

High-quality Cultivation Techniques for Under-forest *Auricularia auricula* in the Eastern Liaoning Mountainous Region and Analysis of Key Issues

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Abstract This article provides a systematic review of high-quality cultivation techniques for under-forest *Auricularia auricula* in the eastern Liaoning mountainous region and analyzes the key issues associated with its cultivation. The technical key points of each stage—from site selection, mushroom stick production, spawn running management, and ear emergence management to harvesting and processing—are elaborated in detail. Furthermore, key issues such as pest and disease control and environmental regulation are analyzed, and corresponding solutions are proposed. This work aims to provide technical support for the under-forest *A. auricula* industry and to promote its sustainable development.

Key words Under-forest, *Auricularia auricula*, Cultivation technology, Eastern Liaoning mountainous region

1 Introduction

Auricularia auricula has a smooth, fresh, and crisp texture, is rich in nutrition, and exhibits notable medicinal properties, making it highly favored by consumers^[1]. The under-forest cultivation model fully utilizes the advantages of forest space and natural environmental conditions by innovatively integrating forestry with the edible fungus industry. This cultivation model not only enhances the income of farmers in forest areas but also promotes the sustainable utilization of forest land resources, thereby offering a model for the efficient economic development of forest areas.

Currently, the under-forest cultivation of *A. auricula* in Liaoning Province has reached a stable scale, with its models and mechanisms progressively maturing. The integration of scientific and technological advancements has greatly enhanced the brand's impact, establishing it as a key industry for promoting rural income growth. Major production areas, including Fushun County, Fengcheng City, and Xifeng County, have utilized rotated branches from tussah oak forests as raw materials for *A. auricula* cultivation. This practice not only revitalizes idle or abandoned forest land resources and produces nutrient-rich mushroom food, but also establishes an efficient ecological model characterized by a "forest-fungus" closed loop, contributing to the goal of high-quality agricultural development through efficient resource utilization and

environmental coordination. The application of intelligent facilities and equipment, alongside the continuous advancement of cultivation techniques, has resulted in the annual production volume of *A. auricula* in the eastern Liaoning mountainous region remaining stable at over 30 million sticks. The average yield per bag has increased from 40 g to more than 60 g. The cultivation of under-forest *A. auricula* is progressing towards standardization and automation. Meanwhile, there is a growing consensus within the industry to avoid the use of chemical agents and to promote green food certification.

The complexity of high-quality cultivation techniques for under-forest *A. auricula* limits the high-value development of this industry. Achieving high-quality cultivation requires mastery of a series of essential core technologies, as well as the ability to address various unexpected issues that may arise during the cultivation process in a timely and appropriate manner. Therefore, this article aims to provide an in-depth discussion of the key technologies and practical issues associated with the cultivation of under-forest *A. auricula*.

2 Key technologies

2.1 Site selection Selecting an appropriate site for under-forest cultivation is a key element for success. The chosen forest land should satisfy the following conditions.

2.1.1 Avoiding pollution sources. The cultivation environment should be situated at a considerable distance from pollution sources, including industrial wastewater, waste gases, waste residues, and pesticide residues, to ensure the quality and safety of *A. auricula* production.

2.1.2 Convenient transportation. Convenient transportation conditions facilitate the movement of mushroom sticks and raw materials, as well as the outward transport of *A. auricula* products post-harvest, thereby effectively reducing transportation costs and labor

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intensity.

2.1.3 Gentle terrain. The slope should be less than 25°. Terrain with such a gradient is convenient for placing mushroom sticks and conducting routine agricultural management activities, and effectively prevents issues such as the slipping of mushroom sticks or water accumulation caused by uneven terrain.

2.1.4 Appropriate canopy density. A canopy density ranging from 0.6 to 0.8 within the forest stand is considered optimal. This range not only offers moderate shade to *A. auricula*, thereby protecting it from the adverse effects of direct sunlight on its growth, but also satisfies the species' requirements for temperature, humidity fluctuations, and CO₂ concentration during the ear emergence stage^[2].

