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Original Paper

Research Progress and Trends in *Morchella* Studies

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Abstract

Morels are highly valued edible and medicinal fungi that have attracted growing attention owing to their nutritional value, bioactive properties, and economic significance. This review summarizes recent advances and future prospects in morel research, with a particular focus on four major areas: taxonomy, chemical constituents and bioactivities, artificial cultivation technologies, and strain breeding. Through a comprehensive analysis of relevant studies conducted both in China and abroad, this review highlights the transition of morel taxonomy from traditional morphology-based identification to more precise molecular phylogenetic classification. It also summarizes the major bioactive compounds identified in morels, including polysaccharides, proteins, amino acids, phenolic compounds, flavonoids, sterols, and fatty acids, as well as their reported biological activities, such as immunomodulatory, antioxidant, and antitumor effects. In addition, the development of artificial cultivation techniques is reviewed, illustrating the progression from early exploratory efforts to facility-based, large-scale, and standardized production systems. The potential applications of modern biotechnological approaches, including molecular markers and genomics, in the selection of elite germplasm and the breeding of superior strains are also discussed. Overall, morel research has gradually established a relatively comprehensive framework encompassing fundamental biological studies, functional component development, and industrial applications, thereby providing an important reference for future research and the sustainable development of the morel industry.

Keywords

Morchella spp., taxonomy, bioactive compounds, artificial cultivation, strain breeding

1. Introduction

Morels (*Morchella* spp.), belonging to the family Morchellaceae in the order Pezizales of the phylum Ascomycota, are a group of economically and nutritionally important fungi with both edible and medicinal value. In Europe, morels are renowned for their unique aroma and taste and are often regarded as the "king of mushrooms," second only to truffles (*Tuber* spp.) in culinary prestige (Clowes & Les, 2012). In North America, they are also highly favored by mushroom enthusiasts and wild foragers, making them one of the most commercially valuable wild edible fungi (O'Donnell et al., 2011).

In recent years, with the growing interest in healthy diets and the expansion of the natural functional food market, morels have attracted extensive attention from both the scientific community and industry. This is largely due to their rich content of polysaccharides, sterols, unsaturated fatty acids, trace elements, and other bioactive substances, as well as their diverse biological activities, including immunomodulatory, antioxidant, anti-inflammatory, and antitumor effects (Liu et al., 2010; Li et al., 2019).

Traditionally, morels have been mainly harvested from the wild. However, because of sparse natural distribution, large year-to-year fluctuations, and ecological degradation, wild morel resources have become increasingly depleted (Pilz et al., 2008). To achieve sustainable utilization and large-scale production, many countries have carried out systematic studies on the biological characteristics, taxonomic identification, artificial cultivation, physiological ecology, chemical composition, and molecular breeding of morels (Li, Chen, & Zhang, 2023; Masaphy, 2010).

This review systematically summarizes recent research progress in morel taxonomy, chemical composition and bioactive substances, artificial cultivation technology optimization, and cultivar breeding. It also analyzes current problems and challenges in this field and discusses future directions for both fundamental research and industrial application of morels.

2. Biological Characteristics of Morels

The biological characteristics of morels (*Morchella* spp.) are fundamental to understanding their taxonomy, artificial cultivation, and breeding, and they also represent a critical link between basic research and industrial application. As ascomycetes, morels have a relatively complex life cycle, typically involving spore germination, mycelial growth, sclerotium formation, primordium differentiation, and fruiting body development (Liu & Dong, 2020; Masaphy, 2017). Compared with many other edible macrofungi, morels are particularly sensitive to environmental fluctuations. Different developmental stages show strong dependence on temperature, moisture, nutrient supply, and the soil microbial environment, which is considered one of the major reasons for the instability often observed in artificial cultivation (Mu, Hao, You, Wang, Qiang, Liu, & Wang, 2024).

2.1 Life Cycle and Reproductive Characteristics

The sexual reproduction and mating-type system of morels have become key topics in recent biological studies. Existing evidence indicates that mating-type genes (MAT1-1 and MAT1-2) are closely associated with sexual development, fruiting body formation, and genetic stability in morels. Different mating-type compositions and their dynamic distribution may influence normal development and yield stability in cultivated strains (Liu et al. 2018). The sexual developmental process is closely related to mating-type composition, and interactions between mycelia of different mating types may influence subsequent fruiting body formation (Mu, Hao, You, Wang, Qiang, Liu, & Wang, 2024). During the vegetative growth stage, morels can form sclerotia, which are considered to be closely related to stress survival, nutrient storage, and subsequent fruiting body development (Liu & Dong, 2020). Recent studies on cultivated morels have further shown that mating-type genes are not entirely constant in their distribution across different developmental stages and tissues; rather, their dynamic changes appear to be associated with normal fruiting body development and genetic stability (Liu et al., 2018).

