that case, farmers have to abandon shellfish cultivation. Black spot in *Panax pseudoginseng* can reduce the yield by over 90% by attacking stems, leaves and flowers. The cultivation of Chinese wolfberry, peony, safflower, chrysanthemum, mulberry white bark and other medicinal herbs requires management of 16 different diseases [1].

Historically, conventional approaches to plant management have played a significant role, yet they are accompanied by various limitations and challenges. These problems include the adverse effects of environmental contamination caused by the overuse of chemical pesticides and insecticides, which will destroy the ecological balance and

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damage the water quality. Chemical pesticides not only target harmful organisms but also have detrimental impacts on non-target species, leading to ecosystem degradation. The residues left by these substances on agricultural products may be harmful to human health. Moreover, the emergence of resistance in pests and pathogens diminishes the effectiveness of traditional pesticides and requires frequent use, which increases the possibility of pest outbreaks. Additionally, conventional plant management methods entail substantial manual labor and financial expenses, which potentially destroys ecological harmony [2].

Given the growing emphasis on environmental conservation and food safety, the limitations of traditional plant control methods have become more obvious. Therefore, it is urgent to explore and promote environmentally friendly, safe, and sustainable plant control technologies, such as biocontrol methods and microbial agents. Microbioccontrol technology encompasses five key categories, namely antibiosis, competition, re-parasitism, induced resistance, and bioprophylaxis [3]. With the development of medicinal chemistry and

pharmacology, it is found that active components in traditional Chinese medicine such as alkaloids, flavonoids, polysaccharides, saponins, terpenes, and quinones have effects such as anti-inflammatory, antioxidant stress, protecting the intestinal mucosal barrier, and regulating gut microbiota. Traditional Chinese medicine (TCM) is a national treasure of our country and plays an important role in disease prevention and control, medical services, and response to public health emergencies. Over the past 40 years of reform and opening up, the Chinese medicine manufacturing industry has grown rapidly at an average annual rate of over 15%, increasing pressure on the supply of medicinal resources. The transformation of Chinese medicinal materials from wild harvesting to large-scale planting is an inevitable requirement for the development of the modern pharmaceutical industry and a necessary means to ensure supply. This article reviews the role of microorganisms in controlling traditional Chinese medicinal plants, and the key microbial control systems, including the future prospects of using microorganisms to control medicinal plants, as illustrated in Fig. 1.

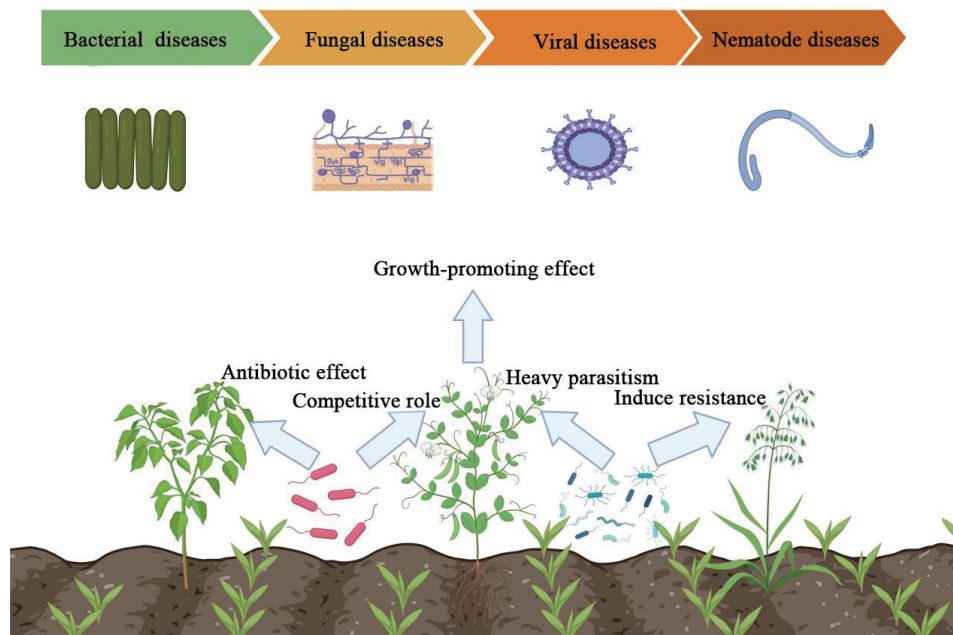


Fig. 1 Relationship between microbioccontrol and herbal medicine cultivation



2 Microbiodiseases

The country has diverse geographical landscapes and distinctive ecological characteristics. Different altitudes promote the growth of abundant Chinese medicinal resources, yielding superior

quality medicinal ingredients. The latest national inventory of Chinese medicinal resources reveal the existence of up to 43 common ailments. This study primarily centers on prevalent conditions like Wheel streak disease, Root rot disease, Viral disease, and Root knot nematode disease, as shown in Table 1 [4].