2.1.5 Excellent water source conditions and good water quality. An adequate and clean water supply is essential to meet the substantial water requirements during the cultivation of *A. auricula*. This ensures the efficient execution of processes such as water spraying and atomization, thereby guaranteeing the safe and high-quality production of *A. auricula*.

2.1.6 Good ventilation. The natural environmental conditions of forest land are diverse and complex. Factors such as geographical location, topography, landforms, climatic characteristics, tree species, and their growth patterns exert a decisive influence on the regional microenvironment. During the growth period of *A. auricula*, continuous ventilation is essential to regulate the moisture levels of the ear pieces, reduce the proliferation of pests and diseases, and simultaneously provide adequate oxygen to the mycelium and fruiting bodies within the mushroom sticks. This process establishes an optimal micro-ecological environment conducive to the growth of *A. auricula*.

2.2 Mixing and bagging The production of mushroom sticks is a critical step in the under-forest cultivation of *A. auricula*, directly influencing both the yield and quality of the crop.

2.2.1 Culture medium formula. The reference formula for the cultivation of *A. auricula* consists of 88% broad-leaved sawdust, 10% bran, 1% gypsum powder, and 1% lime powder. The moisture content of the culture medium should be maintained at approximately 58%. To enhance both the yield and quality of *A. auricula*, the addition of 2% soybean meal and 1% white sugar to the above-mentioned culture medium is recommended^[3].

2.2.2 Mixing materials. Various raw materials should be weighed according to the specified formula ratios and thoroughly mixed using a medium-sized mixer with an output power of 4 kW at 380 V and a conventional motor speed of 1 400 rpm. Initially, auxiliary materials such as wheat bran, soybean meal, and gypsum should be stirred for 8 to 10 min. Then, the main ingredients are added, and mixing continues for an additional 5 to 8 min. Water is finally added incrementally and mixed thoroughly. The moisture content of the culture medium is maintained at 58% ± 2%. The production process strictly adheres to the principles of mixing materials, loading sticks, and sterilizing on the same day to ensure

product quality and production efficiency.

2.2.3 Bagging. Specialized plastic bags with a specification of 16.5 cm × (35 – 38) cm are typically selected for *A. auricula* cultivation. Industrialized production is conducted using a fully automated assembly line, which includes mixers, bagging machines, bag neck forming machines, and sterilizers. Under standard conditions, an optimal loading height ranges from 20 to 21 cm, with a wet material mass of approximately 1.1 to 1.2 kg.

2.3 Sterilization and inoculation The prepared mushroom sticks are placed in an autoclave for sterilization. During this process, the pressure should be maintained between 1.3 and 1.5 kg/cm², with a typical duration of 1.5 to 2 h. Once the pressure gauge needle returns to zero, the mushroom sticks should be promptly removed and transferred to a sterile inoculation room. If atmospheric pressure sterilization is employed, the cold air inside must first be expelled, after which the temperature should be increased to 100 °C and maintained for 6 to 8 h. When the internal temperature of the mushroom stick falls below 28 °C, liquid or branch strains of *A. auricula* can be inoculated onto the sticks.

2.4 Spawn running management After inoculation, the mushroom sticks are transferred to the spawn running room, where spawn running can be conducted using one of two methods. The first method involves multi-layer culture racks, consisting of 3 – 5 tiers of metal or wooden racks within the spawn running room, with 3 to 4 layers of mushroom sticks placed on each tier. The second method employs grid culture racks, typically comprising 15 to 20 grid layers, each with an edge diameter of 11 – 12 cm, and with the bottom layer positioned 10 – 15 cm above the ground. Both methods offer advantages such as enhanced ventilation, efficient heat dissipation, easy cleaning and observation, which collectively reduce the risk of contamination and improve the uniformity of spawn running. The spawn running stage is critical for mycelial growth and nutrient accumulation, necessitating strict control of environmental conditions.

