

Part I Shiitake

Chapter 5

Pest and Disease Management of Shiitake**BIOLOGY AND CONTROL OF PESTS AND DISEASES IN SHIITAKE LOG CULTIVATION**Won-Chull Bak¹ and Hyunjong Kwon (Miji)²¹Korea Forest Research Institute, 207, Cheongnyangni 2-dong, Dongdaemun-gu, Seoul, 130-712, Korea (wcbak@foa.go.kr)²MushWorld, Korea**Introduction**

A wide range of pests and diseases occur during shiitake log cultivation. Some diseases destroy or damage the shiitake mushrooms, and insects and other animal pests also reduce yields and quality. It is impossible to block other wood-inhabiting fungi from the logs used in the outdoor cultivation of shiitake, because the spores of wood-inhabiting fungi are naturally carried in the air. These spores can quickly establish a new colony when exposed to a suitable substrate under favorable conditions. However, if the growing environment is properly managed, pest fungi could not present a serious problem.

Pests which affect the logs, mycelium, fruiting bodies and harvested mushrooms, can be divided by organism type (*i.e.* microorganism, insect, or mammal) and affected site (log, mycelia, shiitake fruiting bodies (growing/harvested)).

Table 1. Pests and diseases affecting shiitake cultivation

		Logs	Mycelia	Fruiting bodies	Stored mushrooms
Fungi	Dry	<i>Diatrype</i> , <i>Schizophyllum</i> , <i>Coriolus</i> , <i>Stereum</i>	<i>Hypocrea</i> , <i>Hypoxyton</i>		
	Humid	<i>Coriolus</i>	<i>Trichoderma</i>		
	Hot & Humid	<i>Bulgaria</i> , <i>Inonotus</i>	<i>Nitschkia</i> , <i>Trichoderma</i>		
Insects		<i>Moechotypa</i> , <i>Xylebrorus</i>		<i>Dacne</i>	<i>Nemapogon</i>
Mollusca				Slugs, Snails	
Mammals		Mice, Squirrels		Mice, Squirrels Deer, Rabbits	

Pests cannot be completely controlled by chemicals, and there are other problems with chemical use. Fungicides can also kill the desired fungus, shiitake. The desirability of organic food that has been produced without using chemicals is an important recent trend. The prolonged use of chemicals may lead to some kind of resistance to the chemicals in the pest population. To minimize disease problems and to favor the growth of shiitake it is important to provide optimum growing conditions and practices based on a full understanding of the biology of shiitake and the pests. This knowledge involves biology of shiitake, plant pathology, entomology and zoology.

Basic Practices for Disease and Pest Management

- ▷ Maintain the proper moisture content of log for shiitake growth: between 30 and 50%.
- ▷ Provide good ventilation and drainage. Damp conditions favor the growth of shiitake's competitors.
- ▷ Do not expose the logs to direct sunlight. Shiitake mycelia may suffer water-lacking stress under dry conditions.
- ▷ Perform timely inoculation of logs in order that shiitake could pre-occupy the logs.
- ▷ Eliminate or exclude the contamination sources. Contaminated soil, piles of dead leaves and mushroom stubs after harvest can be a possible access for disease, competitor and weed fungi to shiitake fungus.
- ▷ Remove spent and contaminated logs immediately.

Fungi

Pest fungi can be divided into three categories based on the degree of damage inflicted. Disease fungi are capable of attacking and killing shiitake mycelium. Competitor fungi do not actually attack shiitake, but they do diminish the crop by occupying space and withdrawing nutrients from the logs. Weed fungi, while not usually a problem, limit the growing area of shiitake.

