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POWDER-POST BEETLES INFESTATION IN WOOD AND BAMBOO STRUCTURES

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INTRODUCTION

Wood and bamboo have been proven for centuries to provide a good service when used properly (Mbereyaho et al. 2019, Manandhar et al. 2019). Despite their scarcity, wood and bamboo are still widely used in construction. Both are highly sustainable building materials, as they are environmentally friendly, affordable, versatile and durable materials (Figure 1). Appropriate maintenance of these material's building structure requires an understanding of wood/bamboo defects and their related problems.

The two main categories of wood/bamboo defects are due to biological and non-biological deterioration. Biological deterioration is caused by fungi, termites, wood borers and marine borers (Reinprecht 2016). All of these pest agents in poor condition (exposure to fluctuating relative humidity levels), can easily damage wood even if preventive measures have been taken. Non-biological deterioration on the other hand is caused by environmental exposure which includes physical decay, excessive moisture content, dimensional instability and chemical deterioration. These deteriorations usually resulted to the loss of large amounts of raw materials or the destruction of finished wood and bamboo products. Large quantities of wood and bamboo are destroyed each year by insect borers, although the extent of the loss has yet to be assessed (CABI 2019). Infestation in storage yards starts with improperly dried, untreated wood and bamboo, and stockpiling with susceptible wood and immature bamboo stems.

Figure 1 Wooden and bamboo building structures (istockphoto.com)

At a time when the supply of wood is easily available and the price is relatively cheap, building/house owners are not so worried about the material (wood) used even though it rots faster and needs replacement. However, this situation has changed due to the high demand and insufficient supply of wood, which has resulted in consumers wanting as much durability as possible on every piece of wood used (Pandey 2022).

The susceptibility of various commercially important Malaysian timbers/bamboos to powder-post beetle attack over the two decades has been assessed and documented by researchers in Wood Entomology Laboratory, Forest Research Institute Malaysia (FRIM), through examination of wood sample collection and also from other field observations. Even in the pre-war years (world war 1), the powder-post beetle was recognized as a major threat to seasoned hardwoods (Menon 1957).

The majority of wood borer attacks are attributed to powder beetles, especially from the species of *Minthea* (*Minthea rugicollis* and *M. reticulata*) and *Heterobostrychus aequalis,* and *Dinoderus minutus* for wood and bamboo, respectively. In addition to these four main species, several other species such as bark borers (e.g. *Cossus chlorates*), pinhole borers (e.g. *Xyleborus perforans* and *Arixyleborus rugosipes*) and carpenter bee (*Xylocopa latipes*) can sometimes be detected in timber construction, although they are commonly found in forests or timber yards. The attack is due to the presence of starch and other carbohydrates (e.g. sucrose, glucose and fructoce). However, it also depends on the species and moisture content of the wood/bamboo. Powdery dust that comes out of wood or bamboo holes indicates a powder-post beetle's attack has occurred or is occurring.

The purpose of this article is to describe the important characteristics (biological properties, life cycle and damage done) of the common types of three species of wood and bamboo borers and suggesting treatments that can be used by users in a simple way. Should there be any doubt about the type of borer present, or the most suitable treatment for a particular set of conditions, further advice may be acquired from Forest Research Institute Malaysia (FRIM).

DESCRIPTION

Biology

a. *Minthea* spp.

Minthea spp. is sub-cosmopolitan in the tropics (Asia, East Africa and Northern Australia) (Abood et al. 1992), and it is very common in regions with high rainfall (Beeson & Bhatia 1973). It is also a dominant powder-post beetle in Malaysia, feeding on the sapwood of fallen trees species and capable of girdling trees in the forest. The beetles can be found in sawmills and timber yards. Due to these, *Minthea* spp. is known to be among the most significant enemy of seasoned hardwoods (Browne 1938).

The powder-post beetles (*Minthea* spp.) are small, narrow insects (Table 1). After mating, the female beetle looks for a suitable place to lay her eggs and continues to attack (bites) the wood for food. A series of grooves on the surface of the attacked wood are formed as a result of the feeding activity. These bite marks may indicate whether the wood contains starch (an essential larva dietary requirement), and make that holes (bite marks) in the wood for subsequent egg-laying. She inserts her ovipositor (egg laying) into the open pores of the sapwood. Each female may lay approximately 70 eggs, with a usual limit of 3 eggs per pore (Peters et al. 1996).