Table 1 Types of microbioprevention and microbioccontrol

Type of causation	
Wheel streak disease	Root rot disease
Grey mold disease	Spot blight
Powdery mildew	Yellow melon mosaic virus
Viral disease	Sunburn disease
Leaf mildew	Bituminous coal disease
Leaf spot disease	Black spot disease
Anthrax	Root knot nematode disease
Rust disease	Sclerotinia disease
Brown spot disease	Charcoal rot
Downy mildew	Mosaic disease
White silk disease	Soft rot
Pseudo-rust	Declining disease
Scab	canker
Huanglong disease	Penicilliosis
Coal pollution disease	Gummy disease
Plaster disease	Branch blight
Yellow leaf disease	Dry rot disease
Blight disease	Leaf spot mold leaf spot
Angular spot disease	Bacterial wilt
Scab disease	Botrytis cinereus
Chlorosis	

2.1 Types of hot spot microbiodiseases

Five major disease categories are widely studied in herbal cultivation, namely fungal, bacterial, nematode, viral, and parasitic diseases [1].

2.1.1 Fungal diseases

Fungal diseases in plants are primarily caused by fungal infection, constituting approximately 70%-80% of total infection. Fungal pathogens

have the ability to penetrate plants through the natural openings like wounds, stomata, lenticels and stigmas, or penetrate the plant surface to initiate active invasion [5]. These pathogens can induce a range of severe diseases in cultivated medicinal plants, making disease control a key concern. Common symptoms associated with fungal diseases include wilting, necrosis, spotting, rotting, deformities and tuberculosis [6]. The following table shows fungal diseases and fungal distribution, and the image example is shown in Fig. 2 [7].



Fig. 2 Fungal diseases

Table 2 Fungal diseases and fungal distribution

Type of disease	Fungal distribution
Chrysanthemum brown spot	Flagellate subphylum
Sclerotinia sclerotiorum	Subphylum zygomycetes
Safflower anthracnose	Ascomycetes subphylum
Rootrot of Rehmannia glutinosa	Basidiomycetes subphylum
Fritillaria cinerea	Half-known subphylum

2.1.2 Bacterial diseases

Bacteria are recognized as plant pathogens, causing diseases such as shellfish soft rot, ginger plague, and mint green wilt in agricultural production. Unlike some pathogens, plant pathogenic bacteria usually invade the host plant through wounds or natural openings, rather than directly penetrate the epidermis. These bacteria multiply within plant tissues and are released onto the plant surface in a viscous form, which can be spread

between plants through rain and water droplets [5]. Transmission of plant pathogenic bacteria can occur through various means, including rain, organisms, seedlings, and grafting. Lacking chlorophyll, these bacteria exhibit different lifestyles, including parasitism or saprophytism. Common symptoms of bacterial plant diseases include necrosis, rot, chlorosis and deformities. The following table shows bacterial diseases and symptoms, and the image example is shown in Fig. 3 [7].



Fig. 3 Bacterial diseases



Table 3 Bacterial diseases and symptoms

Bacterial disease	Symptomatic
Fritillaria soft rot	Necrosis
Ginger blast	Rot
Mint bacterial wilt	Wilting Yan Abnormal shape

2.1.3 Viral diseases

Virus is a pathogen second only to fungi in terms of the influence. They are totally dependent on the host, which makes them particularly harmful and difficult to manage. This has become the major factor that hinders the development of medicinal plants like Radix et Rhizoma Ginseng, Radix et Rhizoma Dioscoreae and Semen Armeniacae. Virus is a special parasitic organism with a non-cellular structure that can only thrive by parasitizing living organisms and cannot be cultivated in artificial environment. Viruses have a broad host range and can infect plants from various families and

genera. They reside in the host cells, but can not actively infect. Instead, they rely on external forces and fine wounds for invasion. Once the invasion happens, the virus initiates activities such as nucleic acid replication, protein expression and progeny granuloma assembly. As the virus multiplies within the infected plant, it disturbs numerous physiological processes and hinders normal growth and development. This disruption is eventually manifested as symptoms such as discoloration and deformities, which can lead to necrosis and decay [5]. The following table shows the types of viral disease restrictions and symptoms, and the image example is shown in Fig. 4 [7].