2.4.1 Temperature and humidity. The temperature of the culture medium within the stick is typically 2 – 3 °C higher than the room temperature. To prevent excessive temperatures that may adversely affect mycelial growth, the temperature in the culture room should not exceed 26 °C. During the industrial production of high-quality mushroom sticks, temperature regulation must be adjusted according to specific stages following inoculation: (i) from day 1 to day 7 post-inoculation, the temperature should be maintained between 24 and 26 °C; (ii) from day 8 to day 20 post-inoculation, the temperature should be controlled within 22 to 24 °C; and (iii) from day 21 post-inoculation until full colonization, the temperature should be kept between 20 and 22 °C^[4].

The relative humidity in the culture room is generally maintained between 50% and 70%. Under the coordinated management of temperature, humidity, and ventilation, artificial humidification indoors is generally unnecessary^[5].

2.4.2 Lighting and ventilation. The culture room should be

maintained in a dark environment. After the mushroom sticks have been cultivated for 7 d, ventilation and air exchange should be conducted twice daily, in the morning and evening, for 30 to 40 min each time. This procedure ensures the freshness of the air, supplies adequate oxygen for mycelial growth, and removes gases such as carbon dioxide from the environment^[6].

2.4.3 Control of mixed microorganisms. An appropriate quantity of quicklime is spread on the floor of the culture room to establish an alkaline environment, thereby reducing the risk of mold and other mixed microorganism growth. Throughout the cultivation process, movement of mushroom sticks should be minimized to the greatest extent possible. When inspecting for mixed microorganisms, mushroom sticks must be handled with care. If contamination by mixed microorganisms is detected, the affected mushroom sticks should be promptly removed and placed in a cooler area for continued observation. In cases of relatively mild contamination, the ear emergence management remains unaffected.

2.5 Post-ripening management of mushroom sticks After the mycelium has fully colonized the mushroom sticks, the temperature is maintained at 15–20 °C, and the post-ripening process continues for 5–7 d. Subsequently, the mushroom sticks are transferred to the production site, where they are stacked and arranged before being covered with plastic film and straw mats.

2.6 Site cleaning After selecting the forest land, the site must be cleaned to remove weeds, vines, and other debris. Concurrently, the passageways should be renovated to facilitate smooth movement for production personnel and equipment, thereby meeting the essential requirements for daily operations. In addition, water pipelines need to be installed on the mushroom beds where the fruiting bodies emerge.

2.7 Puncturing holes for ear induction After 5–7 d of stacking management, the mycelium reaches physiological maturity, at which point the puncturing operation is performed. The holes are created using a punching machine, typically forming "Y-shaped" small openings with a diameter of 0.4–0.6 cm and a depth of 0.5–0.8 cm. Each mushroom stick is punctured with 200 to 240 holes^[7].

After perforating the mushroom sticks, they are neatly arranged on the mushroom bed within the forest to facilitate centralized ear induction treatment. The inoculation site should be oriented downward, maintaining a spacing of 2–3 cm between each stick. Then, the sticks are covered with a layer of plastic film, over which straw mats or sunshade nets are placed^[8]. Environmental conditions are regulated to sustain an internal temperature of 18–25 °C and a relative humidity of 80%–90%. Following 7 to 10 d of cultivation, primordia begin to develop gradually.