2.2 Nutritional and Ecological Characteristics

In terms of nutrition, morels are generally regarded as soil-borne heterotrophic fungi capable of utilizing organic carbon from soil and exogenous nutrient sources to complete mycelial growth and fruiting body formation (Liu & Dong, 2020). Comparative genomic studies have shown that some morel species possess strong lignocellulose-degrading potential, providing a molecular basis for their ability to utilize complex organic substrates (Liu et al., 2018). Morels also interact closely with soil microbial communities, and associated bacterial and fungal groups may promote or inhibit mycelial extension, sclerotium formation, and fruiting (Tan et al., 2021). Recent field cultivation studies have shown that morel yield fluctuations are closely associated with soil microecological structure, mineral nutrition status, and changes in key microbial communities, suggesting that ecological adaptation is regulated not only by the fungal genetic background itself but also by the surrounding soil ecosystem (Yue, Hao, Wang, Xiao, Zhang, Chen, Chen, & Zhang, 2024).

2.3 Environmental Response Characteristics of Fruiting Body Formation

Morel fruiting body formation is highly sensitive to environmental conditions. Existing studies and cultivation practices indicate that appropriate low-temperature stimulation, high air humidity, suitable soil moisture, and stable aeration are all important factors promoting primordium differentiation and fruiting body development (Masaphy, 2017; Mu, Hao, You, Wang, Qiang, Liu, & Wang, 2024). In contrast, nutrient imbalance, excessive fluctuations in temperature and humidity, or disturbances in soil microecology can readily lead to primordium abortion, uneven fruiting, or unstable yield (Yue, Hao, Wang, Xiao, Zhang, Chen, Chen, & Zhang, 2024). For this reason, artificial cultivation of morels usually requires coordinated management of exogenous nutrient release, casing soil, temperature and humidity control, and soil microbial regulation (Liu, Ma, Zhang, & Dong, 2018). Therefore, morels are considered a group of edible fungi with high sensitivity to ecological conditions and complex developmental regulation, which not only increases the difficulty of cultivation and breeding but also provides important opportunities for research on their physiological ecology and developmental biology (Mu, Hao, You, Wang, Qiang, Liu, & Wang, 2024).

3. Taxonomic Research on Morels

Taxonomic research on morels has evolved from traditional morphology-based classification to modern molecular and genomic approaches. Early studies mainly classified the genus according to external morphological traits of the ascocarp, such as cap height and shape, honeycomb-like ridge arrangement, fruiting body color, and the mode of attachment between stipe and cap, dividing the genus into major groups such as black morels, yellow morels, and half-free morels (O'Donnell, Cigelnik, Weber et al., 1997). However, morphological traits in morels are strongly influenced by habitat and developmental stage and exhibit high plasticity, which has resulted in controversy and confusion in traditional classification systems (Kuo, 2005). During this period, synonymy and homonymy frequently occurred, and species diversity was substantially underestimated.

From the late twentieth century to the early twenty-first century, the introduction of molecular biology greatly promoted morel taxonomy. Early studies often used the ITS region as a DNA barcode, but a single molecular marker was insufficient to distinguish closely related species (Du, Zhao, & Yang, 2012). Subsequently, multilocus phylogenetic analysis became widely adopted, especially combinations of ITS, EF1-α, RPB1, and RPB2, which provided much higher resolution for phylogenetic reconstruction and species delimitation (O'Donnell et al., 2011; Du, Zhao, & Yang, 2012). On this basis, researchers proposed three major evolutionary lineages: Rufobrunnea, Esculenta, and Elata, and identified numerous cryptic species, expanding global morel diversity to at least 70-80 lineages (Richard et al., 2015). This stage marked the transition of morel taxonomy from a largely ambiguous system to a relatively clearer systematic framework.

With the development of high-throughput sequencing technologies, morel taxonomy has entered the genomic era. Genomes of multiple representative species have been assembled, and comparative genomic analyses have revealed not only genomic differences among lineages but also important functional genes related to environmental adaptation and metabolism (Lo et al., 2019). Genome-level data have unique advantages in resolving closely related species complexes, inferring historical hybridization among lineages, and reconstructing evolutionary timescales. At the same time, population genetics and coalescent-based species delimitation methods have been introduced, allowing researchers to overcome inconsistencies among single-gene trees and to characterize phylogenetic relationships more accurately (Li et al., 2020).