Fig. 4 Viral diseases

Table 4 Viral Disease Restriction Types and Symptoms

Type of restriction	Symptomatic
Radix Pseudostellariae	Discoloration
Rehmannia glutinosa	Abnormal shape
Pinellia ternata	Necrosis Rot



2.1.4 Nematode diseases

Phytopathogenic nematodes pose a significant threat to various plant species, including medicinal plants like ginseng, Rhizoma Ligustici Chuanxiong, and Luo Han Guo, and more than 50 other species. These nematodes can cause damage to medicinal plants, with symptoms resembling those of common plant diseases. The above-ground damage may be

manifested as necrosis of terminal and flower buds, curling of stems and leaves, tissue necrosis, and the development of leaf and seed galls. Underground damage, on the other hand, may lead to symptoms such as root necrosis, shortened roots, root knots and root galls [5]. The following table shows the nematode disease restrictions and symptoms, and the image example is shown in Fig. 5 [7].

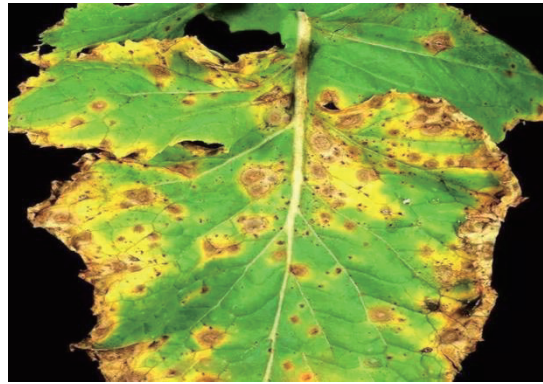


Fig. 5 Nematode diseases

Table 5 Nematode disease limiting species and symptoms

Type of restriction	Symptomatic
Ginseng	Necrosis
Ligusticum chuanxiong	Leaf gall
Siraitia grosvenorii	Seed gall
Rehmannia glutinosa	Shortened root
	Root knot
	Root gall

2.1.5 Parasitic diseases

Certain seed plants that lack sufficient chlorophyll or have degenerated organs can not feed themselves, but parasitize other plants. These parasitic plants are primarily found in the families of Moraceae, Santalaceae and Orobanchaceae. Hemiparasitic plants usually target woody hosts and have no obvious symptoms of parasitism. However,

when the number of parasitic plants increases significantly, the growth of the host plant is hindered, resulting in premature leaf shedding, delayed germination, or even death of terminal branches [5]. Additionally, many parasitic plants possess medicinal properties, such as Cuscuta, Moraceae and Orobanchaceae. The following table shows the distribution and symptoms of parasitic diseases, and the image example is shown in Fig. 6 [7].



Fig. 6 Parasitic diseases

Table 6 Distribution and symptoms of parasitic diseases

Parasitic distribution	Symptomatic
Mulberry parasite family	Early defoliation
Convolvulaceae	Sprouting slowly
Ledangke	The top branch withered.

3 Types of microbioccontrol

3.1 Bioprotection against fungi

Various fungi species have been extensively studied and applied to control soil-borne fungal diseases. Among them, Xylaria fungi are particularly well studied and utilized for this purpose. Additionally, systematic research has been conducted on fungi such as shield shell mold for controlling mycobacterial diseases caused by nuclear disk fungi, light purple penicillium for controlling plant nematode-related diseases, grape stem blight for preventing grapevine stem blight, and oligoandrogenic rot fungi for preventing and controlling Rickettsia infections, among others [3].

Some wood mold fungi have strong anti-Fusarium activity, and are usually used as beneficial microorganisms for biological control Duan et al. [8] used the method of indoor antagonistic tests and field experiments to target the Fusarium causing root rot in Salvia miltiorrhiza. Results showed that the application of the Trichoderma harzianum T23 biocontrol agent at 715 kg·hm⁻² had the best

effect. Field control of root rot in medicinal herbs such as Ophiopogon japonicus, Salvia miltiorrhiza, and Ligusticum chuanxiong reached over 70%, demonstrating the potential application of wood mold in controlling root rot in Salvia miltiorrhiza.

3.2 Bacteria prevention

Among the bioprotective bacteria, Bacillus species have been extensively studied, along with Agrobacterium radiobacterium fluorescens and non-pathogenic mutants of certain bacteria.

Du et al. observed the uneven distribution of Bacillus subtilis SBS-208 on tomato leaves by scanning electron microscopy, predominantly colonizing areas around wounds, leaf depressions, and root hairs. It was found that the bacteria successfully colonized both natural and sterilized soils, with lower quantities in natural soils compared to sterilized soils. The latest progress in molecular biology and biochemical analysis has introduced new techniques and instruments for studying the competitive interactions of biocontrol bacterial colonization and population dynamics. Techniques



such as scanning electron microscopy, fluorescent labeling, ELISA, PCR, and others have been employed to investigate the competitive role of *Bacillus subtilis* [9].