The eggs will hatch after about 14 days and the larvae feed on the starch in the sapwood until they are fully grown. The larvae caused the damage in the wood by making long, irregular tunnels (which normally follow the wood grain) and covering it with very fine, flour-like powder. The period of larval development varies from 2 to 12 months or longer (depending on the species) and it depends on temperature, humidity and starch availability in the sapwood (Peters et al. 1996, Thomas & Browne 1980). When the larva matures, it turns into a pupa and this pupa builds an oblong passageway the same width as the larval gallery, tightly packed with dust at its entrance (Browne 1938). *Minthe*a spp. has a much shorter (about 12 days) pupa stage. Newly formed adults chew holes through the wood surface, laying eggs for the next brood.

Table 1 Biology and life cycle of three important wood borers to wood and bamboo

Description	Species		
	Minthea spp.	*H. aequalis*	*D. minutus*
Biology	Body – brown, flattened, elongate insects and elytra covered with regular rows of yellowish hairs (Figure 1a). Size – 1.8 to 3.5 mm long. Larva – small (about 3.0 mm), white and 'C'-shaped. Pupae – not available. Others – A major pest of rubberwood in Malaysia.	Body – elongate, cylindrical, reddish brown to brownish black, moderately glossy, without dorsal pubescence (Figure 1b). Size – 6.0 to 15.0 mm (long) and 2.0 to 3.5 mm (wide). Larva – 15.0 mm long, white to yellowish. Pupae – Not available. Others - cylindrical insect with a rough hooded prothorax and usually curved hooks or projections at the hind ends of the strongly punctured elytra.	Body – cylindrical, reddish, blackish brown or dark-brown, elongate-columnar, covered with dense tiny punctures and hair (Figure 1c). Size – 2.5 to 4.0 mm (long). and 0.9 to 1.5 mm (wide). Larva – 3.0 to 4.0 mm long, milky-white and 'C'-shaped. Pupae – 2.5 to 4 mm (long). Others – the most important pest species of bamboo.
Life cycle	2 to 6 months depending on the starch, wood moisture content and temperature. Minimum period is about 2 months and 3 weeks, but can exceed more than 4 months. The average life span of adults is 2.5 months.	Variable from one to six years and confined to wood containing starch especially in sapwood.	Depends on surrounding temperature. In the tropics, breeding continues throughout the year. Can achieve six to seven life cycle in a year, but usually two to four.

b. *Heterobostrychus aequalis*

According to Browne (1950), *H. aequalis* is the most destructive Bostrychid powder-post beetle in Malaysia. Beeson (1941) reported that larger Bostrychid borers target wooden packing-cases, boxes, plywood chests and panels, sapwood in furniture and fittings of building. This borer is also a common pest in sawmills and wood-based industry factories. Booth et al. (1990) discovered that it is prevalent from South East Asia to the Solomon Islands, New Caledonia and can also be found in Madagascar.

The female beetle can lay eggs on the rough surfaces of sawn timber and logs from which the bark has been removed. It can penetrate into the natural crevices and holes of the woods to lay eggs. The eggs are deposited singly and will hatch in about a week. The larva emerge from the wood by gradually widening the tunnel [tunnel size can reach up to 37.5 cm (length) × 0.65 cm (diameter)]. In a crowded infestation, a tunnel is generally convoluted and intersecting the tunnels of other larvae (Table 1). It is tightly packed with moderately fine wood-dust. Most of the starch is digested especially those in dried sapwood. In dark coloured woods, the dust in the tunnel is often lighter in colour, which indicate the removal of starch during digestion. Pupation will take place in a wood cell at the end of the tunnel or in an offshoot. Immature beetles (the stage of development just before adulthood) will remain in the wood for variable periods (some take as little as 30 days while others may take up to two to one years to fully develop) before becoming adults. As the skin has hardened and darkened, it will emerge from an exit hole on the wood surface (Beeson 1941).