Hypocrea schweinitzii (asexual stage: *Trichoderma longibrachiatum*)

Disease fungus, dry, freshly inoculated logs

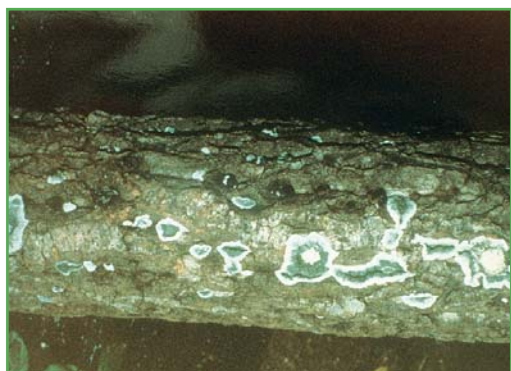


Figure 1. *Trichoderma longibrachiatum*

This fungus occurs when the logs are exposed to direct sunlight for at least one day. It causes serious damage by producing antifungal compounds that lead to the cessation of shiitake mycelial growth.

Morphology and symptoms

In the asexual stage (*Trichoderma longibrachiatum*), a white colony appears on the bark surface of the log. The colony grows bigger, with the center of the colony growing into a green button-shape. As time passes, the green buttons turn brown or dark brown.

Conditions of occurrence

This fungus always exists in and around a log stacking yard, but presents no damage to the shiitake logs unless the logs are exposed to direct sunlight. Warm temperature or low moisture content inside the logs can lead

to high population of this fungus in the logs.

Control measures

- ▷ To prevent the infection, avoid direct sunlight by using shade netting.
- ▷ Protect shiitake mycelia from high temperatures by providing sufficient shade.
- ▷ Logs heavily infected by *Trichoderma* should be removed from the fruiting site to stop the dispersal of *Trichoderma* spores.

Hypoxylon truncatum

Disease fungus, dry, mid temperature

Hypoxylon can be a serious problem during shiitake cultivation. They are antagonistic to shiitake and can stop its growth. *Hypoxylon* invades logs during the early spring months.

Morphology and symptoms

A yellowish green colony (asexual stage) appears initially on the log ends. The colony spreads towards the bark surface and results in stroma¹ formation.



Figure 2. Asexual stage and stromata of *Hypoxylon truncatum* on the log end

¹ stroma : pl. stromata. a compact mass of somatic hyphae

Fruiting bodies start as tiny dark spots, usually in cracks in the bark. During the late summer months, the dark spots gradually develop into small, hard, brick-red to black molds, usually less than 3/8 inch (2-10mm) in diameter (Fig. 2). During the later stages of infection, the bark falls off the logs.

Conditions of occurrence

Direct sunlight is conducive to *Hypoxylon* development. Direct sunlight falling on the bark of shiitake logs can raise the internal temperature to levels which inhibit the shiitake growth, but encourage the growth of *Hypoxylon*.

Control measures

- ↳ Do not expose the logs to direct sunlight.
- ↳ *Hypoxylon* levels can be decreased by shading the logs from direct sunlight.
- ↳ Severely infected logs should be removed to lower disease spore concentrations.

