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Research Progress on Phalaenopsis Diseases and strategy of Green Control

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Abstract

Phalaenopsis spp., known for its gorgeous morphology, bright and showy colors, and long-lasting blooms, is often referred to as the "Queen of Orchids" and owns high ornamental and economic value. However, some diseases in the *Phalaenopsis* orchids severely affect the flower quality, plant growth, ornamental and economic value. This paper reviews the current research progress of common *Phalaenopsis* diseases and subsequent chemical and biological control methods, which provides comprehensive understand of disease prevention and control strategies in *Phalaenopsis* orchids.

Keywords

Phalaenopsis; Disease management; Chemical control; Biological control; Orchid diseases

Introduction

Phalaenopsis, commonly known as moth orchid, belongs to the genus Phalaenopsis (Orchidaceae). Phalaenopsis spp. is renowned for its graceful shape, rich coloration, long blooming period, and well-arranged inflorescences, earning it the title of "Queen of Orchids" [1]. It is currently one of the most competitive and high-value ornamental flowers [2]. As one of most popular potted plant with showy flower, the market demand for Phalaenopsis orchids increased year by year. However, due to inadequate management of temperature, light, humidity, water, and fertilizers in greenhouses, coupled with a single measure for pest and disease control, resulted in significant economic losses [3]. Fungal diseases (such as anthracnose, gray mold, southern blight, and Fusarium root (stem) rot etc.) and bacterial diseases (soft rot and leaf spot), and viral diseases (ORSV (Odontoglossum ringspot virus), CyMV (Cymbidium mosaic virus), CMV (Cucumber mosaic virus), etc) are common diseases and popular in Phalaenopsis spp.. This review systematically summarizes the etiological characteristics, epidemic patterns, and research progress of green control technologies for three major diseases (fungal, bacterial, and viral) affecting Phalaenopsis orchids. Moreover, progress of chemical and biological technologies in Phalaenopsis diseases prevention and control are also reviewed in this paper. Our data provide a comprehensive understand of Phalaenopsis diseases and strategy of prevention and control.

1. Common diseases of Phalaenopsis and their causal agents

Table 1 summarizes the pathogenic characteristics and epidemiological patterns of common fungal and bacterial diseases affecting *Phalaenopsis* orchids, including anthracnose (*Colletotrichum* spp.), stem rot *(Phytophthora* spp.), gray mold (*Botrytis cinerea*), southern blight (*Sclerotium rolfsii*), root rot (*Rhizoctonia solani*), black head disease, bacterial soft rot (*Erwinia* spp.), leaf spot diseases, and fusarium wilt (*Fusarium oxysporum*). The majority of *Phalaenopsis* diseases are caused by microbial infection, typically characterized by initial leaf spotting, subsequent lesion expansion, and eventual plant death. Table 2 summarizes the pathogenic patterns of common viral diseases in *Phalaenopsis* orchids. These viral diseases are primarily caused by viruses including Odontoglossum ringspot virus (ORSV), *Cymbidium mosaic virus* (CyMV), *Lily yellow mosaic virus* (orchid strain, LYMV), and *Tomato spotted wilt virus* (TSWV).

Table 1. Incidence Patterns of Common Fungal and Bacterial Diseases in Phalaenopsis

Disease type	Pathogen	Incidence pattern	Reference
Anthracnose	*Colletotrichum gloeosporioides* *C.phalaenopsidis* *C.cymbidiicola*	At the initial infection stage, small, chlorotic-brown lesions with slight depressions appear on leaf surfaces. Lesions expand concentrically, transitioning from brown to dark brown with pronounced central sunken areas in advanced stages. The characteristic symptom includes acervuli (black fruiting bodies) scattered or arranged in concentric rings across lesion surfaces. Under high humidity, orange conidial masses are exuded from these structures. Infection primarily occurs through natural openings at leaf apices or margins, with rapid progression leading to foliar necrosis, desiccation, and abscission.	[4,5]
Stem Rot	*Fusariumoxyspor umf.*sp.*cubense*	*Fusarium oxysporum* primarily infects the roots, leaf bases, and pseudobulbs of *Phalaenopsis* orchids, with the basal leaf region serving as the primary infection court. The disease exhibits rapid progression and high incidence, affecting both seedlings and mature plants throughout their growth cycle. Initial symptoms manifest as small water-soaked brown lesions at the leaf base, which rapidly expand into reddish-brown necrotic areas, sunken lesions, or dry rot patches. These lesions often coalesce, forming extensive necrotic zones. Pathogen colonization of vascular bundles leads to occlusion, resulting in blackening or dark brown discoloration of the leaf base and pseudobulb tissues. The infection spreads acropetally through the vascular system, inducing characteristic sectoral yellowing (chlorosis) in the foliage. This yellowing typically follows the pattern of the affected vascular tissues. In severe cases, the vascular blockage disrupts water and nutrient transport, ultimately causing leaf wilting, desiccation, and abscission.	[6,7]