2.8 Placement of mushroom sticks After ear induction, management during the ear emergence period is conducted. There are mainly two methods for placing mushroom sticks. (i) Open field placement: the land is prepared by forming ridges that are

10–15 cm higher than the surrounding ground, with a width of 1.2–1.5 m and a working path of 30–50 cm. Quicklime is evenly distributed on the ridge bed, after which black plastic film with perforations is laid. The mushroom sticks are then placed on the plastic film, maintaining a spacing of approximately 10 cm between them. (ii) Hanging method: a rope is used to suspend the mushroom sticks on a support structure. One end of a three-strand nylon rope is fixed to the support, while the other end is tied in a knot to which 7–8 tripod hooks are attached. A mushroom bag is first positioned between the three strands of the rope with the bag opening facing downward. A tripod hook is placed on top, followed by a mushroom bag, and then another tripod hook. Each string sequentially holds 6–9 bags. The distance between adjacent strings should be 25–35 cm, and the bottom mushroom bag should be suspended 15–20 cm above the ground^[9].

2.9 Ear emergence management The management practices during the ear emergence period are key determinants of the yield and quality of *A. auricula*. At this stage, it is essential to effectively coordinate various environmental factors. *A. auricula* exhibits a high water demand during the ear emergence period. Water should be applied reasonably, taking into account prevailing weather conditions and the developmental status of ear slices. Typically, water is sprayed 2–3 times daily. The volume of water applied each time should be sufficient to maintain moisture on the ear slices without causing water accumulation. Under high-temperature conditions, humidity within the cultivation environment can be increased through fine mist spraying, which also helps to reduce the ambient temperature around the mushroom sticks. On rainy or cloudy days, the frequency or amount of water spraying should be reduced or suspended, depending on the specific circumstances.

2.10 Pest and disease control In the high-quality production process of under-forest *A. auricula* cultivation, pests and diseases are the most significant influencing factors. It is essential to adhere to the fundamental principle of "prioritizing prevention and implementing comprehensive control measures".

2.10.1 Agricultural control. High-quality strains should be bred, with a focus on selecting strains that show strong stress resistance and high purity to minimize the likelihood of infection originating from the source.

Optimization of cultivation management can be achieved through several approaches. First, it is essential to rationally plan the cultivation area within the forest and maintain an appropriate density of mushroom sticks. Second, regular removal of dead branches and fallen leaves from the cultivation site is necessary to ensure cleanliness and order. In the case of disease occurrence, affected sticks should be promptly removed, and lime powder is applied around them for disinfection. Besides, implementing crop rotation or intercropping strategies can help reduce the accumulation of pathogenic bacteria at the cultivation site.

In terms of environmental regulation, measures such as forest

pruning and the installation of shading nets are implemented to optimize light exposure and ventilation conditions. Micro-sprinkler irrigation systems are employed to precisely regulate environmental humidity, thereby preventing water accumulation.

2.10.2 Physical control. (i) Light trapping technology. The installation of black light lamps and frequency-vibrancy pest-killing lamps in the forest facilitates the establishment of an efficient ecological prevention and control network, effectively interrupting the emergence and reproductive cycles of pests. Black light lamps employ ultraviolet light sources with a wavelength of 365 nm to attract adult pests commonly found on edible fungi, such as Lepidoptera and Coleoptera, and utilize high-voltage grids to achieve lethal shock. The frequency-vibrancy pest-killing lamps operate synergistically with the high-voltage grids by emitting light waves at specific frequencies, thereby reducing energy consumption while enhancing trapping efficiency. This integrated technology maintains pest populations below the economic threshold, thereby minimizing the reliance on chemical pesticides and simultaneously improving both the quality and yield of *A. auricula*.

(ii) Color board trapping method. The use of yellow sticky boards suspended at an appropriate height is an effective method for controlling small pests, including mushroom flies and mushroom mosquitoes. The boards should be hung at a height corresponding to the growth layer of *A. auricula*.

(iii) Sweet and sour liquid trapping. Initially, sugar, vinegar, wine, and water are thoroughly combined in a volumetric ratio of 3 : 4 : 1 : 2, after which the mixture is poured into an open container. Empirical evidence suggests that containers exhibiting bright colors, such as red, yellow, and orange, are more effective in attracting pests. Finally, the containers are suspended 20–30 cm above the mushroom sticks. The density of the hanging devices should be adjusted according to the cultivation area and the severity of pest infestation. Typically, one trapping device is settled per 4–5 m². During the process, it is essential to regularly monitor the number of insects captured in the containers and promptly remove the trapped insects to prevent decomposition, which could produce unpleasant odors and reduce trapping efficacy. It is recommended to conduct inspections every 2–3 d and to dynamically adjust the number of suspended traps based on the observed insect population density.

