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国内外蓝莓真菌性病害为害特征及其病原菌种类研究进展

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摘要： 蓝莓 *Vaccinium* spp. 因高经济价值和营养价值在国内外被广泛种植，其真菌性病害是制约蓝莓产业发展的主要生物胁迫因素。目前蓝莓上已报道发生的真菌病害多达20余种，严重制约该产业发展。该文系统综述了枝枯病、溃疡病、根腐病、叶斑病、炭疽病、白粉病、灰霉病和果腐病等主要蓝莓真菌性病害的病原菌种类与分布、典型症状及为害程度，这些病害发生严重时可导致的产量损失为20%~85%，病原真菌多样性高，涵盖间座壳属 *Diaporthe*、镰孢属 *Fusarium*、新壳梭孢属 *Neofusicoccum*、拟盘多毛孢属 *Pestalotiopsis*、疫霉属 *Phytophthora*、刺盘孢属 *Colletotrichum* 和链格孢属 *Alternaria* 等20余属的150多种。同时总结了上述病原菌的主要传播途径，并提出了栽培措施、化学防治和生物防治等方面的病害综合管理策略。此外，分析明确了当前蓝莓真菌性病害研究在病原学、病害流行学及抗性育种等方面存在不足，提出未来工作应加强病害的病原学与流行规律研究，选育高产优质抗病新品种，并推广以农业和生物措施为核心的绿色防控技术，从而为中国蓝莓产业的健康发展提供理论支撑与实践指导。

关键词： 蓝莓；真菌病害；田间症状；病原真菌；综合防治

Research progress on the occurrence, damage, and pathogen identification blueberry fungal diseases in China and abroad

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Abstract: Blueberries (*Vaccinium* spp.) are widely cultivated worldwide for their high economic and nutritional value. However, fungal diseases constitute a major biotic constraint limiting the development of the blueberry industry. To date, more than 20 fungal diseases have been reported on blueberry, causing substantial economic losses. This review systematically summarizes the pathogen species, geographic distribution, typical symptoms, and damage severity of major fungal diseases affecting blueberry production . The principal diseases discussed include stem blight, canker, root rot, leaf spot, anthracnose, powdery mildew, gray mould, and fruit rot. Previous studies have shown that severe outbreaks of these diseases may result in yield losses ranging from 20% to 85%. Pathogenic fungi associated with blueberry exhibit high diversity, encompassing over 150 species from more than 20 genera,

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including *Diaporthe*, *Fusarium*, *Neofusicoccum*, *Pestalotiopsis*, *Phytophthora*, *Colletotrichum*, and *Alternaria*. In addition, the main transmission routes of these pathogens are summarized. Based on current knowledge, integrated disease management strategies are proposed, including cultural practices, chemical control, and biological control. Furthermore, the current shortcomings in research on blueberry fungal diseases are clarified, particularly in aspects of etiology, disease epidemiology, and resistance breeding. Future work should focus on strengthening studies on pathogen biology, epidemic dynamics, breeding of high-yield, high-quality, and disease-resistant cultivars, and promoting green control technologies centered on agricultural and biological measures. Overall, this review provides both strong theoretical support and targeted practical guidance for the healthy development of the blueberry industry in China.

Key words: *Vaccinium* spp.; fungal disease; field symptom; pathogenic fungi; integrated management

蓝莓 *Vaccinium* spp. 属于杜鹃花科越橘属 *Vaccinium* 落叶灌木，其栽培历史悠久，种质资源多样，因其突出的经济与营养价值而在全球范围内被广泛引种与栽培。据国际蓝莓组织统计，截至2024年，全球蓝莓栽培面积已达279 012 hm^2，总产量达2 150.61万t。我国作为全球最大的蓝莓生产国，2024年栽培面积达95 880 hm^2，约占全球总面积的34%。蓝莓在我国贵州、云南、安徽、四川、辽宁、山东等多个省份均有分布，其中贵州省种植面积居全国首位（李亚东等，2025）。

蓝莓作为一种高端水果在全球农业中占据重要地位。然而，这一产业的发展严重受到病害的制约，据不完全统计，全球范围内已报道的蓝莓病害有40余种。其中，仅真菌病害就有27种，占据主导地位。常见的蓝莓真菌性病害主要包括叶斑病、枝枯病、溃疡病、灰霉病、炭疽病、锈病、白粉病、果腐病、根腐病等，这些病害发生在蓝莓不同的生长阶段，对蓝莓的整个生长周期构成威胁，常导致蓝莓叶片早衰、果实腐烂和植株死亡，从而造成严重的经济损失。据报道，1959年，美国北卡罗来纳州种植园枝枯病发病率为9%，机械化操作造成的伤口加剧了该病害的传播，至1985年发病率升至23%，严重影响了该地区的蓝莓生产（Milholland，1972；Creswell，1987）；智利部分产区蓝莓枝枯病和茎溃疡病发病率达15%~45%（Espinoza et al.，2009）；在美国和拉脱维亚等地，由间座壳属 *Diapothe* 真菌引起的枝枯病、枯萎病、茎溃疡、叶斑病和果腐病等在适宜条件下可导致植株死亡，减产高达70%（Dharmaraj et al.，2022）。我国蓝莓产业的发展也面临类似挑战，山东省日照市蓝莓枝枯病的发病率约为1%~3%；江苏省南京市蓝莓炭疽病的发病率超62%，全年侵染叶片、枝条与果实，严重影响其产量与品质（Feng et al.，2024）；四川省部分产区叶斑病和溃疡病发病率甚至超过80%（Zheng et al.，2023）。这些真菌性病害的发生已成为制约全球蓝莓产业健康发展的主要因素，病害的高效防控是保障蓝莓产业安全和可持续发展的必然选择。本文通过系统性综述国内外蓝莓主要真菌性病害的病原菌种类与分布、典型症状及为害程度，分析并探讨不同产区病原菌的差异性及传播途径，以期为今后蓝莓真菌病害的诊断、病原鉴定及绿色防控提供参考。