Disease type	Pathogen	Incidence pattern	Reference
Gray Mold	*Botrytis Cinerea*	Gray mold, caused by *Botrytis cinerea*, primarily affects the floral organs of *Phalaenopsis* orchids. Initial infection results in small water-soaked circular lesions (0.1–0.15 cm diameter) on petals and sepals, which gradually darken from brown to dark brown. Under conditions of high relative humidity, characteristic grayish-brown mycelial growth and conidial masses may develop on lesion surfaces.	[8]
Southern blight	*Sclerotium rolfsii*	Southern blight, caused by *Sclerotium rolfsii* (teleomorph: *Athelia rolfsii*), infects *Phalaenopsis* orchids via roots, pseudobulbs, or basal stem tissues near the substrate surface. The pathogen establishes primary infection foci that expand centrifugally, producing fan-like mats of white, silky mycelia which encircle the stem base and bear black sclerotia (1–2 mm). Systemic basipetal chlorosis and desiccation of foliage ensue as mycelia colonize the plant base. Cortical maceration and soft rot of the basal stem lead to vascular occlusion, rapid wilting, and whole-plant mortality.	[9,10]
root rot	Fusarium Pythium sp. Acremonium	Initial infection is characterized by root tips and root hairs losing turgidity, turning brown, and becoming soft, with symptoms progressing basipetally. Subsequently, entire roots darken from brown to black, and the epidermis detaches from the stele. Root tissues become water-soaked, undergo soft rot, and exude macerated material when gently pressed. Foliar symptoms include chlorosis starting in basal and peripheral leaves, which progressively desiccate, wrinkle, become flaccid, lose luster, and eventually abscise; leaf bases concurrently shrink and desiccate. Basal stem tissues develop water-soaked, brown lesions that expand acropetally. Complete loss of structural support leads to plant lodging, with acropetal progression of foliar chlorosis and desiccation culminating in whole-plant mortality.	[11,12,13]
black head disease	Colletotrichum sp. Fusarium sp. C. orchidearum Fusarium solan	Black head disease in Phalaenopsis orchids consists of two etiological types: anthracnose-type, caused by Colletotrichum spp., and fusarium-type, caused by Fusarium spp. Anthracnose-type infections initiate as chlorotic to brown lesions, predominantly on basal stems or inner leaf sheaths. These lesions rapidly expand into blackish-brown necrotic patches with grayish-white centers and dark-brown margins, often displaying concentric rings. Wounds formed during inflorescence emergence are particularly susceptible; severe infections result in plant lodging. Fusarium-type infections initially manifest as water-soaked chlorosis of basal stems, progressing to blackish-brown sunken lesions. Affected tissues become fragile and prone to breakage, with white mycelial growth developing	[14]

Disease type	Pathogen	Incidence pattern	Reference
		on lesion surfaces under high humidity. Leaves exhibit progressive acropetal yellowing or reddening, ultimately leading to leaf abscission and whole-plant death.	
soft rot	Erwinia chrysanthemi Pseudomonas spp. Dickeya dieffenbachiae	Localized water-soaked, semi-translucent lesions expand rapidly, rendering the stem base discolored with a faint acidic odor, without apparent wilting. Subsequently, infected tissues soften into a pulpy consistency; water-soaked lesions girdle the stem and rupture upon gentle pressure, accompanied by marked pungent odor and leaf drooping. Ultimately, leaves undergo complete soft rot and drooping, followed by parchment-like desiccation; the stem base or root collar fractures, exhibiting internal cavity formation, extremely acrid odor, and culminating in whole-plant collapse and mortality.	[15,16,17]
leaf spot	Cylindrosporium	Sub-millimeter water-soaked lesions initiate on the abaxial surface, rapidly penetrating mesophyll to manifest as brownish-black circular lesions on the adaxial surface. Lesions progressively enlarge into irregular or sunken morphologies exhibiting chlorotic halos, purple-black concentric zonation, or black sporulating structures. Advanced infections induce basipetal chlorosis, necrosis, fragmentation, and leaf abscission.	[18]
wilt	Xanthomonas Fusarium	Fusarium wilt, caused by Fusarium oxysporum, initiates infection in lower mature leaves, inducing chlorosis, loss of luster, and wilting. Symptoms progress acropetally, with middle and upper leaves becoming flaccid, drooping, and brown. Water-soaked lesions develop on the stem base, progressively turning black. Under high humidity, white to pink mycelial growth and conidial masses develop on lesions. In advanced stages, lower leaves abscise and shrivel, culminating in whole-plant yellowing, wilting, and mortality. A diagnostic hallmark is brown to dark brown vascular discoloration in basal stem cross-sections.	[19,20,21]