(iv) Setting up insect-proof nets. Typically, white insect-proof nets with a mesh size ranging from 60 to 80 are selected, which can provide a more effective barrier against insects.

(v) Manual control measures. Regular inspections are conducted to manually remove fruiting bodies or insect bodies infected by pests and diseases in order to prevent their further spread.

2.10.3 Chemical control. Due to the implementation of under-forest cultivation methods, the random application of chemical pesticides is prohibited, as it may lead to environmental pollution and significantly affect the quality of *A. auricula*. Therefore, agricultural and physical control measures are mainly employed in

practical production, with chemical control reserved solely for emergency situations. When chemical pesticides are utilized, strict adherence to usage regulations is essential. Priority should be given to pesticides with high efficacy, low toxicity, and low residues. For example, chlorantraniliprole is recommended for controlling lepidopteran pests, while carbendazim is suitable for managing fungal diseases. It is important to avoid pesticide application during the ear emergence period of *A. auricula*. At the same time, pesticide dosages must be carefully regulated, and safety intervals must be observed to ensure that residue levels remain within acceptable limits.

2.11 Harvesting and drying

2.11.1 Harvesting method. When the diameter of the ear slice reaches 3 to 4 cm, exhibiting a generally spread-out structure with slightly curled edges, a contracted ear root, lighter coloration, and reduced thickness, it is ready for harvesting.

The mushroom stick fork is utilized to lift the mushroom stick. The ear base is grasped between the index finger and thumb and rotated to detach it, after which it is placed into the collection container. Subsequently, the mushroom stick is returned to its original position on the mushroom bed. For mushroom sticks with varying sizes of ear slices, a strategy involving the selection of larger slices while retaining the smaller ones may be employed.

2.11.2 Drying. *A. auricula* should be dried promptly after harvest. Drying nets are placed on drying racks and covered with rainproof plastic film. Given the difference among *A. auricula* products, the drying methods must be adjusted accordingly.

After harvesting fibrous-type varieties, the material should be promptly spread flat on the drying net. It is generally recommended to arrange them in a single layer, as this facilitates faster moisture loss and promotes proper setting. Typically, complete drying can be achieved within 1–2 d. The ear slices should not be turned over randomly before they are fully set, as this may affect their quality. During nighttime, a plastic film cover should be applied to prevent dew from wetting the ear slices, thereby preserving their quality.

For semi-fibrous *A. auricula*, the slices should not be spread too thickly to ensure optimal drying. The setting time should be minimized. Once the ear slices have set, multiple drying nets containing *A. auricula* should be combined and transferred to a well-ventilated, shaded shed equipped with bed frames for air-drying. The slices should only be bagged and stored in the warehouse after they are thoroughly dried.

The processing of non-fibrous ear slices involves two primary stages: rapid water loss and setting, followed by slow air-drying. To improve the aesthetic quality and uniformity of ear slices, a secondary shaping procedure may be performed. This procedure is conducted as follows: first, once the ear slices are thoroughly dried, an appropriate amount of clean water is sprayed onto them using a spray bottle to make the slices moist and soft. Afterwards, the ear slices are grasped with both hands and gently rubbed to

gether with the palms to roll them inward into a strip-like shape. Finally, the shaped ear slices are subjected to air-drying. After they have completely dried, they should be promptly packaged and stored in the warehouse.