1 蓝莓真菌病害种类、分布、典型症状及病原菌种类

1.1 蓝莓枝枯病

蓝莓枝枯病是一种全球性分布的真菌性病害，自1950年在美国首次报道以来（Ru et al.，2022），已广泛分布于北美洲（美国、加拿大）、亚洲（中国、韩国）、南美洲（秘鲁）及大洋洲（澳大利亚）等蓝莓栽培地区。该病害对1~2年生的幼株为害较重，但也会侵染成株。其症状呈渐进性的特点，发病初期枝条基部或分叉处出现红褐色至黑色小斑点，逐渐扩展为椭圆形或梭形病斑，表皮开裂，后期病原菌会导致枝条快速枯萎，发病枝条上的叶片变褐或变红，病原菌通过维管组织向基部蔓延，内部组织通常会呈现褐色坏死，最终可能导致整个植株死亡（赵琳，2020）。该病害严重削弱植株的整体长势和光合作用能力，导致其上着生的花芽和果实也随之坏死脱落，严重影响了蓝莓植株的寿命和产量。

目前已知能引起蓝莓枝枯病的病原真菌种类较多，国内外已报道的包括间座壳属、拟盘多毛孢属 *Pestalotiopsis* 以及葡萄座腔菌属 *Botryosphaeria* 等60种病原菌。具体的病原真菌及其分布如表1所示。

表1 蓝莓枝枯病相关真菌及分布

Table 1 Fungi related to blueberry stem blight and their distribution

属名 Genus	种名 Species	分布 Distribution	参考文献 Reference
间座壳属 *Diaporthe*	含糊间座壳 *D. ambigua*	智利、葡萄牙 Chile, Portugal	Zhao et al., 2019a; Hilário et al., 2021
	扁桃间座壳 *D. amygdali*	葡萄牙 Portugal	Hilário et al., 2021
	D. crousii	葡萄牙Portugal	Guarnaccia et al., 2021
	甜樱间座壳 *D. eres*	德国、立宛陶、波兰、荷兰、克罗地亚、葡萄牙、俄罗斯、芬兰、美国、中国、意大利、塞尔维亚 Germany, Lithuania, Poland, Netherlands, Coratia, Portugal, Russia, Finland, USA, China, Italy, Serbia	Lombard et al., 2014; Cardinaals et al., 2018; Ivić et al., 2018; Hilário et al., 2021; Gomzhina et al., 2022; Klein-Gordon et al., 2023; Martino et al., 2023; Blagojević et al., 2024
	茴香间座壳 *D. foeniculina*	葡萄牙、智利、塞尔维亚、意大利 Portugal, Chile, Serbia, Italy	Guarnaccia et al., 2020; Hilário et al., 2020a; Blagojević et al., 2024
	D. hybrida	葡萄牙Portugal	Hilário et al., 2021
	D. leucospermi	葡萄牙Portugal	Hilário et al., 2021
	D. malorum	葡萄牙Portugal	Hilário et al., 2021
	D. mutila	新西兰、智利New Zealand, Chile	Tennakoon et al., 2018; Núñez et al., 2025
	D. neotheicola	智利Chile	Zhao et al., 2019a
	D. oxe	乌拉圭Uruguay	Sessa et al., 2018
	D. phillipsii	葡萄牙Portugal	Hilário et al., 2020a
	D. rudis	新西兰、荷兰、智利、意大利、葡萄牙、波兰 New Zealand, Netherlands, Chile, Italy, Portugal, Poland	Udayanga et al., 2014; Cardinaals et al., 2018; Zhao et al., 2019a; Guarnaccia et al., 2020; Hilário et al., 2020a; Michalecka al., 2023
	D. sterillis	意大利Italy	Guarnaccia et al., 2020
	大豆间座壳*D. sojae*	中国China	Li YK et al., 2023
	D. unshiuensis	中国China	Zhou et al., 2025a
	D. vacuae	葡萄牙Portugal	Hilário et al., 2020a
	D. vaccinii	立宛陶、美国、波兰、拉脱维亚、荷兰、意大利、葡萄牙 Lithuania, USA, Poland, Latvia, Netherlands, Italy, Portugal	Kačergius et al., 2004; Lombard et al., 2014; Guarnaccia et al., 2020; Hilário et al., 2021
拟盘多毛孢属 *Pestalotiopsis*	*P. australis*	西班牙、葡萄牙Spain, Portugal	Santos et al., 2022
	烟色拟盘多毛孢 *P. adusta*	中国China	Zheng et al., 2023
	P. angustata	智利Chile	Espinoza et al., 2008
	P. biciliate	西班牙、葡萄牙Spain, Portugal	Santos et al., 2022
	P. chamaeropis	西班牙、葡萄牙、中国 Spain, Portugal, China	Santos et al., 2022; Zheng et al., 2023
	忽视拟盘多毛孢 *P. neglecta*	智利Chile	Zhao et al., 2019a
	棕榈拟盘多毛孢 *P. trachicarpicola*	中国China	Zheng et al., 2023
新拟盘多毛孢属 *Neopestalotiopsis*	棒孢新拟盘多毛孢 *N. clavispora*	乌拉圭、西班牙、智利、塞尔维亚、韩国、中国 Uruguay, Spain, Chile, Serbia, Korea, China	González et al., 2012; Borrero et al., 2018; Lee et al., 2019; Zhao et al., 2019a; Zheng et al., 2023
	N. chrysea	中国China	Shi et al., 2017
	N. longiappendiculata	南非South African	Van der Vyver et al., 2025
	蔷薇新拟盘多毛孢 *N. rosae*	西班牙、秘鲁、葡萄牙、塞尔维亚、美国 Spain, Peru, Portugal, Serbia, USA	Rodríguez-Gálvez et al., 2020; Santos et al., 2022; Blagojević et al., 2024; Dietsch et al., 2025
	N. scalabiensi	西班牙、葡萄牙Spain, Portugal	Santos et al., 2022