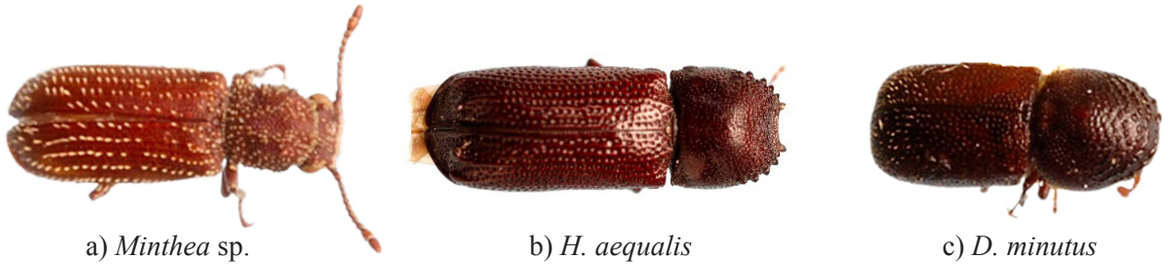
Menon (1957) reported that under favourable conditions, the beetles have a life cycle of 4 to 6 months, but according to Beeson (1941), the life cycle from egg to adult beetles requires a minimum time of one year. The longest period recorded is five years (in plywood) and six years (in opium chests of semul).

c. *Dinoderus minutus*

Dinoderus minutus is the most prominent powder-post beetle that attacks dry bamboo and other bamboo products mainly throughout the tropics (Abood 2008). In Asia, there are six species that have always received research attention because of the significant damage they have caused. These powder-post beetle can be spread through the trade of bamboo or bamboo products, whether domestic or imported (Dong & Wei 1997). It is reported that the attack is not related to the season but depends on the quality of the bamboo (Nair et al. 1983).

To lay eggs, adult beetles look for wounds, cracks and end cut of bamboo stems to make holes that eventually become tunnels. The tunnel will be made horizontally along the fibrovascular tissue of the bamboo stem. A female can lay about 20 eggs that hatch in 5 to 8 days. Given the longitudinal position of the larvae inside the bamboo stem, a tunnel (can reach up to 15 to 20 mm long) develops, making the bamboo stem more hollow (more damaged) as a result of this life cycle process (Table 1). The process of developing into pupae takes about 40 days. The new adult beetle will be developed 4 days later (Singh & Bhandhari 1988).

Dinoderus minutus, like *Minthea* spp. and *H. aequalis* (Figure 2)*,* is likely to attack bamboo due to its starch and sugar content as well as physical properties (*D. minutus* population increases when the relative humidity is low and vice versa). The attack is intense at high moisture content (60 to 130%) and more severe as moisture content decreases (15 to 30%). The life cycle of *D. minutus* recorded in previous studies varies; 98.28 days (Norhisham et al. 2015) and less than 2 months (https://pestweb.com/pests/767/bamboo-borer) due to variations in environmental conditions.



a) *Minthea* sp. b) *H. aequalis* c) *D. minutus*

Figure 2 The most significant powder post beetle species attacks wood and bamboo

Signs of infestation

Most wood borer damage is significant on sapwood. This matter is taken seriously by sawmillers and timber merchants. They are now making extensive effort to hinder the presence of borer-prone sapwood in the timber they sell.