3 Analysis of key technical issues

3.1 Importance of site selection and layout In the under-forest cultivation of *A. auricula*, the selection and management of forest land are critically important. The community structure of various tree species can create significant microclimatic variations. For example, differences in morphological characteristics and transpiration rates between coniferous and broad-leaved forests, combined with multiple interacting factors, result in significant environmental differences within the region. Empirical evidence indicates that broad-leaved forests or mixed coniferous and broad-leaved forests with a canopy density between 0.6 and 0.8 are relatively ideal sites for cultivation. Such forest lands should possess favorable drainage and ventilation conditions. In practical production, ideal forest land resources that satisfy the above conditions are limited, resulting in a relatively narrow range of available options. Compared to open-field cultivation, site planning for under-forest cultivation has greater challenges. To successfully cultivate high-quality *A. auricula*, it is essential to conduct planning based on specific environmental conditions, including the appropriate determination of mushroom stick density, the design of operational paths, and the arrangement of shading and ventilation facilities. Inadequate planning can directly and negatively affect both the growth performance and management efficiency of *A. auricula*.

3.2 Challenges in regulating under-forest environmental factors

3.2.1 Temperature. The optimal temperature range for the formation of ear buds and the development of fruiting bodies of *A. auricula* is 22 – 25 °C. However, the temperature under the forest canopy is significantly influenced by external environmental conditions. Compared to open-field and greenhouse cultivation, it fluctuates more frequently and is challenging to regulate promptly. This variability is a critical risk factor impacting both yield and quality. For example, a sudden decrease in temperature within forest areas during spring can adversely affect the activity of mycelial cells, resulting in the "fist-shaped" deformation of fruiting bodies and increased nutrient consumption from mushroom sticks. In severe instances, this may cause necrosis and erosion of the fruiting body tissues. If the continuous high temperature in the forest area reaches 30 °C during the summer, inadequate treatment measures can result in significant metabolic disorders in *A. auricula* mycelium, including imbalances in respiration and enzyme activity. This leads to a marked decline in the growth rate and stress resistance of the mycelium and, in severe cases, causes denaturation of mycelial proteins, ultimately resulting in large-scale mortality.

3.2.2 Humidity. The regulation of humidity within the cultiva-

tion environment of under-forest *A. auricula* is characterized by complexity and variability. Humidity levels are influenced by multiple factors, including meteorological conditions, the canopy density, and ventilation pathways. The interaction of these variables presents significant challenges to the precise management of moisture, becoming a critical bottleneck that limits the high-quality and efficient production of under-forest *A. auricula*. Throughout the developmental stages of fruiting bodies, it is essential to maintain an adequate water supply and implement "alternating dry and wet" management practices, while also addressing the drainage of excessive rainfall. Failure to do so may result in water accumulation on mushroom sticks, which can lead to diminished yields or complete crop failure.

3.2.3 Light. The growth of *A. auricula* is influenced by the stimulation of scattered light. When the forest canopy density is excessively high, resulting in insufficient light, the growth rate of *A. auricula* mycelium decreases, the coloration of the fruiting bodies becomes paler, and their quality deteriorates. Conversely, if the canopy density is too low, excessive light exposure may occur, leading to increased temperatures within the mushroom stick, which can damage both the mycelium and fruiting bodies. Therefore, appropriate human intervention and regulation of light conditions should be implemented based on the specific characteristics of the forest area.

3.2.4 Ventilation. Air circulation within the under-forest environment is generally limited. Inadequate ventilation can result in elevated CO₂ levels and reduced O₂ concentrations. Such conditions may negatively impact the respiration and growth of *A. auricula* and potentially promote pest and disease issues affecting this species. Thus, the density of *A. auricula* mushroom sticks should be appropriately regulated based on temporal and spatial factors.

3.3 Frequent occurrence of pests and diseases and challenges in their management The complexity of the forest ecological environment provides favorable conditions for the proliferation of pests and diseases. Variations in temperature and humidity within the forest are closely associated with the incidence of these pests and diseases. During spring, rising temperatures and increased humidity facilitate the germination of numerous spores from mixed microorganisms. The hot and humid conditions in summer further accelerate pest reproduction. Moreover, anthropogenic factors such as excessive planting density, inadequate ventilation, and poor sanitation exacerbate the severity of pest and disease problems. Effective pest and disease management is therefore a key factor for the successful under-forest cultivation of *A. auricula*.