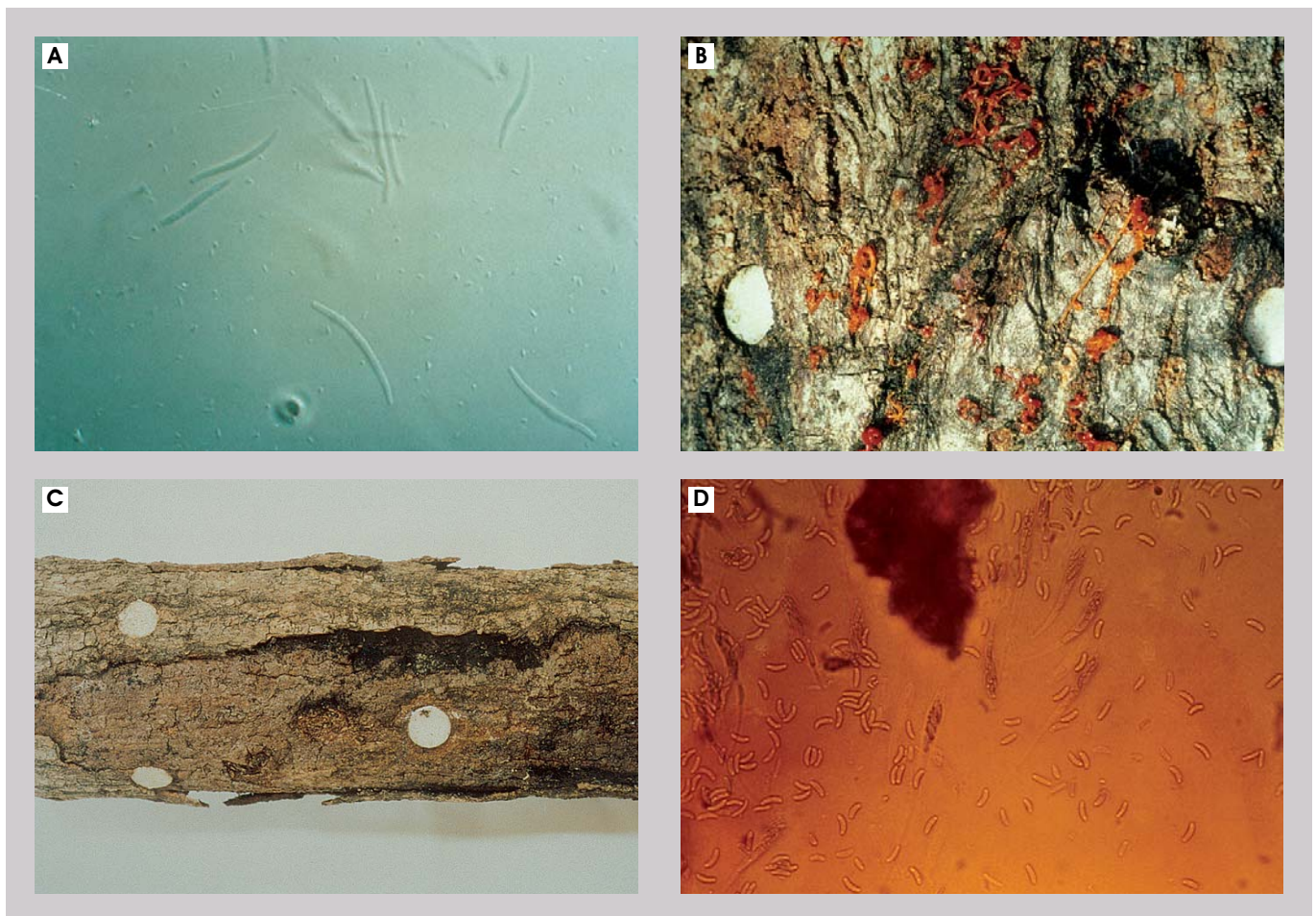
Diatrype stigma (asexual stage : *Libertella betulina*)

Disease fungus, dry, mid temperature

Diatrype stigma, with an associated asexual stage, *Libertella betulina*, which attacks shiitake by secreting anti fungal compounds. Severe infections can also result in total loss of the bark.

Morphology and symptoms

During the asexual stage, this fungus produces conidia² (Fig. 3A), which enter through cracks in the bark. The conidia in mass are orange and form small hooked curls *ca.* 1/2 inch (1.3cm) in length (Fig. 3B). If the bark is removed, additional spore masses are exposed. At the sexual stage, usually occurring in the autumn months, the fungus forms hard, crusty stromata, which are blackish brown on the surface (Fig. 3C). Dark zone lines are formed between the colonies of the fungus and shiitake (Fig. 3E) and the bark sloughed off (Fig. 3F). The affected logs with their bark removed are subject to secondary contamination by other fungi, such as *Trichoderma* or *Hypocrea*.



² conidium : pl. conidia. a small sexual spore, produced vegetatively by special cells on a conidiophore



Figure 3. Symptoms and spores of *Diatrype stigma* and *Libertella betulina* **A:** Conidia of asexual stage **B:** Spore horns of *Libertella betulina* **C:** Stromata (sexual stage) formed under the bark **D:** Ascospores of sexual stage **E:** Zone lines between shiitake (a) and *Diatrype* (b) colonies, and spore horns (c) **F:** Debarked log

Conditions of occurrence

The fungus usually invades dry logs, especially newly felled logs.