续表1 Continued

属名 Genus	种名 Species	分布 Distribution	参考文献 Reference
	N. vaccinii	西班牙、葡萄牙、塞尔维亚 Spain, Portugal, Serbia	Santos et al., 2022; Blagojević et al., 2024
	N. vacciniicola	葡萄牙 Portugal	Santos et al., 2022
	N. mesopotamica	智利 Chile	Barrera-Merino et al., 2025
新壳梭孢属 *Neofusicoccum*	*N. australe*	新西兰、葡萄牙、智利、澳大利亚、西班牙 New Zealand, Portugal, Chile, Australia, Spain	Tennakoon et al., 2018; Scarlett et al., 2019; Zhao et al., 2019a; Santos et al., 2022
	N. arbuti	智利 Chile	Dharmaraj et al., 2022
	桉树新壳梭孢 *N. eucalyptorum*	葡萄牙 Portugal	Hilário et al., 2020b
	N. luteum	新西兰 New Zealand	Tennakoon et al., 2018
	N. macroclavatum	澳大利亚 Australia	Scarlett et al., 2019
	N. nonquaescalus	智利 Chile	Millas et al., 2023
	N. occulatum	澳大利亚 Australia	Scarlett et al., 2019
	N. kwambonambiense	墨西哥、美国、澳大利亚 Mexico, USA, Australia	Sakalidis et al., 2013; Scarlett et al., 2019
	小新壳梭孢 *N. parvum*	澳大利亚、阿根廷、韩国、意大利、新西兰、中国、美国、墨西哥、智利、葡萄牙、乌拉圭、塞尔维亚 Australia, Argentina, Korea, Italy, New Zealand, China, USA, Mexico, Portugal, Uruguay, Chile, Serbia	Espinoza et al., 2008; Wright et al., 2010; Choi et al., 2012; Tennakoon et al., 2018; Zhao et al., 2019a; Millas et al., 2023; Spetik et al., 2023; Blagojević et al., 2024
	茶藨子新壳梭孢 *N. ribis*	美国、新西兰、智利 USA, New Zealand, Chile	Tennakoon et al., 2018; Millas et al., 2023
	N. vaccinii	中国 China	Zhao et al., 2022
	N. vitifusiforme	中国 China	Dissanayake, 2016
葡萄座腔菌属 *Botryosphaeria*	葡萄座腔菌 *B. dothidea*	秘鲁、韩国、中国、美国、澳大利亚、葡萄牙 Peru, Korea, China, USA, Australia, Portugal	Choi, 2011; Yu et al., 2012; Tennakoon et al., 2018; Scarlett et al., 2019; Hilário et al., 2020b
	B. corticis	美国 USA	Milholland, 1984
毛色二孢属 *Lasiodiplodia*	假可可毛色二孢 *L. pseudotheobromae*	美国、中国、澳大利亚、摩洛哥 USA, China, Australia, Morocco	Scarlett et al., 2019; Goura et al., 2024
	可可毛色二孢 *L. theobromae*	美国福佛罗里达州、澳大利亚、秘鲁、西班牙、智利、中国、墨西哥、新西兰 Florida USA, Australia, Peru, Spain, Chile, China, Mexico, New Zealand	Flor et al., 2022; Rodríguez-Gálvez et al., 2020; Avilés et al., 2021; Xu et al., 2015
	L. mediterranea	美国 USA	Wiseman et al., 2017
	L. vaccinii sp.nov	中国 China	Zhao et al., 2019b
	L. laeliocattleyae	秘鲁 Peru	Xu et al., 2015
壳球孢属 *Macrophomina*	豆类壳球孢 *M. phaseolina*	塞尔维亚、中国 Serbia, China	Zhao et al., 2019a
丽赤壳属 *Calonectria*	柯氏丽赤壳 *C. colhounii*	美国 USA	Sadowsky et al., 2011
	C. pseudoreteaudii	中国 China	Chen et al., 2023a
背芽突霉属 *Cadophora*	*C. luteo-olivacea*	意大利 Italy	Guarnaccia et al., 2020
长孢盘菌属 *Godronia*	*G. cassandrae*	挪威 Norway	Strømeng & Stensvand, 2001
长颈座壳属 *Peroneutypa*	帚状长颈座壳 *P. scoparia*	意大利 Italy	Guarnaccia et al., 2020
截盘多毛孢属 *Truncatella*	狭截盘多毛孢 *T. angustata*	智利 Chile	Espinoza et al., 2008

1.2 蓝莓溃疡病

蓝莓溃疡病最早于1931年在美国首次被报道(Weingartner, 1969),该病害主要发生在枝干上,初期表现为小型褐色斑点,随后逐渐扩展成椭圆形或不规则的褐色溃疡斑,严重时患病处表皮开裂,边缘轻微隆起。剖开受害枝条,可见内部维管组织发生明显的褐变坏死,严重阻碍水分和养分的输送,导致枝条枯死。发病后期,病斑表面可能出现黑色小点状的分生孢子器,在潮湿条件下更为明显。严重时整体树势衰退,果实产量和品质下降(Ramsdell, 1983; Dharmaraj et al., 2022)。据报道,在智利蓝莓种植区,溃疡病发病率可达15%~45%,我国也曾报道四川省某蓝莓种植区溃疡病发病率高达80%以上(Zheng et al., 2023),造成极大的经济损失。

蓝莓溃疡病由葡萄座腔菌属、新壳梭孢属 *Neofusicoccum*、间座壳属和拟盘多毛孢属等多种病原真菌引起(表2),其中葡萄座腔菌 *Botryosphaeria dothidea* 被认为是目前蓝莓溃疡病的主要病原菌(崔增杰等, 2010),在我国山东、辽宁、云南等省的蓝莓主产区广泛分布(赵琳, 2020)。