In the under-forest cultivation of *A. auricula*, an integrated approach combining agricultural, physical, biological, and chemical control methods is essential for the effective prevention and management of diseases and pests. Meantime, it is important to enhance scientific management practices and minimize dependence on chemical pesticides to establish an ecologically balanced forest planting environment. By coordinating diverse prevention and con-

tol strategies and rigorously managing all aspects of cultivation, economic losses caused by pests and diseases can be effectively reduced, thereby ensuring the yield and quality of under-forest *A. auricula* and promoting the green and sustainable development of this industry.

4 Conclusions

The under-forest cultivation model of *A. auricula*, recognized as an environmentally sustainable and efficient planting approach, has exhibited significant developmental potential. Forest ecosystems naturally provide shaded and humid conditions, which are advantageous for the cultivation of *A. auricula*. Utilizing these natural benefits not only conserves land resources and reduces production costs but also fosters economic development within forest areas^[10]. Nevertheless, to achieve high-quality yields in under-forest *A. auricula* production, cultivators must possess comprehensive techniques, including site selection, mushroom stick production, spawn running management, and ear emergence management, and effectively address key challenges such as pest and disease control, environmental regulation, and the enhancement of both yield and quality.

References

[1] ZHU Y. Study on the countermeasures to promote the high-quality development of *Auricularia heimuer* industry in China[J]. Northern Horticulture, 2024(16): 144–149. (in Chinese).

[2] PAN PK. High-efficiency cultivation technology of *Auricularia heimuer* under forest in Liaodong mountain area[J]. Liaoning Forestry Science and Technology, 2019(3): 71–73. (in Chinese).

[3] ZHANG JC, MA QF, MA YP, *et al.* Study on optimal formula of sawdust and wheat bran for *Auricularia heimuer* cultivation[J]. Edible Fungi of China, 2020, 39(3): 17–20. (in Chinese).

[4] XIAO L. High-efficiency cultivation technology of *Auricularia heimuer* under forest in Liaodong region[J]. Liaoning Forestry Science and Technology, 2021(4): 71–72. (in Chinese).

[5] ANAERGULI D. Key points of cultivation technology and management measures of *Auricularia heimuer*[J]. Agricultural Engineering Technology, 2019, 39(5): 76. (in Chinese).

[6] WU TY. Analysis of under-forest black fungus cultivation technology in Qiandongnan region[J]. Horticulture & Seed, 2025, 45(7): 23–25. (in Chinese).

[7] DING J, ZHANG J, ZHANG YY, *et al.* Cultivation technology of inter-planting *Auricularia heimuer* in mulberry garden[J]. Edible Fungi, 2021, 43(6): 59–60. (in Chinese).

[8] PEI JQ. Cultivation techniques of uniwafer *Auricularia auricula* in Fushun area[J]. Forest By-product and Speciality in China, 2024(2): 55–57. (in Chinese).

[9] ZHANG HX, LAN XY. Cultivation technology of wooden frame hanging bag of *Auricularia heimuer* in Jilin region[J]. Special Economic Animals and Plants, 2025(4): 126–128. (in Chinese).

[10] WU X. Study on the current situation of cultivation of edible fungi under the forest and development strategies[J]. Edible Fungi of China, 2020, 39(5): 23–26. (in Chinese).

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[16] TURNER TR, JAMES EK, POOLE PS. The plant microbiome[J]. Genome Biology, 2013, 14(6): 209.

[17] RODRIGUEZ RJ, WHITE JF JR, ARNOLD AE, *et al.* Fungal endophytes: Diversity and functional roles[J]. New Phytologist, 2009, 182(2): 314–330.