Wang et al. reviewed polymerase chain reaction (PCR) amplification of DNA from isolated bacterial strains by using various primers and the Southern hybridization technique, which facilitates the differentiation of bacterial isolation ratios that produce distinct antagonistic compounds from the root and leaf peripheries of plants. In this way, the colonization and persistence of various biocontrol strains on plant surfaces can be understood clearly. Raaijue conducted an experiment in which Phl+ *Pseudomonas* spp. and PCA+ *Pseudomonas* spp. were inoculated onto wheat seeds, which were subsequently sown across six different plant species. The study aimed to assess the colonization efficacy of these two strains within the rhizosphere across different soil types, including four susceptible soils and two inhibitory soils. The findings indicated that the concentration of Phl+ *Pseudomonas* spp. detected in the two inhibitory soils was 5.1×10^5 to 2×10^6 CFU/g, whereas Phl+ *Pseudomonas* spp. was either undetected or exhibited the concentration 40 times lower than that of PCA+ *Pseudomonas* spp. in the susceptible soils. The total number of *Pseudomonas fluorescens* isolates in the six tested soils changed a little, ranging from 5×10^6 to 1×10^7 CFU/g, and the concentration of *Pseudomonas aeruginosa* was in a similar range. However, the isolation ratio of Phl+ *Pseudomonas* spp. to *Pseudomonas fluorescens* in diseased soils ranged from 3.0% to 12%, while in susceptible soils, this ratio was less than 0.1%. These experimental results further prove that the proliferation of Phl+ *Pseudomonas* spp. producing 2,4-diacetylphloroglucinol (DAPG) is a significant contributor to the development of disease-suppressive soils associated with wheat total erosion disease [10].

3.3 *Biodefense against actinomycetes*

Various types of actinomycetes are utilized for biocontrol purposes, with a particular focus on streptomycetes due to their extensively studied inhibition mechanisms. My-costop, a popular live actinomycetes preparation, is commonly employed worldwide to combat soil-borne pathogens like *Pythium* spp, *Fusarium* spp, *Phytophthora* spp. and *Rhizoctonia* spp. This product, which utilizes the fine yellow *Streptomyces* (*Streptomycesmicroflavus*) strain “5406”, is effective in controlling diseases in greenhouse ornamental plants and vegetables. *Streptomycesmicroflavus* can produce a variety of antibiotics during its growth to suppress plant pathogens, as well as hormones that stimulate plant cell division and elongation. Actinomycetes play a significant role in the global pharmaceutical market, with 67% of antibiotic products derived from microorganisms, two-thirds of which are sourced from actinomycetes. In addition to antibiotics and enzymes, actinomycetes metabolites also include organic acids, steroids, vitamins, nucleotides and enzyme inhibitors[11].

Ma GL[12] identified five strains of actinomycetes that exhibited a significant inhibitory effect on ginseng rust rot fungi, achieving inhibition rates ranging from 53.8% to 61.9%. They investigated the optimal conditions for the liquid fermentation of three actinomycete strains that demonstrated a strong antagonistic effect against ginseng rust rot. Furthermore, they discovered that ten strains of actinomycetes were capable of inhibiting five strains of *Phytophthora quinquefolium*, as well as ginseng rust rot and ginseng root rot. The five tested pathogens could induce the actinomycetes to produce chitinase and cellulase. The actinomycetes secreted chitinase, cellulase, and other enzymes that degrade the fungal cell wall when in contact with the hyphae of the pathogens, thus destroying pathogen mycelium and inhibiting infection.



4 Summary

The application of microbial control technology in agriculture is increasingly recognized for its eco-friendliness and effectiveness. This approach involves the targeted use of beneficial microorganisms to combat specific pests or pathogens, thereby reducing reliance on chemical pesticides. By improving soil health and crop yields, microbial control technology not only helps to manage resistant pests and pathogens but also improves the diversity and abundance of soil microbes. Strategies such as increasing soil organic matter, incorporating beneficial microorganisms, and utilizing fermented grass slurries and biocontrol formulations can improve soil structure and nutrient availability, thus effectively managing crop diseases and pests.

Despite the challenges of high costs, long research and development process, and unexpected results, microbial control technology has broad prospects in promoting sustainable agriculture and ecological balance. This study examined existing experimental findings, provided a detailed description of various key biocontrol strains, summarized the known disease-causing species, and conducted comparative analysis to highlight the progress of microbial control technology compared with traditional methods. In addition, the application of microbial control technology in cultivating traditional Chinese medicine was explored, in order to provide great potential for future research and in-depth investigation. The study underscores the importance of further exploration into the intricate aspects of microbial control technology.

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