Control measures

- ↳ Don't expose logs to dry conditions during felling.
- ↳ Logs heavily attacked by *Libertella* should be removed.

Schizophyllum commune

Competitor fungus, dry, mid temperature

This common wild fungus is classified as a medicinal mushroom used in traditional oriental medicine.

Morphology and symptoms

The fruiting bodies are leathery, fan-shaped and covered with fine hairs. The fungus is commonly found on dry-spots in logs, particularly second-year shiitake logs. The affected log turns dark brown under the bark.

Conditions of occurrence

They are usually found under dry conditions, especially where direct sunlight strikes logs during the hot dry season.

Control measures

- ↳ Protect logs against direct sunlight by using shade netting.



Figure 4. Fruiting bodies of *Schizophyllum commune*

Disease fungus, humid, low temperature

Trichoderma polysporum

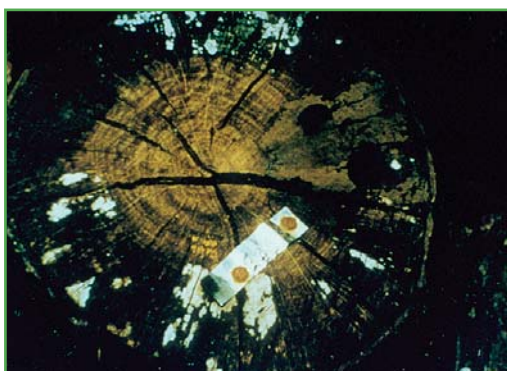


Figure 5. *Trichoderma polysporum* occurring on the log end

The fungus is associated with *Hypocrea pachybasioides* (sexual stage). It doesn't develop into a green colony, unlike other *Hypocrea* species.

Morphology and symptoms

White stromata appear dotted on the log end and turn into light-brown lumps. Colonizing logs rapidly, it eliminates white shiitake mycelia. It builds up large colonies long before it is observed. When the temperature increases, other *Trichoderma* species invade the fungus-infected logs.

Condition of occurrence

Humid season with low temperature. This fungus grows best at 20-25 °C, 100% relative humidity, and 65% log moisture content.

Control measures

- ↳ One of the highest incidences occurs during the snow melting season, when temperatures are low but humidity is high. Do not expose logs to excessive humidity during the snow melt period.
- ↳ Carefully watch logs for any suspicious colonies.

Bulgaria inquinans

Weed fungus, humid, mid temperature



Figure 6. Fruiting bodies of *Bulgaria inquinans* on the log surface

As a weed fungus, this species decays wood and only competes with shiitake mycelia for space. It presents little problem, and disappears later during the spawn run.

Morphology and symptoms

Dark-brown circular fruiting bodies of this fungus change to a black-purple color. These fruiting bodies are soft and rubbery in wet weather and 0.5-4cm wide and 1cm high. Black spots are visible under the bark of the affected logs.

Conditions of occurrence

Humid environments with mid temperature.

Control measures

- ↳ Inoculate properly dried logs with fast-colonizing, vigorous spawn.

Coriolus versicolor

Competitor fungus, dry, mid temperature



Figure 7. Fruiting bodies of *Coriolus versicolor*

This fungus is commonly called “Turkey tail,” and is one of the most common fungi found on shiitake logs. It is also classified as a medicinal mushroom used in traditional oriental medicine.

Morphology and symptoms

The fungus is thin (1-2mm), leathery, velvety and with alternating bands of dark (black, brown, gray, dark-purple or sometimes greenish) and light color. The underside is covered with whitish pores. As a white rot, it also degrades logs and turns them white, competing with other fungus including shiitake for nutrients and space in the logs. The affected area under the bark might be much wider than where the fruiting bodies appear on the logs. A distinct zone line is formed where *Coriolus* and shiitake mycelia encounter.

Conditions of occurrence

This fungus occurs favorably at mid temperatures.

