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Gypsy Moth Handbook

Diseases of the Gypsy Moth: How They Help to Regulate Populations

Diseases of the Gypsy Moth: How They Help to Regulate Populations

by J. D. Podgwaite[1]

In 1974 the U.S. Department of Agriculture initiated the Combined Forest Pest Research and Development Program, an interagency effort that concentrated on the Douglas-fir tussock moth in the West, on the southern pine beetle in the South, and on the gypsy moth in the Northeast. The work reported in this publication was funded in whole or in part by the program. This manual is one in a series on the gypsy moth.

In the Northeastern United States, the gypsy moth is subject to a variety of naturally occurring diseases of two types—infectious and noninfectious. Infectious diseases are the most easily recognized and are caused by several kinds of bacteria and fungi as well as a virus specific to the gypsy moth. In dense gypsy moth populations, infectious diseases are spread from one insect to the next by direct contact or through the air. The noninfectious diseases are not as easily recognized. They are not contagious but result from adverse physiological changes in the insect, generally in response to weather conditions, food quality, or hereditary factors.

Natural diseases do not appear to prevent gypsy moth populations from exploding to outbreak levels; parasites and predators are probably more important in this regard. However, after gypsy moth populations have reached outbreak levels and have caused significant defoliation and tree damage, it is disease, particularly infectious disease, that intervenes to reduce these populations to harmless levels.

In this booklet, some of the natural diseases of the gypsy moth are described as well as some of the disease agents that have been developed for controlling this pest.

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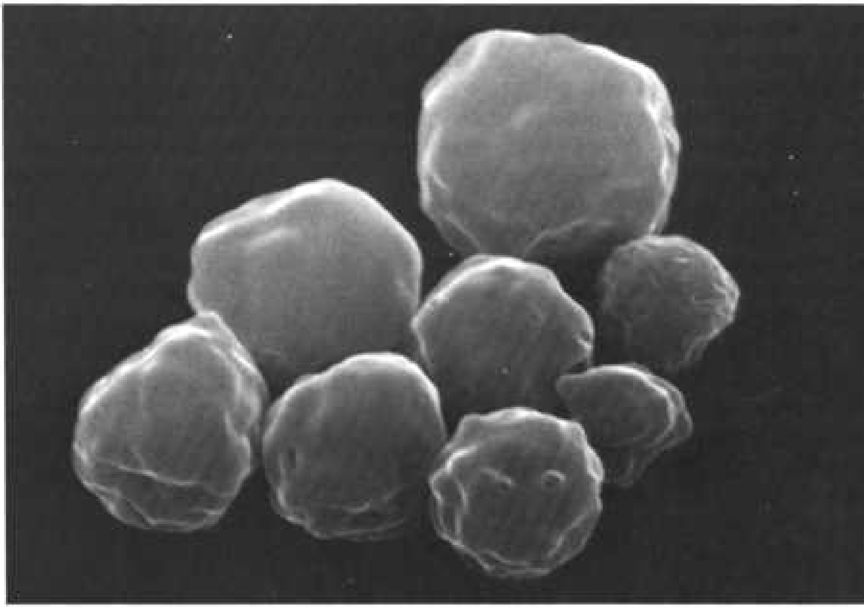
Infectious Diseases



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By far the most devastating disease of the gypsy moth is that caused by the specific nucleopolyhedrosis virus (NPV) that affects the larval and pupal stages of the insect. The disease results in the formation of virus-containing, polyhedral inclusion bodies (PIB's) in the nuclei of cells in the infected insect. The virus is so small that it is best seen with the aid of an electron microscope (figs. 1 and 2).

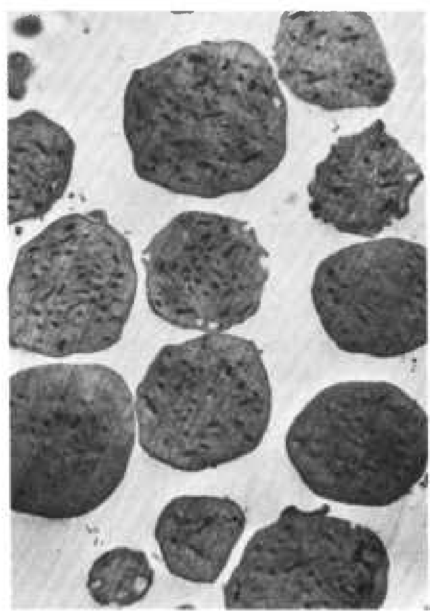

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Figure 1.—Polyhedral inclusion bodies (PIB's) of the gypsy moth nucleopolyhedrosis virus.

Figure 2.—Cross section through PIB's showing the infectious virus rods (virions) within.

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An insect becomes infected by eating foliage that has been contaminated with PIB's. In the gut of the insect, the PIB's dissolve and release the virus rods, which first cross the gut wall and then infect the hemocytes (blood cells). The disease progresses to the fat body and finally to cells of the integument. An infected larva will show signs of the disease by loss of appetite, listlessness, a darkening in color, a moist-appearing integument, and often a tendency to climb upward. Infected larvae usually die within 9–11 days and characteristically hang from foliage or bark in an inverted "V" position (fig. 3).

The dead insect is a sac of PIB's, and when this fragile sac is ruptured, its contents are spilled onto foliage and bark (fig. 4), providing a source of infection for healthy larvae.