Table 2. Common viral disease patterns in *Phalaenopsis*

Disease type	Incidence pattern	Reference
Odontoglossum ringspot virus (ORSV)	Fusarium wilt, caused by Fusarium oxysporum, initiates infection in lower mature leaves, inducing chlorosis, loss of luster, and wilting. Symptoms progress acropetally, with middle and upper leaves becoming flaccid, drooping, and brown. Water-soaked lesions develop on the stem base, progressively turning black. Under high humidity, white to pink mycelial growth and conidial masses develop on lesions. In advanced stages, lower leaves abscise and	[22,23,24]

Disease type	Incidence pattern	Reference
	shrivel, culminating in whole-plant yellowing, wilting, and mortality. A diagnostic hallmark is brown to dark brown vascular discoloration in basal stem cross-sections.	
Cymbidium mosaic virus (CyMV)	Viral infection manifests as scattered, vein-parallel chlorotic streaks or punctate lesions, appearing pale yellow to milky white and semi-translucent. Advancing lesions elongate, widen, and coalesce into characteristic mosaic patterns with irregularly serrated margins. Severe infections result in whole-leaf chlorosis, uneven texture, and mild rugosity. Symptoms are most pronounced on older leaves, whereas new leaves may exhibit transient symptom remission under high light or low temperature. Petals and sepals develop faded stripes or nebulous spots, particularly conspicuous in dark-flowered cultivars; flowers display dulled coloration, mild distortion, and shortened anthesis. Chronic systemic infection induces plant stunting, reduced leaf size with increased fragility, suppressed root apical growth, and marked decline in floral quantity and quality, compromising commercial value. Virus transmission occurs primarily via contaminated tools (scissors, blades), mechanical sap transmission, infected tissue culture plantlets, and limited piercing-sucking insect vectors. No curative treatments exist; prevention and destruction of infected plants remain the only effective management strategies.	[25,26]
Cucumber mosaic	Viral infection in Phalaenopsis orchids initiates on young leaves as short, linear to spindle-shaped, pale-green, translucent chlorotic lesions adjacent to leaf veins, often with yellow halos. Advancing lesions expand along vascular bundles, coalescing into irregular yellow-green mosaic patterns with variegated light and dark green areas. Advanced stages exhibit leaf rugosity, distortion, margin curling, and increased fragility, leading to whole-leaf chlorosis, premature abscission, and apical rosetting of diminutive leaves. Petals and sepals develop faded stripes or nebulous pale-yellow patches, especially in dark-flowered cultivars, with mild floral distortion, shortened anthesis, and premature senescence. Systemic infection induces marked growth attenuation, stunting, reduced leaf size, shortened internodes, compromised root development with necrotic root tips, and whole-plant wilting. Certain cultivars exhibit asymptomatic carrier status under high-temperature or high-light stress, testing virologically positive while phenotypically healthy. The virus spreads rapidly via aphid vectors and mechanical sap transmission; no curatives exist, requiring prevention and destruction of infected plants.	[27]
Tomato spotted wilt virus (Tospovirus)	Odontoglossum ringspot virus (ORSV) infection initiates as pale yellow, subcircular lesions that expand into yellow-green concentric rings (2–8 mm) with distinct margins. Lesion centers become grayish-white, with brown, slightly sunken margins; dark brown necrotic spots develop at corresponding positions on the abaxial surface.	[28]