Control measures

- ↳ Inoculate the logs in a timely manner in order that the shiitake mycelia can pre-occupy them.

Stereum sp.

Competitor fungus, dry, mid temperature

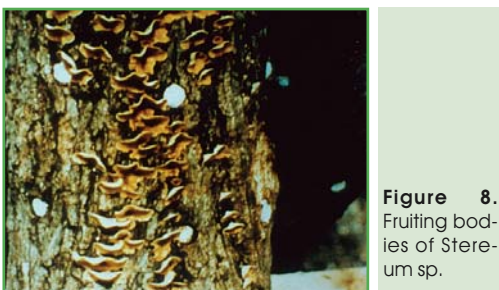


Figure 8. Fruiting bodies of *Stereum* sp.

Morphology and symptoms

The fruiting bodies of this fungus are red, orange or light to dark brown, fan-shaped, overlapped, and leathery with dense hairs. They are densely appressed against the log surface, with only the margins raised.

As a white rot, *Stereum* quickly degrades logs and forms distinct zone lines in the areas where it encounters shiitake mycelia. The fungus prefers to begin growth on uncolonized parts of the logs.

Conditions of occurrence

Half dry, mid temperature conditions

Control measures

- ↳ Perform timely inoculations in order to allow shiitake to pre-occupy the logs.
- ↳ Keep the cultivation site clean and remove contaminated shiitake logs in order not to infect healthy ones.

Inonotus xeranticus

Weed fungus, humid, high temperature

Morphology and symptoms



Figure 9. Fruiting bodies of *Inonotus xeranticus* on the log surface

The fruiting bodies of this fungus are thin, leathery, overlapped, and colored a light gold. Characteristically, numerous, narrow dark brown zone lines (throughout the log when advanced) are observed under the bark. This fungus only competes with shiitake mycelia for log space but mycelial growth of shiitake can be stunted on the affected areas, and this situation might also allow for invasion by other fungi.

Conditions of occurrence

Growth of this fungus is favored by hot and humid conditions. Insufficiently seasoned logs, logs with a wide diameter, logs in humid conditions are prone to the *Inonotus* infection.

Control measures

- ↳ Lay and dry logs sufficiently in a well-ventilated site.

Black-rot disease

Disease fungus, humid, high temperature

Severe damages were reported in Japan and Korea. *Trichoderma harzianum* (sexual stage: *Hypocrea nigricans*) and *Nitschkia confertula* were reported as the causal agents of the black-rot disease in Japan and Korea, respectively.