表2 蓝莓溃疡病相关真菌及分布

Table 2 Fungi related to blueberry canker and their distribution

属名 genus	种名 Species	分布 Distribution	参考文献 Reference
葡萄座腔菌属 *Botryosphaeria*	葡萄座腔菌 *B. dothidea*	美国、中国、乌拉圭、新西兰 USA, China, Uruguay, New Zealand	Demaree & Wilcox, 1942; Tennakoon et al., 2018; Sessa et al., 2018
	B. corticis	美国 USA	Phillips et al., 2006
	B. dolichospermatii	中国 China	Rui-Tian et al., 2021
毛色二孢属 *Lasiodiplodia*	*B. fujianensis*	中国 China	Rui-Tian et al., 2021
	可可毛色二孢 *L. theobromae*	西班牙 Spain	Avilés et al., 2021
	L. vaccinii	中国 China	Zhao et al., 2019b
	假可可毛色二孢 *L. pseudotheobromae*	摩洛哥 Morocco	Goura et al., 2024
新壳梭孢属 *Neofusicoccum*	*N. nonquaescalus*	智利 Chile	Hilário et al., 2021
	小新壳梭孢 *N. parvum*	西班牙、智利 Spain, Chile	Castillo et al., 2013; Dharmaraj et al., 2022
	N. arbuti	智利 Chile	Dharmara et al., 2022
	N. australe	智利、西班牙 Chile, Spain	Castillo et al., 2013; Dharmaraj et al., 2022
间座壳属 *Diaporthe*	*D. australafricana*	智利 Chile	Latorre et al., 2012
	D. passiflorae	智利 Chile	Zhao et al., 2019a
	甜樱间座壳 *D. eres*	克罗地亚、荷兰 Croatia, Netherlands	Martino et al., 2024
拟盘多毛孢属 *Pestalotiopsis*	*P. angustata*	智利 Chile	Espinoza et al., 2008
	疏忽拟盘多毛孢 *P. neglecta*	智利 Chile	Espinoza et al., 2008
	茶褐斑拟盘多毛孢 *P. guepinii*	智利、土耳其 Chile, Turkey	Espinoza et al., 2008
新拟盘多毛孢属 *Neopestalotiopsis*	棒孢新拟盘多毛孢 *N. clavispora*	西班牙、智利 Spain, Chile	Espinoza et al., 2008
外茎点霉属 *Ectophoma*	多喙外茎点霉 *E. multirostrata*	伊朗 Iran	Atashi Khalilabad et al., 2023

1.3 蓝莓根腐病

蓝莓根腐病于1947年首次在美国被报道(Varney & Stretch, 1966)。该病害主要为害根系,根部受侵染后,通常从毛细根先出现坏死斑,随后整体根系逐渐变色、腐烂,导致植株生长发育迟缓。地上部分表现为叶片褪绿黄化、边缘叶片坏死、过早脱落,症状类似营养不良,整体树势衰弱,后期植株生长日益缓慢,最后彻底死亡(Bryla et al., 2008)。据报道,在阿根廷布宜诺斯艾利斯省蓝莓园中根腐病发病率曾高达30%(Pérez et al., 2011),导致大面积树势衰

弱，对产量构成严重威胁。该病害在全球多个蓝莓产区均有发生，已成为影响该产业发展的主要病害之一。

截至目前，国内外已报道的与蓝莓根腐病相关真菌有16种，涉及6个属，分别为镰孢属 *Fusarium*、疫霉属 *Phytophthora*、腐霉属 *Pythium*、丽赤壳属 *Calonectria*、蜜环菌属 *Armillaria* 和拟盘多毛孢属真菌，具体的病原真菌及其分布如表3所示，其中樟疫霉 *Phytophthora cinnamomi* 为常见病原菌，在多个国家均有报道（Bryla et al.，2008；Larach et al.，2009）。

表3 蓝莓根腐病相关真菌及分布

Table 3 Fungi related to blueberry root rot and their distribution

属名 Genus	种名 Species	分布 Distribution	参考文献 Reference
镰孢属 *Fusarium*	层出镰孢菌 *F. proliferatum*	阿根廷 Argentina	Pérez et al., 2011
	F. commune	中国 China	Li S et al., 2023
	尖孢镰孢菌 *F. oxysporum*	中国、阿根廷、智利 China, Argentina, Chile	Pérez et al., 2011; Moya-Elizondo et al., 2019
	木贼链孢菌 *F. equiseti*	中国 China	Fei et al., 2018
新赤壳属 *Neocosmospora*	腐皮新赤壳 *N. solani*	阿根廷 Argentina	Pérez et al., 2007
丽赤壳属 *Calonectria*	冬青丽赤壳 *C. ilicicola*	中国、美国 China, USA	Fei et al., 2018; Haralson et al., 2022
疫霉菌属 *Phytophthora*	恶疫霉 *P. cactorum*	德国 Germany	Nechwatal & Jung, 2021
	P. rubi	西班牙 Spain	Borrero et al., 2024
	樟疫霉 *P. cinnamomi*	智利、美国、意大利、中国、德国、西班牙 Chile, USA, Italy, China, Germany, Spain	Bryla et al., 2008; Larach et al., 2009; Lan et al., 2016; Nechwatal & Jung, 2021; Borrero et al., 2024
	柑橘褐腐疫霉 *P. citrophthora*	智利 Chile	Larach et al., 2009
腐霉属 *Pythium*	*P. sterile*	美国、加拿大 USA, Canada	Jami & Botha, 2023
	华丽腐霉 *P. splendens*	美国 USA	Jami & Botha, 2023
	畸雌腐霉 *P. irregulare*	新西兰 New Zealand	Jami & Botha, 2023
	瓜果腐霉 *P. aphanidermatum*	南非 South Africa	Jami & Botha, 2023
	旋柄腐霉 *P. helicoides*	墨西哥 Mexica	Nuñez-García et al., 2025
新拟盘多毛孢属 *Neopestalotiopsis*	棒孢新拟盘多毛孢 *N. clavispora*	中国 China	Xue et al., 2018
蜜环菌属 *Armillaria*	野生蜜环菌 *A. mellea*	意大利 Italy	Prodorutti et al., 2009
	高卢蜜环菌 *A. gallica*	意大利 Italy	Prodorutti et al., 2009