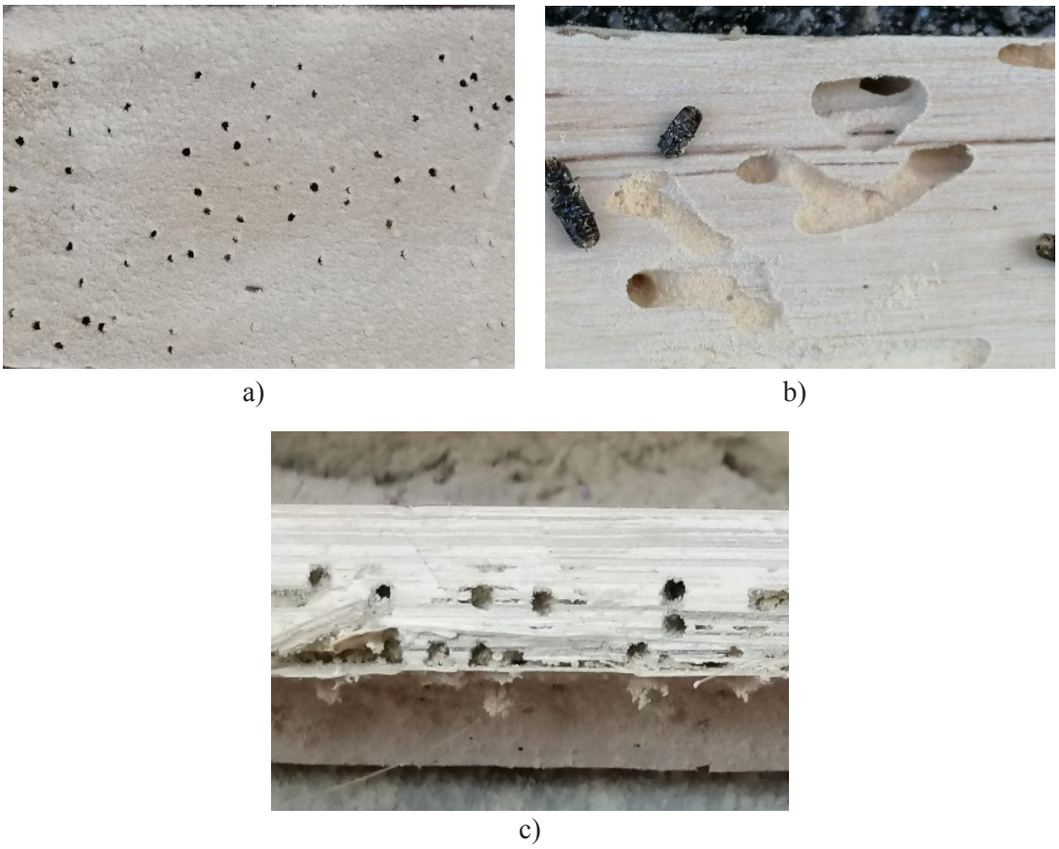
A few of the borers, which normally attack green timber, are able to expand their attack to dry wood. They are able to complete their life cycle in naturally dried timber and emerged. Infested wood may yield beetles for several years and continue until the food source depletes. Certain conditions for a powder-post beetle attack are required, such as the moisture content of the wood, which is maximum at around 15%; the size of the pores, which has to be larger than the diameter of the female ovipositor (1 mm for *Minthea* sp., 3 mm for *H. aequalis* and 1.5 mm for *D. minutus,* respectively), and starch content enough to nourish the larvae (Beesley 1956, Menon 1957).

The first sign of an infestation is observed when fine powder-like frass coming out from tiny round holes in the wood (Table 2). The presence of small, elongated black beetles on the wood surface is another indicator. In an extensive infestation, the entire wood is reduced to dust and

only a thin outer shell is left (Figures 3 and 4) (Ho & Hashim 1993). The key to avoiding serious problems with powder-post beetle is early detection and control.

Table 2 Indication and description of powder-post beetle's attack on wood/bamboo building structures

Factor	Description
Appearance of surface holes	Round holes 1/16" to 1/8" in diameter. Holes and margins unstained.
Direction of galleries	Along the grain then in all directions. In advanced stage of attack, infested wood may be reduced to powder.
Frass (borer dust)	Abundant, tightly packed, smooth and floury feel ejected through cracks, holes, etc.
Timber attack	Both sapwood and heartwood of susceptible timbers. May emerge through face veneers, lining materials and painted surfaces.
Effect of attack	In advanced stage, sapwood is powdered leaving a thin outer shell of wood.
Duration of attack	Attack may continue for several years. Usually partly or recently seasoned timber.



a) b)

c)