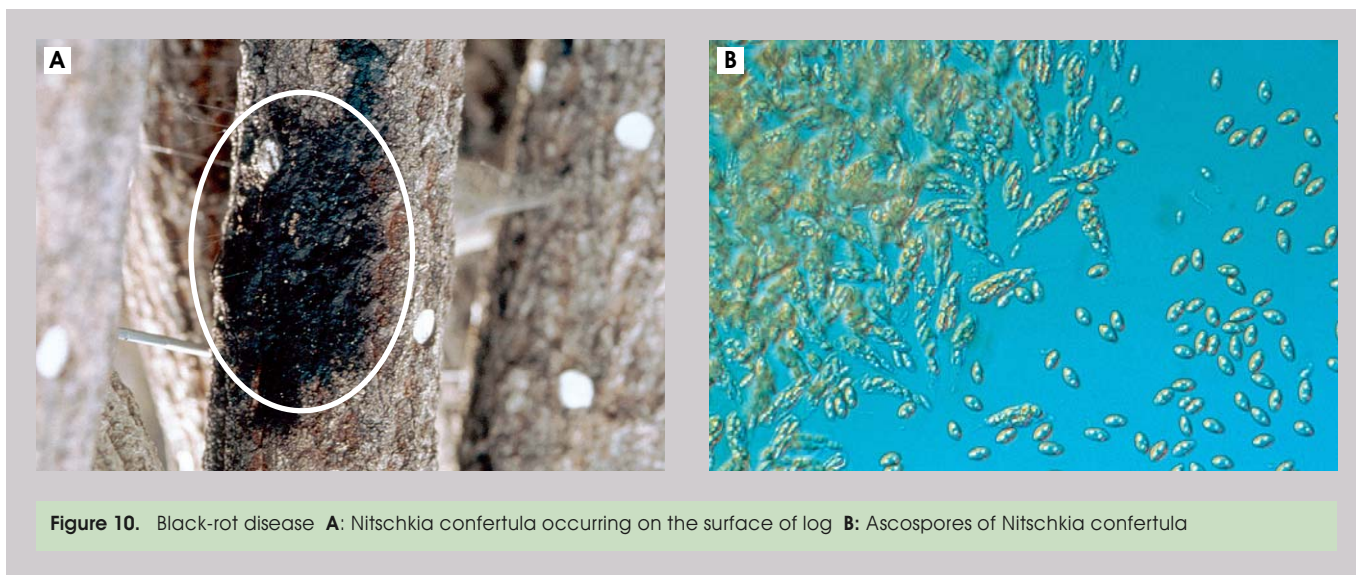


Figure 10. Black-rot disease A: *Nitschkia confertula* occurring on the surface of log B: Ascospores of *Nitschkia confertula*

Morphology and symptoms

These fungi attack logs and cause black-rot. The bark on affected logs appears as if it were burned (Fig. 10A) and is eventually sloughed off.

Conditions of occurrence

Serious damage and infestations are reported in poorly ventilated and badly drained log yards during the rainy season. The growth of this fungus is favored by high temperatures and humidity above 80%.

Control measures

- ↳ Provide good ventilation and remove weeds around the log yard.
- ↳ Avoid humid conditions after rainfall.

Trichoderma viride

Disease fungus, humid, high temperature

Morphology and symptoms

When this fungus occurs the bark of the affected log is peeled off and the exposed log surface becomes a dark brown color. This fungus attacks shiitake mycelia.

Conditions of occurrence

Hot and humid conditions

Control measures

↳ Avoid high humidity.



Figure 11. Wood surface under the bark attacked by *Trichoderma viride*

Animal Pests

Insects that might damage cultivated shiitake by affecting logs or the fruiting bodies include termites, beetles, moths, flies and springtails. Slugs and snails are probably the most commonly encountered animal pests of shiitake, and they cause serious damage by feeding directly on the mushroom caps. Shiitake fruiting bodies are unlikely to be free from attack by wild animals when they are cultivated in forest areas or clearings. Other animals that might feed on shiitake fruiting bodies include deer, mice, squirrels, rabbits and pigs.

Long-horned beetles (Family Cerambycidae)

Freshly inoculated logs

Morphology

Moechotypa diphysis is a long-horned beetle. The body of an adult of this beetle is black and covered with reddish brown hairs. The length of the body is ca. 16-27mm. The larva is cannon-shaped.



Figure 12. Long-horned beetle A: Surface of log damaged by *Moechotypa diphysis* B: Wooden powder from holes of the affected log C: Adult of *Moechotypa diphysis*

Biology

The adults spend winter under the fallen leaves or rotten logs and come out in the following spring. The larvae invade the bark of logs, but avoid the part where shiitake mycelia grow well. As a sign of damage, wooden powder comes out through small holes from the logs.

Control measures

↳ Cover logs with an insect net to prohibit the access of adult insects during the oviposition (egg-laying) period.

Ambrosia beetles (Family Scolytidae)

Freshly inoculated logs

These insects feed on a kind of fungus called "ambrosia" that they introduce when they bore a tunnel into the sapwood and sometimes heartwood³ of freshly sawn logs. It is the fungus, not the beetle or its larvae, that feeds on and sometimes heartwood of logs wood fiber and grows on the walls of the tunnel. An ambrosia beetle attack can be recognized by the whitish boring dust. Bark beetles on the other hand create reddish boring dust. *Xyleborus validus* is an ambrosia beetle, and is commonly found in a wide range of host trees, including shiitake logs.

³ For detailed information on sapwood and heartwood, see SHIITAKE LOG CULTIVATION in Chapter 3.