1.4 蓝莓叶斑病

蓝莓叶斑病于1959年首次在美国被报道（Taylor & Clayton，1959）。在发病初期，叶片表面出现针尖大小的褐色斑点，随后病斑逐渐扩展成圆形或不规则形病斑，叶片开始泛黄、微卷，最终坏死脱落。在我国四川省成都市和雅安市蓝莓种植园中，由多主棒孢霉 *Corynespora cassiicola* 引起的叶斑病的发病率可达80%至90%，几乎蔓延整个植株，导致叶片和枝条枯死（Zheng et al.，2023）。云南省蓝莓产区的叶斑病普遍发病率为15%~20%，发病严重的果园甚至超过75%（Yang et al.，2022），该病害不仅直接损伤叶片，还会进一步影响植株整体长势、降低蓝莓产量和品质。

蓝莓叶斑病由多种病原菌引起，其中最常见的病原菌为细极链格孢 *Alternaria tenuissima*，在全球多个国家均有报道。目前在我国也已发现多种其他病原菌，分别为拟盘多毛孢属、黑孢霉属 *Nigrospora*、间座壳属、棒孢属 *Corynespora* 和弯孢属 *Curvularia* 等相关真菌病原菌，具体的病原真菌及其分布如表4所示。

1.5 蓝莓叶锈病

蓝莓叶锈病于1947年首次被报道于美国（Varney & Stretch，1966）。该病的典型症状是在叶片背面出现黄色至橙色的脓疱状夏孢子堆（Chen，2023b），待表面破裂后，会释放出粉末状的夏孢子。在湿度较大时，孢子堆呈现鲜橙色，干燥后则转变为

锈褐色。发病严重时,病斑密布整个叶片,导致叶片局部或全部枯黄、卷曲,并提前脱落。若不进行有效管理,受侵染的植株会长势衰退,导致产量下降(Ivey,2019)。

目前,国内外报道的蓝莓叶锈病病原菌主要为膨痂锈菌属*Pucciniastrum*的2种真菌*Pucciniastrum minimum*和*Pucciniastrum vaccinii*(表5),这2种病原菌在全球多个国家均有分布。

表4 蓝莓叶斑病相关真菌及分布

Table 4 Fungi related to blueberry leaf spot disease and their distribution

属名 Genus	种名 Species	分布 Distribution	参考文献 References
链格孢属 *Alternaria*	细极链格孢 *A. tenuissima*	澳大利亚、中国、韩国、阿根廷 Australia, China, Korea, Argentina	Luan et al., 2007; Kwon et al., 2014; Fernández et al., 2015
	互隔交链孢*A. alternata*	墨西哥Mexico	Nuñez-García et al., 2025
拟盘多毛孢属 *Pestalotiopsis*	烟色拟盘多毛孢*P. adusta*	中国China	Zheng et al., 2023
	P. chamaeropis	中国China	Zheng et al., 2023
	石楠拟盘多毛孢 *P. photiniae*	中国China	Chen et al., 2010
	棕榈拟盘多毛孢 *P. trachicarpicola*	中国、巴西 China, Brazil	Araujo et al., 2023; Zheng et al., 2023
新拟盘多毛孢属 *Neopestalotiopsis*	棒孢新拟盘多毛孢 *N. clavispora*	中国China	Zheng et al., 2023
黑孢霉属*Nigrospora*	稻黑孢霉*N. oryzae*	中国China	Zhang et al., 2019
	球黑孢霉*N. sphaerica*	阿根廷Argentina	Wright et al., 2008
棒孢属*Corynespora*	*C. cassicola*	美国、阿根廷、中国 USA, Argentina, China	Onofre et al., 2016; Zheng et al., 2023
弯孢属*Curvularia*	中隔弯孢*C. intermedia*	中国China	Kong et al., 2024
丽赤壳属*Calonectria*	*C. pseudoreteaudii*	中国China	Chen et al., 2023a
帚梗柱孢属*Cylindrocladium*	*C. colhounii*	中国China	薛德胜等,2019 Xue et al., 2019
间座壳属*Diaporthe*	刺葵生间座壳*D. phoenicicola*	中国China	Lai et al., 2023
外担菌属*Exobasidium*	斑点外担菌*E. maculosum*	美国USA	Brewer et al., 2014
茎点霉属*Phoma*	巨腔茎点霉*P. macrostoma*	中国China	Yang et al., 2022

表5 蓝莓叶锈病相关真菌及分布

Table 5 Fungi related to blueberry leaf rust and their distribution

属名 Genus	种名 Species	分布 Distribution	参考文献 References
膨痂锈菌属 *Pucciniastrum*	*P. minimum*	美国、澳大利亚、墨西哥、中国、南非、英国、新西兰 USA, Australia, Mexica, China, South Africa, Britain, New Zealand	Babiker et al., 2018; Mostert et al.,2010; Latham et al., 2022; Chen et al., 2023b
	P. vaccinii	西班牙、阿根廷、澳大利亚、加拿大、墨西哥、美国 Spain, Argentina, Australia, Canada, Mexica, USA	Ivey, 2019

1.6 蓝莓白粉病

蓝莓白粉病于2012年在葡萄牙首次被发现(Bradshaw et al.,2025)。该病害主要为害叶片,通常从植株下部叶片开始发生。发病初期,叶面出现褪绿小斑,随后逐渐扩大形成不规则形的白色粉状霉斑。霉层逐渐增厚并可蔓延至整个叶片,严重时叶片正反面均被白色菌丝覆盖(Hildebrand et al.,2016),严重影响叶片的光合作用与养分积累,导致植株结实量下降、果实膨大受阻,果个小,品质变差,造成产量和商品价值显著下降。据美国北卡罗莱纳州立大学的一项新研究显示,全球蓝莓产业每年为预防和减少白粉病所投入的成本在数千万乃至数亿美元之间(Bradshaw et al.,2025),因作物减产和品质降级所带来更大的市场损失尚未计算。

目前，可引起白粉病发生为害的病原菌主要是蓝莓白粉菌*Erysiphe vaccinii*，该菌在摩洛哥、葡萄牙、墨西哥、美国、秘鲁等全球多个国家均有过报道（Bradshaw et al.，2025）。