Nevertheless, even with support from genomic and multilocus methods, morel taxonomy still faces major challenges. On the one hand, differences in sampling range, molecular marker selection, and analytical approaches among studies have led to inconsistent taxonomic conclusions. On the other hand, some newly proposed species have been published with insufficient supporting evidence, which has contributed to duplicate naming and instability in the classification system (Cravero, Bonito, Chain, Bindschedler, & Junier, 2024). In addition, sampling in Asia, Africa, and South America remains inadequate, and many potential new species or regional lineages have not yet been fully revealed. Future research should therefore promote integrative taxonomy by combining morphology, multilocus and genomic data, ecology, and biogeographical evidence to establish a unified, stable, and reproducible taxonomic system for morels (He et al., 2017).

4. Chemical Constituents and Bioactivities of Morels

As important edible and medicinal fungi, morels contain a wide range of chemical constituents, including polysaccharides, proteins, amino acids, flavonoids, phenolics, sterols, volatile compounds, fatty acids, organic acids, and trace elements (Gao, Wang, &Wang, 2019; Tian, Zhang, Shang, & Zheng, 2024). Early studies mainly focused on basic nutritional composition, whereas later studies, supported by advances in separation, purification, and activity evaluation methods, gradually expanded toward the structural characterization, biological activities, and potential applications of functional compounds (Xu, Qian, Meng, & Sun, 2025; Li, Dai, Chen, & Shao, 2026). Overall, research on morel chemistry has developed from simple nutritional evaluation to the screening of bioactive compounds and exploration of their mechanisms of action. Progress in the major categories is summarized below.

4.1 Polysaccharides and Their Bioactivities

Morel polysaccharides are among the most important bioactive compounds, and β-glucans have been studied most extensively (Tian, Zhang, Shang, & Zheng, 2024). Numerous studies have shown that morel polysaccharides exhibit immunomodulatory potential, for example by activating macrophages, T cells, and B cells and enhancing cytokine secretion and antigen responses, thereby suggesting a role in immune regulation (Tian, Zhang, Shang, & Zheng, 2024). At the same time, β-glucans have shown promising antitumor activity, including the inhibition of cancer cell proliferation and the induction of apoptosis in experimental systems (Li, Dai, Chen, & Shao, 2026; Wang et al., 2019) In addition, morel polysaccharides may help regulate glucose metabolism, and experimental evidence suggests that they may reduce blood glucose levels, indicating preliminary potential as an adjunct in diabetes management (Xu, Qian, Meng, & Sun, 2025).

4.2 Proteins, Amino Acids, and Their Bioactivities

Morels contain various essential and non-essential amino acids, among which glutamic acid, leucine, and lysine are relatively abundant (Gao, X., Wang, L. N., & Wang, Z. W., 2019). Their proteins and amino acid components not only contribute to nutritional value but also have been reported to exhibit antioxidant and antimicrobial activities. Amino acids may contribute to antioxidant defense by scavenging free radicals and enhancing the activity of antioxidant enzymes [28]. Meanwhile, some amino acids and small peptides have shown inhibitory effects against bacteria and fungi (Li, Dai, Chen, & Shao, 2026). In addition, amino acids are important for immune cell function and may support immune activity and host defense (Gao, X., Wang, L. N., & Wang, Z. W., 2019).

4.3 Flavonoids and Their Bioactivities

Morels have been reported to contain relatively high levels of flavonoids, whose main physiological function is antioxidant activity. Flavonoids can scavenge excessive free radicals, reduce lipid peroxidation, and protect cells from oxidative damage, thereby showing antioxidant potential (Li, Dai, Chen, & Shao, 2026). They can also exert anti-inflammatory effects by inhibiting inflammatory factors such as TNF-α and IL-6, and may therefore have potential relevance to the management of chronic inflammation-related disorders (Tian, Zhang, Shang, & Zheng, 2024). Some flavonoids also possess antitumor activity by regulating the cell cycle and inducing apoptosis, thereby inhibiting cancer cell proliferation in experimental studies (Xu, Qian, Meng, & Sun, 2025).