[18] YI TF, WU YG, YU J, *et al.* Isolation and identification of endophytic fungi from *Areca catechu* L. [J]. Chinese Journal of Ethnopharmacology and Ethnopharmacology, 2019, 28(23): 22–27. (in Chinese).

[19] SONG WW, NIU XQ, YU FY, *et al.* Isolation and preliminary identification of endophytic fungi from Arecanut (*Areca catechu*) [J]. Acta Agriculturae Jiangxi, 2017, 29(6): 66–69, 74. (in Chinese).

(From page 9)

[3] XIONG F, DAI H, HUANG ZQ. Determination of diniconazole residue in grape by gas chromatography[J]. Chinese Journal of Chromatography, 2002, 20(4): 383–384. (in Chinese).

[4] ZHAO ZY, YUAN H, WU JX, *et al.* Simultaneous determination of 97 pesticide residues in wine by QuEChERS-GC-MS/MS[J]. Liquor-Making Science & Technology, 2016(9): 105–109. (in Chinese).

[5] LI R, CHU DK, ZHANG PJ, *et al.* Determination of 127 pesticide residues in cucumber, Chinese flowering cabbage, grape and banana by QuEChERS/HPLC-MS/MS[J]. Journal of Instrumental Analysis, 2015, 34(5): 502–511. (in Chinese).

[6] KONG XH, HUANG JR, HE Q, *et al.* Determination of 78 pesticide residues in grape seed extract by UPLC-MS/MS[J]. Chinese Journal of

Analysis Laboratory, 2012, 31(5): 38–43. (in Chinese).

[7] LI CJ, LI PP, CHEN M, *et al.* Simultaneous determination of three benzimidazole pesticides in grape juice by high performance liquid chromatography-fluorescence detection [J]. Food Science, 2016, 37(12): 192–196. (in Chinese).

[8] ZOU RB, LIU Y, WANG SJ, *et al.* Development and evaluation of chemiluminescence enzyme-linked immunoassay for residue detection of three organophosphorus pesticides[J]. Chinese Journal of Pesticide Science, 2017, 19(1): 37–45. (in Chinese).

[9] QIU SH. Determination of valsartan benzyl ester in valsartan by relative correction factor method[J]. Drug Standards of China, 2016, 17(6): 426–430. (in Chinese).

[20] MA R, WANG ZL, RUI K. Phyllosphere microbial community structure and diversity of *Areca catechu* with yellow leaf disease[J]. Acta Microbiologica Sinica, 2025, 65(8): 3600–3614. (in Chinese).

[21] DAWSON WO, GARNISAY SM, TATINENI S, *et al.* Citrus tristeza virus-host interactions[J]. Frontiers in Microbiology, 2013, 4: 88.

[22] AGRANOVSKY AA. Principles of molecular organization, expression, and evolution of closteroviruses: Over the barriers[J]. Advances in Virus Research, 1996, 47: 119–158.

[23] LI Y, CUI H, CUI X, *et al.* The altered photosynthetic machinery during compatible virus infection[J]. Current Opinion in Virology, 2016, 17: 19–24.

Analysis Laboratory, 2012, 31(5): 38–43. (in Chinese).

[7] LI CJ, LI PP, CHEN M, *et al.* Simultaneous determination of three benzimidazole pesticides in grape juice by high performance liquid chromatography-fluorescence detection [J]. Food Science, 2016, 37(12): 192–196. (in Chinese).

[8] ZOU RB, LIU Y, WANG SJ, *et al.* Development and evaluation of chemiluminescence enzyme-linked immunoassay for residue detection of three organophosphorus pesticides[J]. Chinese Journal of Pesticide Science, 2017, 19(1): 37–45. (in Chinese).

[9] QIU SH. Determination of valsartan benzyl ester in valsartan by relative correction factor method[J]. Drug Standards of China, 2016, 17(6): 426–430. (in Chinese).