1.7 蓝莓炭疽病

蓝莓炭疽病于2012年在我国辽宁省首次被报道（Liu et al.，2020）。该病害主要为害叶片、花、果实和枝条等多个器官，引起叶斑、花腐、果腐和枝枯等症状。在叶片上，病斑多始于叶尖或叶缘，初期为红褐色圆形或不规则形小斑，随后逐渐扩展，中央呈灰白色，边缘具明显的紫红色晕圈；后期病斑扩展至整个叶片，表面产生黑色小粒点状的分生孢子盘，导致叶片卷曲脱落，严重影响植株长势和产量。果实受害初期表现为浅绿色或淡黄色小点，逐渐发展为灰褐色、不规则形凹陷病斑，在潮湿条件下病斑表面产生橙红色分生孢子团，最终导致果实腐烂。该病害在我国江苏省南京市蓝莓种植区的发病率可超过62%，通过持续为害叶、果和枝梢，对全年生产构成显著威胁（Feng et al.，2024）。

该病害由刺盘孢属*Colletotrichum*真菌引起，广泛分布于全球蓝莓产区，目前已报道侵染蓝莓的有13种（表6），其中以胶孢刺盘孢*Colletotrichum gloeosporioides*和松针刺盘孢*Colletotrichum fioriniae*最为常见，在多国均有报道，是蓝莓炭疽病的主要致病菌。

表6 蓝莓炭疽病相关真菌及分布

Table 6 Fungi related to blueberry anthracnose and their distribution

属名 Genus	种名 Species	分布 Distribution	参考文献 Reference
刺盘孢属 *Colletotrichum*	尖孢刺盘孢 *C. acutatum*	日本、加拿大、中国、西班牙、韩国 Japan, Canada, China, Spain, Korea	Verma et al., 2006; Kim et al., 2009
	隐秘刺盘孢 *C. aenigma*	韩国、中国 Korea, China	Cho et al., 2021; Feng et al., 2024
	嗜金黄刺盘孢 *C.chrysophilum*	巴西 Brazil	Soares et al., 2022
	暹罗刺盘孢 *C. siamense*	中国 China	Liu et al., 2020
	四川刺盘孢 *C. sichuaninese*	中国 China	Liu et al., 2020
	卡哈瓦刺盘孢 *C. kahawae*	中国 China	Liu et al., 2020
	喀斯特刺盘孢 *C. karstii*	中国、巴西 China, Brazil	Liu et al., 2020
	松针刺盘孢 *C. fioriniae*	美国肯塔基州、波兰、韩国、智利、新西兰、中国 Kentucky USA, Poland, Korea, Chile, New Zealand, China	Pszczółkowska et al., 2016; Cho et al., 2021; Castro et al., 2023; Hosking et al., 2024; Zhou et al., 2025b
	果生刺盘孢 *C. fructicola*	韩国、中国 Korea, China	Feng et al., 2024
	C. godetiae	韩国、新西兰 Korea, New Zealand	Choi et al., 2023; Hosking et al., 2024
	胶孢刺盘孢 *C. gloeosporioides*	格鲁吉亚、韩国、中国、美国 Georgia, USA, Korea, China	Ali et al., 2019; Gama et al., 2021; Choi et al., 2023; Feng et al., 2024
	C. helleniense	意大利 Italy	Guarnaccia et al., 2021
	C. nymphaeae	中国、韩国 China, Korea	Liu et al., 2020; Cho et al., 2021

1.8 蓝莓灰霉病

蓝莓灰霉病于2003年在阿根廷首次被报道（Vasquez et al.，2007）。该病害主要为害花、果实、叶片和枝条等器官，通常败花、干枯的柱头、幼果为最易侵染的部位。果实受害初期，表面出现浅褐色、水渍状小斑，多从果蒂或伤口处开始，随后迅速扩展成软腐状病斑，果皮呈半透明状并渗出汁液；随着病情发展，病部产生大量灰褐色绒毛状霉层（为病原菌的分生孢子梗和分生孢子），在高湿条件下霉层尤为明显，后期病果干缩成僵果或脱落。花器受侵染后，花瓣出现褐色水渍斑并褐枯，表面生灰色霉层，导致落花和不能坐果；幼果染病后形成黑色斑点并提早脱落。叶片和枝条上的症状包括嫩枝褐色溃疡斑及叶片边缘向内扩展的V形褐色枯斑（翟浩等，2024）。

该病害具有潜伏侵染特性，病原菌可在果实采前侵入而暂不显症状，直至采后储存和运输过程中遇到高湿才暴发性显现蔓延。如我国南京市江宁区曾在果实采后储存期间大规模发生灰霉病，发病率达8%~12%（Li Q et al.，2023），导致大量鲜果腐烂变质，造成严重的经济损失。

蓝莓灰霉病病原菌主要为葡萄孢属 *Botrytis* 真菌，目前国内外已报道的致病种类包括灰葡萄孢 *Botrytis cinerea*、*Botrytis pseudocinea* 和加州灰葡萄孢 *Botrytis californica*（表7）。其中灰葡萄孢最为常见，该菌分布广泛，已在全球多个蓝莓种植国家发现（Johnston & Mckenzie，1982；Vasquez et al.，2007）。

表7 蓝莓灰霉病相关真菌及分布

Table 7 Fungi related to blueberry gray mold and their distribution

属名 Genus	种名 Species	分布 Distribution	参考文献 References
葡萄孢属 *Botrytis*	灰葡萄孢 *B. cinerea*	新西兰、南非、阿根廷、韩国、智利、美国、墨西哥、中国 New Zealand, South Africa, Argentina, Korea, Chile, USA, Mexico, China	Johnston et al., 1982；Vasquez et al., 2007；Rivera et al., 2013；Saito et al., 2016；Terrones-Salgado et al., 2019；翟浩等, 2024 Johnston et al., 1982; Vasquez et al., 2007; Rivera et al., 2013; Saito et al., 2016; Terrones-Salgado et al., 2019; Zhai et al., 2024
	B. pseudocinerea	美国 USA	Saito et al., 2016
	加州灰葡萄孢 *B. californica*	中国、美国 China, USA	Li Q et al., 2023