4.4 Phenolic Compounds and Their Bioactivities

Phenolic compounds in morels include coumarins, tannins, and caffeic acid derivatives, and these compounds display strong antioxidant and anti-inflammatory activities (Tian, Zhang, Shang, & Zheng, 2024; Xu, Qian, Meng, & Sun, 2025). They protect cells from oxidative stress by scavenging free radicals, inhibiting lipid peroxidation, and blocking inflammatory pathways. Some phenolic compounds have also been shown to inhibit various tumor cells, possibly through mechanisms related to apoptosis induction and proliferation inhibition (Xu, Qian, Meng, & Sun, 2025; Li, Dai, Chen, & Shao, 2026).

4.5 Sterols and Their Bioactivities

Morels contain phytosterols such as β-sitosterol and other active substances with multiple health-promoting functions (Gao, X., Wang, L. N., & Wang, Z. W., 2019; Tian, Zhang, Shang, & Zheng, 2024). Sterols can competitively inhibit intestinal cholesterol absorption, thereby potentially lowering serum cholesterol levels and contributing to cardiovascular health (Gao, X., Wang, L. N., & Wang, Z. W., 2019). In addition, sterols exhibit certain antioxidant and anticancer activities and may exert antitumor effects through the regulation of cell membrane stability and related signaling pathways (Li, Dai, Chen, & Shao, 2026).

4.6 Volatile Compounds and Their Bioactivities

The volatile compounds of morels mainly include alcohols, aldehydes, esters, and olefins. These compounds not only contribute to the characteristic aroma of morels but may also exhibit certain antimicrobial and antiviral activities. Some volatile constituents have been reported to inhibit the growth of bacteria and fungi, suggesting potential anti-infective value. However, current studies on the biological functions of morel volatile compounds remain limited, and their health-related effects require further validation (Zhou et al., 2025).

4.7 Organic Acids and Their Potential Functions

Morels are rich in organic acids such as malic acid, citric acid, and tartaric acid, which play important roles in energy metabolism and antioxidant processes (Gao, X., Wang, L. N., & Wang, Z. W., 2019). Organic acids may help reduce oxidative stress and participate in energy metabolism, thereby contributing to metabolic balance (Gao, X., Wang, L. N., & Wang, Z. W., 2019; Tian, Zhang, Shang, & Zheng, 2024).

4.8 Fatty Acids and Their Nutritional Functions

Morels contain various unsaturated fatty acids, mainly linoleic acid and oleic acid (Gao, X., Wang, L. N., & Wang, Z. W., 2019). These fatty acids may play important roles in anti-inflammatory activity, immune regulation, and cardiovascular health. Linoleic acid has been associated with blood lipid regulation, whereas oleic acid may benefit cardiovascular health through anti-inflammatory effects and possible improvement of vascular function (Tian, Zhang, Shang, & Zheng, 2024; Li, Dai, Chen, &

Shao, 2026).

4.9 Trace Elements and Their Nutritional Value

Morels are rich in trace elements such as potassium, calcium, iron, zinc, and magnesium (Gao, X., Wang, L. N., & Wang, Z. W., 2019; Tian, Zhang, Shang, & Zheng, 2024). Calcium and magnesium are essential for bone development and maintenance of bone density, whereas iron and zinc play central roles in hemoglobin synthesis, immune regulation, and enzyme activity. Moderate consumption of morels can therefore provide multiple essential minerals and contribute to immune support, metabolic balance, and overall health (Gao, X., Wang, L. N., & Wang, Z. W., 2019; Li, Dai, Chen, & Shao, 2026).

5. Progress in Morel Cultivation

The artificial cultivation of morels has undergone a long developmental process, from preliminary attempts to modern industrialized production. This process reflects not only an increasing understanding of morel biology and ecological habits but also the transformation of morels from wild-harvested fungi to artificially cultivated commercial products, thereby providing a solid foundation for scientific application and industrial development.

5.1 Preliminary Exploration Stage (Early 20th Century to the 1970s)

The exploration of artificial morel cultivation began in the early twentieth century. In 1901, the Russian scholar Repin reportedly obtained morel fruiting bodies in a cave for the first time (Repin, 1901). However, because of the complexity of cultivation techniques, morels remained largely dependent on wild collection for a long period, and a systematic cultivation system had not yet been established.

5.2 Technical Breakthroughs and Indoor Cultivation Exploration (1970s–1990s)

In the 1970s, researchers began attempting artificial cultivation, but yields and quality remained unstable due to the lack of an effective technical system (Repin, 1901). In the 1980s, Ower and colleagues in the United States achieved the first systematic breakthrough in indoor morel cultivation (Repin, 1901), laying an important foundation for subsequent technological development. Although commercial application still faced substantial difficulties, this breakthrough provided an important basis for the further development of morel cultivation techniques.