Figure 13. Ambrosia beetle **A:** *Xyleborus validus* **B:** Underside of *Xyleborus validus* **C:** Ambrosia beetle-bored hole

Morphology

The adult insect is cylindrical, shiny black and 3.6-4.0mm long, with spine-like protuberances at the posterior of elytra⁴.

Biology

The species has one generation per year and overwinters as an adult. Female adults excavate through the heartwood. The tunnels branch in the same plane following an annual ring. The adults spend winter under the bark and come out the following spring in search of a new log or wood to inhabit. Pinholes bored by these beetles provide possible pest fungi with invasion routes.

Control measures

- ↳ Cover the logs with fine-meshed net to keep them free from adult beetles, particularly during their oviposition (egg-laying) period.

Pleasing fungus beetle (Family Erotylidae)

Fruiting bodies, stored mushroom

As indicated in their common name, pleasing fungus beetles feed on the fruiting bodies of fungi. A wide variety of fungi serve as hosts for the family as a whole, but each pleasing fungus beetle species seems to be specific to a certain group of fungi. For instance, *Megalodacne* spp. feed on *Ganoderma* spp., while *Triplax* spp. feed on oyster mushrooms (*Pleurotus* spp.). *Dacne fungorum* is one of the pleasing fungus beetles that eat shiitake. Some *Dacne* bore into the stems of plants or wood rather than feed on fungi. *Dacne* is a genus of small beetle of the family Erotylidae. Most species in this widely distributed family are tropical.

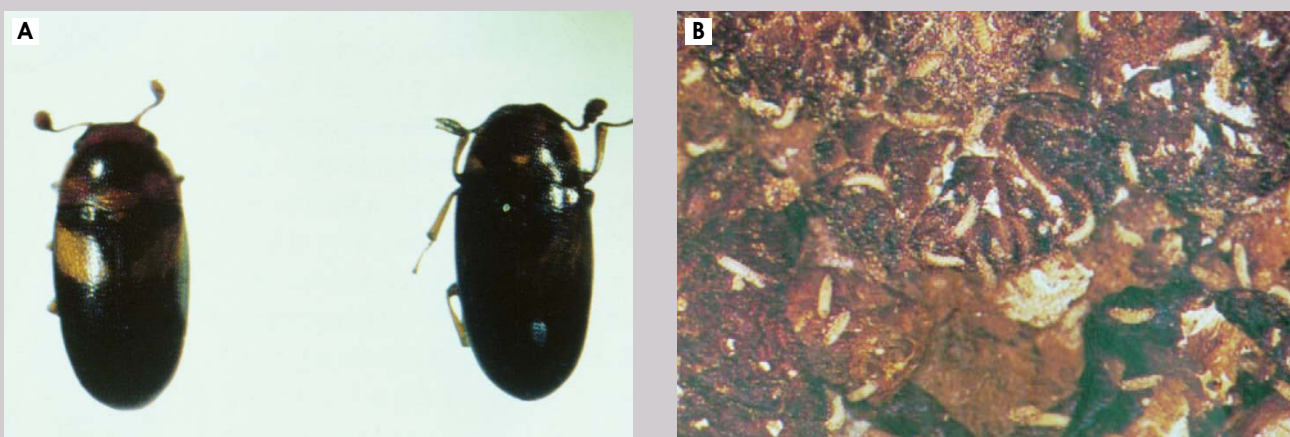


Figure 14. Pleasing fungus beetle **A:** *Dacne fungorum* **B:** Larvae in shiitake in storage (Photo courtesy of Furugawa and Nobuchi)

⁴ elytra: sg. elytron. modified, hardened forewings of certain insect orders, notably beetles (Coleoptera) and true bugs (Hemiptera)

Morphology

The adult bodies are colored a shiny reddish-brown. The fore wings have a V-shape stripe. The length of an adult is *ca.* 3-4.5mm. Important structural characters include their clubbed antenna, and lack of pubescence (fine hairs). *Dacne* is one of the smallest pleasing fungus beetles. The body shape is usually elongate-oval or egg-shaped.