2. Chemical control of Phalaenopsis diseases

Shen et al. [29] determined the antibacterial activity of different disinfectants against the Phalaenopsis bacterial soft rot pathogen (Dickeya fangzhongdai) using the minimum inhibitory concentration (MIC) method, observed the morphological effects of chlorine dioxide (ClO_2) treatment on the pathogen via scanning electron microscopy, and established the minimum bactericidal concentration (MBC) and shortest bactericidal time for various ClO_2 concentrations. Specifically, their study demonstrated that a rapid treatment with 500 μg/mL ClO_2 effectively controls bacterial soft rot in Phalaenopsis caused by this pathogen. Shen et al. [30] reported a MIC of 500 μg/mL for copper oxychloride against Phalaenopsis bacterial soft rot pathogen Dickeya dieffenbachiae, with complete disease suppression at this dosage. Prophylactic application enhanced control efficacy. Ding et al. [31] evaluated a fungicide rotation program for sooty blotch control in Phalaenopsis. The rotation included 30% difenoconazole WG at 1:2500, 45% difenoconazole + thiram WP at 1:2000, 12.5% myclobutanil EC at 1:2000, and 45% prochloraz EC at 1:3000. This strategy effectively controlled sooty blotch while delaying resistance development. Ye et al. [32] demonstrated that prochloraz and flusilazole strongly inhibited Fusarium oxysporum isolated from stem rot-affected Anoectochilus roxburghii. Xu et al. [33] reported that 500 mg/L hymexazol, sulfur + thiophanate-methyl, thiram + ziram, and prochloraz-manganese chloride all completely inhibited mycelial growth and sporulation of Colletotrichum gloeosporioides causing anthracnose in Paphiopedilum. Among these, prochloraz-manganese chloride exhibited the highest toxicity (EC_{50} = 0.09 mg/L) and provided the best control efficacy under greenhouse conditions. Hong [34] showed that application of 1–2 mmol/L Na_2SiO_3 to the hybrid 'Yü-nü-lan' (Paphiopedilum micranthum) delayed the onset of Fusarium oxysporum stem rot by approximately 14 days and significantly reduced the disease index Wei et al. [35] evaluated six fungicides and found that 16.8% cymoxanil + seboctylamine SL (1:1000), 50.5% iprodione + propineb WP (1:800), and 500 g/L iprodione SC (1:1000) provided the best control of Phalaenopsis anthracnose with minimal visible spray residue. Conventional chemical pesticide applications cause environmental pollution, pose operator health risks, and disrupt greenhouse microecosystems. Low-toxicity agents with benign degradation profiles, such as chlorine dioxide (ClO_2), copper oxychloride ($Cu_2(OH)_3Cl$, active ingredient Cu^{2+}), prochloraz, difenoconazole, and myclobutanil, mitigate these adverse effects. However, even low-toxicity chemicals can disturb the greenhouse microecological balance by eliminating beneficial microorganisms and select for resistant pathogen strains, thereby gradually reducing long-term efficacy.

Table 3. Chemical control of common Phalaenopsis diseases

Disease type	Agent type	Dilution factor	Control efficacy	References
Anthracnose	Shuangmei-Xinjun'an aqueous solution、Kuaideyipu、Iprodione	1000× 800× 1000×	Effectively controls anthracnose in Phalaenopsis orchids with minimal foliar residue deposition	[33]

			post-application.	
Stem rot	Prochloraz	500 mg/L	Prochloraz-manganese chloride complex exhibits potent toxicity and high activity, with a median effective concentration (EC50) of 0.09 mg/L.	[33，34]
Gray mold	Flusilazole	2.624×10^{-20}g/L	exhibits strong inhibitory activity against Fusarium oxysporum	[32，36]
Southern blight	'Genhao' 'Hymexazol'	``1000× 1500×	Soil drench application achieved an average disease incidence of 2.8% and a control efficacy of 89.8%. Foliar spray application resulted in a disease incidence of 5.6% and a control efficacy of 80.1%.	[38]
Root rot	Shijingke	200mg/L	Shijunke at 200 mg/L exhibited an inhibition rate of 98.2% against Fusarium oxysporum, the causal agent of root rot.	[39]
Soft rot	ClO_2 $Cu_2Cl(OH)_3$	500μg/mL 500μg/mL	Effective against bacterial soft rot caused by Dickeya fangzhongdai (D. fangzhongdai) in Phalaenopsis orchids. Copper oxychloride at 500 μg/mL active ingredient achieved 100% control efficacy.	[29,30]
Basal rot	Thifluzamide Carbendazim	0.1% 0.1%	0.1% thifluzamide (240 g L^{-1} formulation) or 0.1% carbendazim, applied by 1-min immersion at 26 °C with RH ⩾ 90%, achieved 100% control efficacy against Fusarium oxysporum basal leaf rot and blocked subsequent infection.	[37]