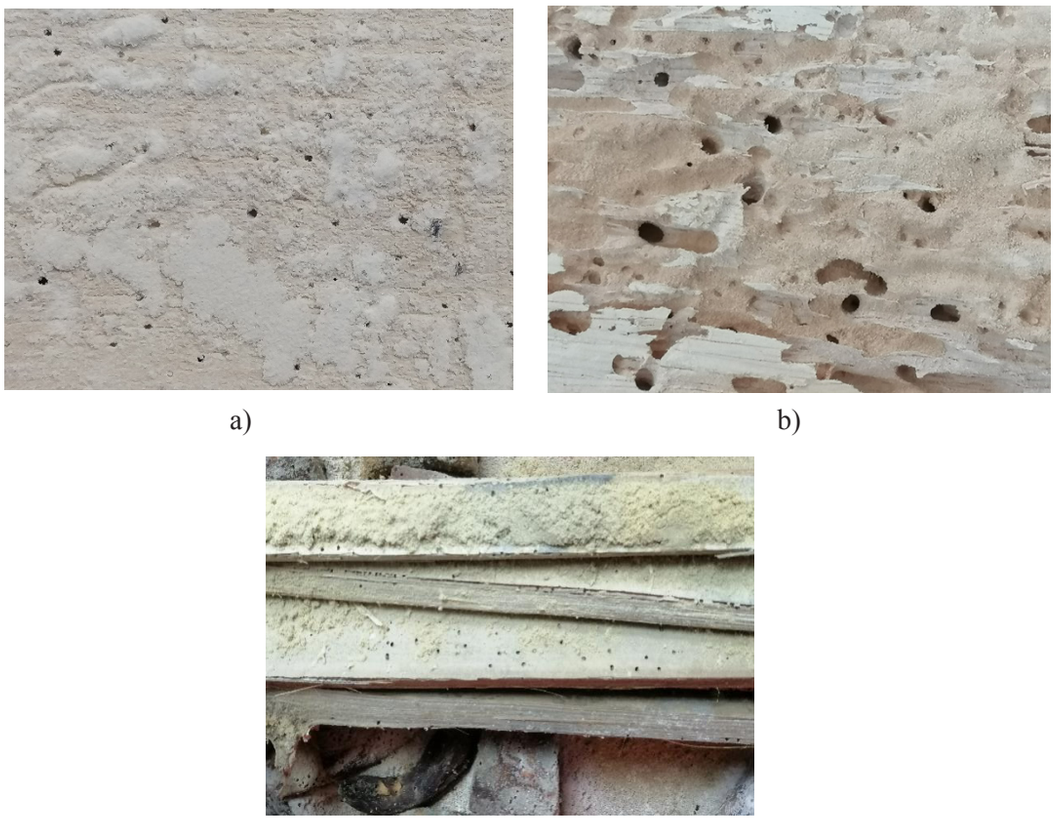
Figure 3 Exit holes and surface gallery of (a) *M. rugicollis,* (b) *H. aequalis* and (c) *D. minutus*

Economic species

Minthea rugicollis, M. reticulata, H. aequalis and *D.minutus* are the most destructive and commonly encountered species in Malaysia (Table 3). Other species include the small powder-post beetle such as *Xylothrips flavipes, Sinoxylon anale* and *Xylopsocus capucinus* (Ho 1998, Abood 1992, Browne 1948).

Table 3 Wood species susceptible to attacks by the three species of powder-post beetles

Powder-post beetle	Wood species	Reference
Minthea spp.	*Dyera costulata, Gonystylus* spp. *Hevea brasiliensis, Dillenia* spp.	Ho (1995)
H. aequalis	*Adina, Albizzia, Anisoptera, Anogeissus, Bambusa arundinacea, Bombax anceps, Boswellia, Canarium* sp., *Cassia fistula, Cedrela angustifolia, C. odorata, Dalbergia, Dendrocalamus strictus, Dipterocarpus tuberculatus, Endospermum* spp., *Koompassia malaccensis, Lagerstroemia calyculata, Mangifera, Parashorea stellata, Pterocarpus macrocarpus, Quercus, Shorea, Sterculia, Tectona, Terminalia Toona ciliata* and *T. sureni.*	Hutacharern and Tubtim (1995), https://entnemdept.ufl.edu/creatures/trees/oriental_wood_borer.htm#descr
D. minutus	*Bambusa arundinacea, B. bambos, B. polymorpha, B. textilis, B. pervariabilis, B. vulgaris, B. breviflora, Dendrocalamus giganteus, D. hamiltonii, D. strictus, Gigantochloa nigrociliata, Thyrsostachys oliveri, Phyllostachys pervariabilis, P. heteroclada, P. heterocycla* and *P. pubescens.*	Hutacharern and Tabtim (1995), Wang et al. (1998), https://www.plantwise.org/knowledgebank/datasheet/19035#HostPlantsSection



a) b)

c)

Figure 4 Heavy infestation by larvae of (a) *M. rugicollis*, (b) *H. aequalis* and (c) *D. minutus*

How to get rid of powder-post beetles

Beesley (1956) reported that wood borers from the group of powder-post beetles are generally a most serious pest than the ambrosia beetles. To maximise the use of wood, we have to eradicate this pest, which can only be done through control measures.