Biology

Adult insects appear in summer and autumn. They lay eggs 3mm deep from the surface of fruiting bodies. The larvae penetrate into the fruiting bodies and cause damage.

Control measures

- ▷ Be careful not to delay the harvest of fruiting bodies. Avoid high temperature and humidity in the fruiting site.
- ▷ For storage, heat dry the fruiting bodies. Install filter-equipped ventilation units at windows.
- ▷ Dispose of spent logs or contaminated fruiting bodies.

Moths

Stored mushrooms

As its common name, the European grain moth, implies, *Nemapogon granellus* is a major pest that causes great damage to stored grains and vegetable products. The moth is found all over the world and also known as the corn moth, and the wine cork moth, because it ruins bottled wine by burrowing into the corks.



Figure 15. Adult and larva (bottom) of *Nemapogon granellus*

Morphology

The adult body has a wingspread of about 15mm. The fore wings are mottled with grayish white and dark brown spots. The hind wings are dark gray and fringed with long hairs. An adult has a yellowish white body 7mm long and a red-brown haired head.

Life cycle

Adults lay eggs in the gills of shiitake pileus. They overwinter as larvae that feed on stored shiitake. An infestation is often discovered when the full grown larvae leave their food source and crawl around to find locations appropriate for pupation. The pupae are often found on the gills of fruiting bodies. The adult moth appears in 2 generations annually. The larvae invade fruiting bodies.

Control measures

- ▷ Fumigate affected fruiting bodies with powdered gypsum or subject them to smoke or fumes in order to exterminate pests and disinfect the crop.
- ▷ Eliminate, cook, freeze or place in air-tight containers all potential sources of food for the moths and employ smoke or fumes in order to exterminate and disinfect the growing area.
- ▷ Heat-dry harvested fruiting bodies in a dryer at 50°C for storage and preserve them in sealed bags in a refrigerator.
- ▷ Set up poisonless moth traps.

Slugs

Fruiting bodies



Figure 16. *Philomycus confusa* eating gills of shiitake

Slugs and snails are among the most serious pests of shiitake cultivated on logs. They are a problem primarily in moist climates. The smaller slugs can build up to high levels before they are noticed. Slugs are widely spread all over the world and damage fruiting bodies by gnawing at them. Slugs inhabit a wide variety of garden plants, forest plants, and particularly cabbage plants. Slugs are found when the ground thaws in the spring until it freezes in the fall. Wet conditions are ideal for slug development.

Morphology

Slugs resemble snails without shells. They have two antennae on their heads and three dark-brown stripes. The bodies are brown, soft, slimy and about 6cm long.

Life cycle

Slug eggs are gelatinous, spherical, and filled with a watery substance. They range from 0.3-0.6cm in diameter. They are usually colorless, often reflecting the color of their surroundings. They become cloudy just before hatching. Eggs are laid in moist areas. Young slugs resemble adults in shape but are smaller and light colored. They become adults after about 5 months.

Control measures

- ↳ Remove them as they appear, usually after a rain-fall.
- ↳ Install filter-installed ventilation units at windows.
- ↳ Carefully and regularly watch log yards for early detection of slugs.
- ↳ Lure them away with vegetables like cabbage (decoying) and collect and destroy them.
- ↳ Eliminate their shelters.
- ↳ Sprinkle lime and wood ash around stacked logs, put a layer of gravel on the ground around the stacks, remove all dead leaves and other organic debris, and keep the soil surface dry.
- ↳ Spread gravel under the fruiting logs, keep vegetation low so that the ground stays dry, and use slug and snail bait.

Mammals**Fruiting bodies**

A wide range of wild and domestic animals including mice, squirrels, deer, rabbits, ducks, geese and pigs feed on shiitake. Some animals are known to be fond of shiitake or to store it as food for winter. In order to discourage them, farmers should identify their pests and then study their behavior and preferences in order to determine the best control strategy for the farm. Fences, barriers and repellants are commonly used.