1.9 蓝莓果腐病

蓝莓果腐病由多种病原菌混合侵染导致，其症状因致病菌不同而存在明显差异。例如，刺盘孢属真菌侵染后通常在适宜湿度下表面会产生橙红色分生孢子团，病斑从果皮逐渐向果心扩展，最终导致果实褐变腐烂（Beg et al.，2025）；而链格孢属 *Alternaria* 引起的腐烂则表现为果实表面出现深色凹陷病斑，并产生白色至灰绿色菌丝层（Zhou et al.，2025b）。尤其在果实运输和储藏期间易大规模发生，造成严重的显著经济损失。在我国西南与东北地区的高丛蓝莓种植区，由真菌引起的果腐病发病率可达5%（Wang et al.，2016），严重影响商品价值，对产业发展构成严重威胁。

引起蓝莓果实腐烂病的真菌病原菌复杂多样，最常见的主要包括链格孢属、葡萄孢属和刺盘孢属这3个属的真菌，具体的病原真菌及分布如表8所示，其中细极链格孢是蓝莓链格孢属果腐病的主要病原菌（Zhu & Xiao，2015）。这类病原真菌常在果实收获后开始侵染，在试验中大多通过浆果分离才暴露出来。

1.10 蓝莓煤污病

蓝莓煤污病发病初期在叶片、枝条或果实表面产生暗绿色点状霉层；病情发展后霉斑扩展成致密绒状黑色霉层，该霉层阻碍光合作用，导致叶片褪绿黄化，新梢生长受阻；果实受害后表面附着黑色污斑，虽不深入果肉，但严重影响商品价值。病害发生与蚜虫、粉虱分泌蜜露密切相关，霉层多沿蜜露滴落路径分布，高湿环境下霉层增厚呈绒毡状。该病害虽不直接破坏植物组织，但显著削弱树势，增加植株感染其他病害的风险。

目前，已报道引起该病害的优势病原菌为枝孢属 *Cladosporium* 真菌（表9），其中以尖孢枝孢 *Cladosporium oxysporum* 和枝细枝孢 *Cladosporium ramotenellum* 最为常见，在我国山东、辽宁以及四川等省的多个蓝莓主产区均有发生（岳清华等，2016）。

1.11 蓝莓僵果病

蓝莓僵果病于1969年首次被报道于加拿大（Alvarez Osorio et al.，2022），病害侵染后初期表现为嫩叶与嫩芽枯萎，中肋及侧叶脉发生褐变。随着病情加重，叶片逐渐坏死，并在叶柄处产生灰色的分生孢子堆。在潮湿环境下，分生孢子可侵染发育中的嫩芽，严重时导致整个花簇枯萎。果实感染初期通常不表现外部症状，直至接近成熟时，染病浆果逐渐转为粉红色或浅棕色，与健康果实的蜡绿色形成明显对比。最终，病果萎缩硬化，呈白紫色或粉红色，表面形成南瓜状的假菌核，且多在采收前脱落（Schilder et al.，2008）。该病害发生严重时，可造成高达70%至85%的产量损失，甚至绝收（Alvarez Osorio et al.，2022），是全球栽培蓝莓最重要的真菌性病害之一。

蓝莓僵果病由链核盘菌 *Monilinia vaccinii-corymbosi* 引起，在英国、美国、奥地利、加拿大等全球多个国家均有报道（Alvarez Osorio et al.，2022）。

表8 蓝莓果腐病相关真菌及分布

Table 8 Fungi related to blueberry fruit rot and their distribution

属名 Genus	种名 Species	分布 Distribution	参考文献 Reference
链格孢属 *Alternaria*	互隔交链孢 *A. alternata*	美国、中国 USA, China	Zhu & Xiao, 2015; Li et al., 2024
	细极链格孢 *A. tenuissima*	中国、美国 China, USA	Luan et al., 2007; Zhu & Xiao, 2015
	枝状链格孢 *A. arborescens*	美国 USA	Zhu & Xiao, 2015
	侵染链格孢 *A. infectoria*	美国 USA	Zhu & Xiao, 2015
	A. rosae	美国 USA	Zhu & Xiao, 2015
	云南铁杉链格孢 *A. dumosa*	美国 USA	Beg et al., 2025
	粗柠檬链格孢 *A. limoniasperae*	美国 USA	Beg et al., 2025
刺盘孢属 *Colletotrichum*	松针刺盘孢 *C. fioriniae*	中国、美国 China, USA	Zhou et al., 2025b
	尖孢刺盘孢 *C. acutatum*	美国 USA	Zhou et al., 2025b
	胶孢刺盘孢 *C. gloeosporioides*	美国 USA	Zhou et al., 2025b
葡萄孢属 *Botrytis*	灰葡萄孢 *B. cinerea*	中国 China	Zhou et al., 2025b
	B. pseudocinerea	中国 China	Zhou et al., 2025b
	加州灰葡萄孢 *B. californica*	中国 China	Zhou et al., 2025b
葡萄座腔菌属 *Botryosphaeria*	葡萄座腔菌 *B. dothidea*	中国 China	Zhou et al., 2025b
枝孢属 *Cladosporium*	*C. guizhouense*	中国 China	Zhou et al., 2025b
间座壳属 *Diaporthe*	*D. anacardia*	中国 China	Zhou et al., 2025b
	D. vaccinii	中国 China	Zhou et al., 2025b
镰孢属 *Fusarium*	*F. annulatum*	中国 China	Zhou et al., 2025b
	锐顶镰孢菌 *F. acuminatum*	中国 China	Wang et al., 2016
新拟盘多毛孢属 *Neopestalotiopsis*	*N. surinamensis*	中国 China	Zhou et al., 2025b

表9 蓝莓煤污病相关真菌及分布

Table 9 Fungi related to blueberry sooty mold and their distribution

属名 Genus	种名 Species	分布 Distribution	参考文献 Reference
枝孢属 *Cladosporium*	球孢枝孢 *C. sphaerospermum*	韩国 Korea	Kwon et al., 2019
	尖孢枝孢 *C. oxysporum*	中国 China	岳清华等，2016 Yue et al., 2016
	枝细枝孢 *C. ramotenellum*	中国 China	岳清华等，2016 Yue et al., 2016
链格孢属 *Alternaria*	互隔交链孢 *A. alternata*	中国 China	岳清华等，2016 Yue et al., 2016