3. Biological Control of Phalaenopsis Diseases

Biological control offers several advantages over chemical control, including higher safety, no residues or toxicity, reduced risk of pathogen resistance development with long-term use, prolonged colonization of biocontrol agents in Phalaenopsis roots eliminating the need for repeated applications, and promotion of plant growth and development. Chen et al. [40] reported that Trichoderma formulations effectively inhibited the growth of Sclerotium rolfsii and provided good control of southern blight disease. Ye et al. [41] found that Trichoderma harzianum, T. koningiopsis, and T. longifialidicum all strongly inhibited the growth of Fusarium oxysporum ASP01, the causal agent of stem rot, and significantly reduced disease incidence. Pujasatria et al. [42] demonstrated that root colonization by Tulasnella calospora enhanced systemic resistance in Bletilla striata, improving resistance against leaf infection by the bacterial soft rot pathogen Dickeya fangzhongdai.Po-Hung Wu et al. [43] showed that Phalaenopsis orchids inoculated with Ceratobasidium sp. AG-A (R02) and Rhizoctonia solani AG-6 (R04) exhibited significant resistance to soft rot disease, with notably reduced lesion radius.Galih Chersy Pujasatria et al. [44] found that Bletilla striata plants inoculated with Tulasnella calospora and Serendipita vermifera showed enhanced resistance against bacterial soft rot caused by Erwinia chrysanthemi on leaves. Ye et al. [45] demonstrated that Piriformospora indica enhanced resistance in Oncidium orchids against the Gram-negative bacterium Erwinia chrysanthemi by regulating plant miRNA and defense gene expression. Jiang et al. [46] reported that the Cymbidium faberi endophytic fungus Fusarium solani strain Z2 effectively inhibited F. oxysporum, the causal agent of orchid stem rot, while Dichotomopilus funicola strain Z3 showed high inhibitory activity against Colletotrichum gloeosporioides, the causal agent of orchid anthracnose. Inoculation with strain Z3 significantly reduced disease incidence in Cymbidium goeringii 'Green Cloud'. Current research on biological control of Phalaenopsis primarily focuses on orchid mycorrhizal fungi, which have demonstrated significant disease resistance effects. Surendra Sarsaiya et al. [47] isolated two strains of Tulasnella spp. (Tul-OM1 and Tul-OM2) from the roots of wild Grammatophyllum speciosum in Indonesia. These strains exhibited significant antagonistic activity against Fusarium proliferatum in vitro and reduced disease incidence by 55–62% in G. speciosum seedlings under greenhouse conditions. Chen et al. [48] reported that inoculation of Phalaenopsis spp. with orchid mycorrhizal fungi (Tulasnella calospora TC-2 and Ceratobasidium sp. CB-1) significantly reduced the incidence of yellow leaf disease caused by Fusarium proliferatum and F. solani under greenhouse conditions. Wang et al. [49] isolated the endophytic bacterium Bacillus amyloliquefaciens from healthy Oncidium orchids. This strain showed potential as a biocontrol agent against Oncidium diseases, with demonstrated efficacy in controlling anthracnose through dual culture and fermentation broth assays. It exhibited inhibitory activity against eight different pathogenic fungi. Yao et al. [50] found that Streptomyces vinaceus displayed excellent antifungal activity against various fungi, achieving 70.06% control efficacy against anthracnose in Cymbidium ensifolium under laboratory conditions and 66.27–68.54% under field conditions. This strain showed promising biocontrol potential against Colletotrichum gloeosporioides.

4. Discussion

Chemical methods remain the primary strategy for disease control in Phalaenopsis cultivation, despite their well-documented drawbacks. Although chemical application rapidly suppresses symptoms, long-term use of the same compounds readily induces pathogen resistance [51] and may cause phytotoxicity to the orchids. Furthermore, these pesticides not only target pathogens but also adversely affect non-target beneficial microorganisms, thereby disrupting the stability of the greenhouse microecosystem. In contrast, biological control represents a more sustainable yet less implemented alternative. This approach primarily involves the application of beneficial microorganisms, including orchid mycorrhizal fungi (e.g., Tulasnella spp., Piriformospora indica), fungi with biocontrol properties (e.g., Trichoderma spp.), and plant-growth-promoting bacteria (e.g., Bacillus amyloliquefaciens). These symbionts establish symbiotic relationships with Phalaenopsis, wherein their hyphal coils rapidly colonize cortical cells, physically reducing available infection sites for pathogens. Concurrently, symbiotic fungi secrete antimicrobial compounds (e.g., phenolic derivatives, siderophores). Siderophores, in particular, sequester iron, an essential micronutrient, thereby inhibiting pathogen growth. As an environmentally friendly strategy, biological control offers long-term sustainability; once established, it reduces the need for repeated applications, minimizes environmental disturbance, and lowers the risk of resistance development. However, current biocontrol technologies for Phalaenopsis are largely confined to laboratory research. The development of commercial biocontrol formulations is therefore crucial to enhance production efficiency in the Phalaenopsis industry and substantially reduce dependence on chemical pesticides.

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