5.3 Formation and Promotion of Modern Cultivation Models (2000s–Around 2010)

In the twenty-first century, with the development of protected agriculture, morel cultivation models gradually diversified, including greenhouse cultivation, semi-natural field cultivation, and soilless cultivation (Xu et al., 2022). Modern technologies have improved yield and quality by precisely regulating temperature and humidity (15–22°C, 80%–90%), light conditions (low-intensity diffused light), and carbon dioxide concentration to promote fruiting body development (Liu et al., 2021). Cultivation systems also shifted from single-layer planting to multilayer vertical systems, thereby increasing land-use efficiency and yield per unit area. Soilless cultivation techniques, such as substrate culture and trough cultivation, have also been introduced to reduce dependence on farmland and improve production efficiency (Shi et al., 2023). Zhao Qi and colleagues proposed a biomimetic cultivation technology for pointed morels by simulating natural soil, temperature, humidity, and light conditions and combining systematic spawn management from mother culture to stock culture and cultivation spawn, thereby achieving high and stable yields under artificial conditions (Zhao et al., 2009).

5.4 Maturation and Promotion of Cultivation Technology in China

In China, field ecological cultivation gradually matured around 2012 and entered the stage of large-scale demonstration and extension (Xu et al., 2022). Early commercial field cultivation mainly involved black morels, especially *M. importuna*. With the improvement of cultivation techniques and the advancement of elite strain selection, cultivation later expanded to *M. sextelata*, *M. septimelata*, and several other cultivable black morel species, forming a cultivation pattern dominated by black morels (Narimatsu, Sato, & Sakamoto, 2023; Zhang, Si, Lv, Zhu, Du, Ma, & Qu, 2025). Meanwhile, cultivation practices evolved from relatively extensive open-field systems to refined models integrating exogenous nutrient bags, casing soil, and environmental regulation. On the one hand, exogenous nutrient bags developed from empirical use to optimization in terms of nutrient release, substrate formulation, and feeding time (Shi et al., 2023; Narimatsu, Sato, & Sakamoto, 2023). On the other hand, cultivation environments diversified from single open fields to flat sheds, flat sheds with small tunnels, vegetable greenhouses, forest-based systems, and warm sheds, with increasing emphasis on the coordinated regulation of temperature, water, soil, and microbial environments. This transition has promoted the development of morel cultivation from simple fruiting induction to more stable and productive systems, with gradual improvements in productivity and stability.

5.5 Breakthroughs in International Cultivation Technology

In recent years, international research on the optimization of cultivation environments and stable yield regulation has continued to advance. For example, crop rotation patterns and improvements in the soil microenvironment have been demonstrated to enhance morel yield and cultivation stability. In addition, studies have reported relatively stable and high-yield cultivation and management technologies for *M. esculenta* (He, 2024). However, in general, the cultivation stability and industrial scale of yellow morels still lag behind those of black morels (Zhao et al., 2009).

6. Research Progress in Morel Breeding

As fungi of important economic and medicinal value, morels have been the subject of continuous breeding research over recent decades. Owing to their complex heterotrophic life cycle, diverse genetic backgrounds, and strong ecological adaptability, artificial cultivation has long been challenged by unstable strains and large yield fluctuations (Cai et al., 2020). These issues have made strain improvement one of the core research directions in morel studies.

6.1 Traditional Breeding and Wild Resource Screening

Early morel breeding mainly relied on traditional methods based on phenotypic traits such as morphology, growth cycle, yield performance, and resistance ability (Du, Wang, Sun, Xiong, & Yu, 2019). Researchers collected fruiting bodies from different ecotypes and systematically evaluated their morphology, biomass accumulation, and environmental adaptability to identify germplasm resources suitable for regional cultivation (Li et al., 2016). Although this stage of breeding was time-consuming and relatively inefficient, it laid an important foundation for the development of modern breeding strategies.

6.2 Marker-Assisted Selection

With the development of molecular biology, molecular marker technologies such as ISSR, SSR, and SNP have been widely applied to the analysis of genetic diversity and phylogenetic relationships in morel germplasm resources. Marker-assisted breeding can facilitate the identification of strains with superior performance in yield, stress tolerance, and market traits, thereby improving breeding efficiency and shortening the selection cycle compared with traditional breeding.