Any evidence of powder-post beetles infestation should not be ignored as the beetles can remain active long after the wood has been used (Terry 1999). There are five general options for powder-post beetles control. Selecting the best option depends on a number of factors, such as the severity of infestation, the location of infestation, potential for re-infestation and cost of treatment. Since the damage inflicted by powder-post beetle is slow, there is plenty of time to decide on control strategies (Koehler & Oi 2003).

Powder-post beetle's infestation control relates to type and beetles species. There are two control methods namely chemical and non-chemical treatments.

Chemical treatment

1. **Insecticide.** There are many insecticides on the market that can be used to control powder-post beetle's infestations. This includes copper chrome boron (CCB), ammonical copper arsenate (ACA), copper naphthenate, Bis-(N-cyclohexyl-diazeniumdioxide)-copper (Cu-HDO), cypermethrin and Bis-tri-butyltin oxide (TBTO).

2. **Wood finishes** such as paint, varnish or wax can prevent infestations of powder-post beetles that lay eggs on unfinished bare wood. Varnish can protect wood/bamboo from attack by adult beetles because these beetles could not penetrate the varnished surface due to the toxicity of the materials used, preventing adult beetles from laying eggs.

3. **Surface treatment.** The other option is to treat the surface of the treat bare wood. Spraying or brushing insecticides on the surface would create a barrier that can kill adult beetles as they consume the wood and killing newly hatched larvae as they attempt to bore into the wood.

4. **Fumigation.** The last option and the most effective method of controlling powder-post beetles is by fumigation. This is usually done in areas with severe infestations or in areas with infestations in some inaccessible places, or on high value items. This method will kill all stages of the powder-post beetle and will not leave any residues of chemical used in or on the wood. The disadvantage is that it is expensive, highly toxic to living things, including humans and only provide current protection (not for future attacks).

Non-chemical treatment

1. **Reduction of moisture content**. It is recommended that the moisture content of wood must be reduced to 12% because moisture content above 13% is an effective condition for larvae to survive. Make sure good ventilation is improved, no leaks and drainage problems in a building are corrected. However, this method may not be sufficient to control the powder-post beetle's infestation completely because wood/bamboo take a long time to dry out.

2. **Prevention.** Most beetle problems occur in wood/bamboo buildings or in manufactured wood/bamboo products (i.e. furniture, panelling or flooring). Serious infestations occur when infested wood/bamboo products are installed in the house. Prevention of infestation is through inspection and make sure infestation-free wood is used.

3. **Seal unfinished wood.** Unfinished wood should be sealed to prevent borers from attacking. Sealing can be done in several ways, either by wrapping the wood in thick plastic or painting with watered down white paint or seed's hemp oil.

4. **Temperature treatment.** Heat treatments (50−60^{o}C) for 6 hours or temperatures of -18^{o}C for 72 hours can kill all life stages of powder-post beetle in the wood. The duration for temperature treatment depends on the thickness of the infested wood/bamboo.

5. **Replace, remove or destroy** infested wood is a good measure if the infestation appears to be localised, especially when structural wood/bamboo is involved. Always check the emergence of holes around the infested wood/bamboo.

CONCLUSION

Wood and bamboo, being natural materials high in starch content, are susceptible to being attacked by powder beetles because starch is the primary food source for this group of insects. Confirming the presence of the beetles is a critical first step in moving on with control management. It is also critical to appropriately diagnose the problem in order to avoid wasting both resources and time. Proper control management can extend the life of these two building materials.

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Powder-post beetles are the pests of dry wood/bamboo either when these materials are in storage or applied to building structures. To date, the discussion on the resistance of materials and treatments against powder-post beetles has been very limited. Identifying and avoiding conditions that may lead to this deterioration is important to ensure proper (not attacked by any pest agents) wood/bamboo performance in the production of the final product. This article reviews the most common powder-post beetles of wood and bamboo structures in Malaysia. Three powder-post beetles species were discussed, including their general physical descriptions, possible damage, wood species susceptible to these pest agents and measures to eliminate them.

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