2 蓝莓真菌病害的传播与防控

2.1 蓝莓真菌病害的传播

蓝莓真菌病害的侵染来源主要为带病苗木，这也是病害远距离传播和新建园发病病原菌的最主要来源。感病母株（包括接穗、插条）若携带潜伏的病原菌，在移栽后遇到适宜条件即发病。蓝莓真菌病害的病原菌通常以菌丝、菌核或分生孢子在病残体或土壤中越冬和存活，成为来年的侵染源。许多重要的蓝莓病害病原菌能在土壤中长期存活，如引起根腐病的镰孢属和疫霉属（Bryla et al.，2008）。真菌病害的病原菌主要通过气流、风雨、灌溉水、土壤、农事操作等途径传播到健康植株上（Ramsdell，1983）。除了高温高湿的环境条件；修剪后未及时清理病残体，人员衣物、鞋靴接触了病株或病残体，再接触健康植株等人为因素导致的农事操作不当，也可促进病原菌的传播、加重病害发生。

2.2 蓝莓真菌病害的防控

真菌病害对蓝莓产业造成的为害是全方位的，不仅侵染植株叶片，导致光合作用受阻、树势衰弱；更直接为害果实，造成采前落果和采后腐烂，严重降低果实商品价值。此外，枝干病害和根部病害严重时则直接导致植株死亡。因此，未来的病害防控必须坚持“预防为主，综合防治”的原则。

在农业防治方面，选用抗病品种、建立果园时使用无菌种苗，加强栽培管理（合理修剪以通风透光、科学肥水增强树势），及时清除病枝落叶病果。

化学防治方面，已有研究表明，咯菌腈和嘧菌酯对蓝莓根腐病具有一定的防控效果，其药效试验结果表明，咯菌腈可以使根腐病发生率由75%降低至40%（Haralson et al.，2013），同时，咯菌腈和嘧菌酯还可防治蓝莓采后灰霉病、炭疽病等病害的发生（Bell et al.，2021）。除此之外，在病害高发期和流行前科学使用高效、低毒的百菌清、石硫合剂、戊唑醇、苯醚甲环唑等杀菌剂是控制病害暴发的重要手段（孟怡君，2023）。

生物防治方面，芽胞杆菌*Bacillus*和假单胞菌*Pseudomonas*可有效抑制由灰葡萄孢引起的蓝莓灰霉病和由交链格孢引起的链格孢果腐病。此外，木霉菌*Trichoderma*也被认为是控制蓝莓采后病害最重要的拮抗剂菌，因为它能够抑制由真菌引起的水果病害（Bell et al.，2021）。同时，有生防试验结果证实，竹醋与桃胶复配处理能100%防治蓝莓病害。该处理对病害的发展也具有强力抑制作用，可使病斑直径从对照组的9 mm成功降至1.90 mm（Shi et al.，2019）。

3 展望

在全球范围内，蓝莓真菌病害的病原菌种类多样，已报道的病原菌涵盖超过20属150余种。本文系统综述了国内外蓝莓主要真菌病害的为害特点及病原菌种类，通过对枝枯病、溃疡病、根腐病、叶斑病、炭疽病、灰霉病等10余种主要病害的分析表明，多种蓝莓病害的病原菌种类并不唯一，而且十分复杂，如蓝莓枝枯病可由间座壳属、拟盘多毛孢属和新壳梭孢属等多个属至少60种病原真菌引起。此外，值得注意的是，引起蓝莓病害的病原菌的分布呈现出显著的地域性差异，如间座壳属病原菌在葡萄牙、意大利、荷兰、北美和中国广泛分布，拟盘多毛孢属及新拟盘多毛孢属病原菌在智利、中国、西班牙、美国等地报道较多，新壳梭孢属病原菌小新壳梭孢*Neofusicoccum parvum*在全球多个大洲均有分布，包括亚洲（如中国、韩国）、北美洲（美国）、南美洲（智利）以及大洋洲（澳大利亚）等。更为复杂的是，同一种病原菌在不同条件下可引起截然不同的病害。例如，小新壳梭孢既可引起枝枯病，也可引起溃疡病，棒孢新拟盘多毛孢*Neopestalotiopsis clavispora*可引起枝枯病和叶斑病，这一现象凸显了病原菌致病机制的多样性与病害症状的复杂性。这种分布和症状差异与气候条件、栽培品种及地域性农业等多种因素密切相关。因此，不同蓝莓产区面临的病害威胁和优势病原菌种群可能存在差异，这要求防治策略必须建立在本地化的病原菌鉴定和监测基础上。尽管国内外围绕蓝莓病害研究已有了一定的积累，但仍存在许多待解决的问题，如多种新发病原菌和土传病原的越冬越夏场所、侵染循环、流行规律等尚未完全明晰；全球蓝莓主产区生态气候条件多样，各国、各地区优势病原菌的种类组成及动态变化仍需进一步梳理，以支撑精准防控体系的构建与推广应用；此外，抗病种质资源的挖掘与利用仍显不足。

未来应全面梳理蓝莓真菌性病害的田间症状、为害情况及病原菌种类，加强对病原菌的精准鉴定，特别是明确引起同一病害的不同病原菌的地理分布和致病性；深入研究蓝莓真菌病害的发生规律，包括病原菌的传播途径、侵染机制、病害流行的环境条件等，为病害的动态监测、精准预警和科学防控提供技术支撑。此外，还应聚焦生物防治、农业防治等绿色防控技术的研发与集成应用，筛选高活性生防微生物菌株，研发新型高效生物制剂，减少化学药剂的使用次数和用量，降低环境污染风险及农药残留隐患；同时加大抗病品种聚合育种与推广力度，提高蓝莓对真菌病害的抗病性，构建蓝莓真菌性病害的综合防控体系，助力蓝莓产业的绿色高质量发展。

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