In phylogenetic studies, O'Donnell et al. (2011) were the first to systematically classify the genus *Morchella* using multilocus sequences such as LSU, EF-1α, RPB1, and RPB2, revealing multiple independent genetic groups and providing abundant genetic resources for breeding (O'Donnell et al., 2011). Subsequently, many studies used RAPD, AFLP, ISSR, and related methods to analyze the genetic structure of strains from different geographical origins and revealed substantial genetic differentiation among strains (Song, Liu, Li, Ma, Chai, & Zhao, 2024).

6.3 Genomic and Functional Gene Research

Advances in morel genome sequencing and transcriptome analysis have provided a basis for functional gene mining. Studies have preliminarily identified important genes associated with fruiting body formation, stress response, and reproductive cycle regulation, thereby providing candidate targets for future molecular-assisted breeding (Sun et al., 2022).

6.4 Practical Application and Elite Strain Breeding

In practical applications, Chinese research teams have reportedly bred elite cultivated strains such as Nonghei-1 and Heiyou-1, which show high yield, stable production, strong stress resistance, and stable commercial traits. In addition, the environmental adaptability of these elite strains has been evaluated in different regions, providing technical support for large-scale production and industrial development.

6.5 Resistance Breeding

Resistance breeding is an important direction in morel improvement, mainly aiming to enhance adaptation to abiotic and biotic stresses and thereby improve cultivation stability and yield security. Existing studies indicate that resistance research in morels has already involved specific strains and stress types. For abiotic stress, *M. sextelata* has been used in studies on salt tolerance, heat tolerance, and cadmium tolerance. Under NaCl stress, significant changes have been observed in mycelial growth, biomass, membrane permeability, and antioxidant physiological indicators, suggesting that this species may provide a basis for screening salt-tolerant strains. Under heat stress, transcriptomic, metabolomic, and proteomic studies of *M. sextelata* have shown that heat-shock proteins, cell wall integrity maintenance, and antioxidant systems are closely associated with heat tolerance. Under heavy metal stress, recent studies have revealed the mechanisms of Cd^{2+} absorption and adaptation from physiological, ultrastructural, and transcriptomic perspectives. Meanwhile, *M. spongiola* has also been investigated under cadmium stress, and the results showed that Cd exposure can induce mycelial morphological changes, oxidative damage, and antioxidant defense responses, indicating interspecific differences in heavy metal tolerance that may be useful for breeding.

In addition, morel resistance studies have gradually expanded to disease resistance and continuous cropping tolerance. For example, pathogen identification and detection studies have been conducted on bacterial red stipe disease and stipe rot in *M. sextelata*, providing a basis for disease-resistance breeding. Other studies have indicated that continuous cropping obstacles in morels (Xu, Zhang, Li, Li, & Xu, 2024) are closely related to soil microbial imbalance, pathogen accumulation, and autotoxic substance buildup. Studies on allelopathic compounds have involved cultivable species such as *M. sextelata*, *M. importuna*, and *M. eximia*, thus providing a basis for future breeding aimed at tolerance to continuous cropping and soil-borne diseases. Overall, current morel resistance breeding has developed from simple stress physiology toward multiple parallel directions, including salt tolerance, heat tolerance, heavy metal tolerance, disease resistance, and continuous cropping tolerance. However, most studies still focus mainly on resistance evaluation and mechanistic analysis, and the breeding of stable resistant strains directly applicable to production remains insufficiently developed.

7. Conclusion

Morels, as globally important edible and medicinal fungi, have witnessed remarkable research progress over the past decades. Significant advances have been made in taxonomy, bioactive compounds, artificial cultivation, and strain breeding, gradually leading to the establishment of a relatively systematic research framework. The application of molecular technologies has promoted the improvement of taxonomic systems, studies on bioactive substances have revealed their important nutritional and medicinal value, advances in cultivation technology have facilitated the transition from wild harvesting to large-scale production, and strain breeding has begun to move toward molecular and precision-based approaches.

However, several challenges remain in morel research, including the lack of a unified taxonomic system, insufficient stability in artificial cultivation, serious problems related to diseases and continuous cropping, and a shortage of elite cultivars. Future research should strengthen interdisciplinary integration, with particular emphasis on taxonomic standardization, elucidation of developmental and regulatory mechanisms, optimization of efficient and stable cultivation techniques, and the breeding of superior cultivars, so as to promote the sustainable development and high-value utilization of the morel industry.

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