In many dense gypsy moth populations, this virus kills up to 70 percent of the larvae and reduces populations to levels where they cause only minimal defoliation and tree damage in the following year. Because this virus is such an effective natural pathogen, it has been developed for use in gypsy moth management programs. The product is called Gypchek (fig. 5), a dry powder containing PIB's of the virus. It has been shown to be effective in reducing gypsy moth populations and is safe for man and wildlife. In April 1978, Gypchek was registered as a microbiological


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control agent with the Environmental Protection Agency (EPA), for use under the supervision of the Forest Service.

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Figure 3.—A typical NPV-killed gypsy moth larva.

Figure 4.—Ruptured NPV-killed gypsy moth larvae on leaves.

Figure 5.—Gypchek, an NPV product recently registered with EPA for gypsy moth control.

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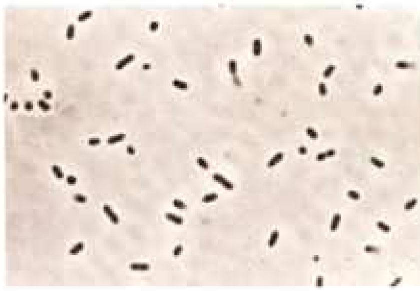

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Figure 6.—*Streptococcus faecalis,* a bacterial pathogen often causing small-scale epidemics in gypsy moth populations.

Figure 7.—*Serratia marcescens,* overall probably the most effective naturally occurring bacterial pathogen.

Figure 8.—*Serratia liquefaciens,* a bacterial pathogen but of lesser importance than *S. faecalis* or *S. Marcescens.*

Figure 9.—*Pseudomonas aeruginosa,* a common bacterial pathogen of man and the gypsy moth.

Figure 10.—*Bacillus cereus,* a common bacterium that is weakly pathogenic for gypsy moth larvae.

Infectious diseases caused by the bacterial pathogens *Streptococcus faecalis, Serratia marcescens, Serratia liquefaciens, Pseudomonas aeruginosa,* and *Bacillus cereus* are also important in gypsy moth regulation (figs. 6–10). Although the collective mortality caused by these bacteria in dense populations usually does not exceed 15 percent, there are at times pockets of bacterial disease that may account for up to 60 percent of the total mortality within a given area. These bacteria find their way onto foliage, either carried there by the wind or deposited in the droppings of birds and small animals, where they are consumed by larvae. Once in the larva's gut, the bacteria produce enzymes that allow penetration of the gut wall and the invasion of the hemocoel (body cavity). Unlike NPV which infects blood cells, these bacteria simply multiply in the fluid portion of the hemolymph (blood) and kill larvae either through the production of toxic substances or by depleting the insects of nutrients. Of these naturally occurring bacteria, *S. faecalis* and *S. marcescens* are probably the most effective in killing gypsy moth larvae (figs. 11 and 12). In fact, *S. faecalis* has been reported to cause small-scale epidemics in gypsy moth populations.

Unfortunately, most of the bacteria mentioned do not lend themselves to development as microbial control agents, because they are all very susceptible to deactivation by sunlight when exposed on leaf surfaces and some of them are related to bacteria that cause disease in man and other animals. In fact, *Pseudomonas aeruginosa* is a common pathogen of plants and man, and there would be some risk to nontarget animals if such bacteria were introduced into the environment.


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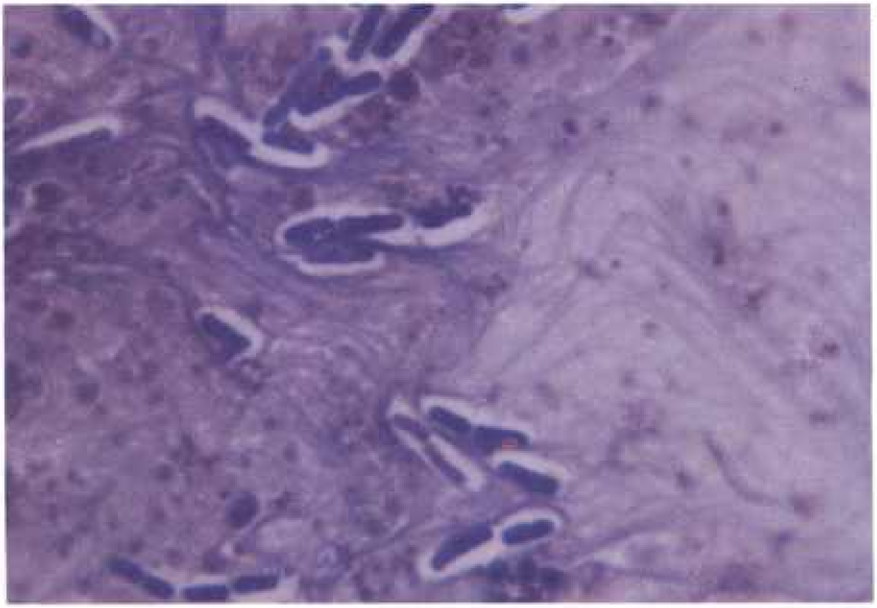
Figure 11.—A healthy (large) gypsy moth larva and one killed by *S. faecalis.*

Figure 12.—A larva killed by *S. marcescens.* Note the rose-colored underside.



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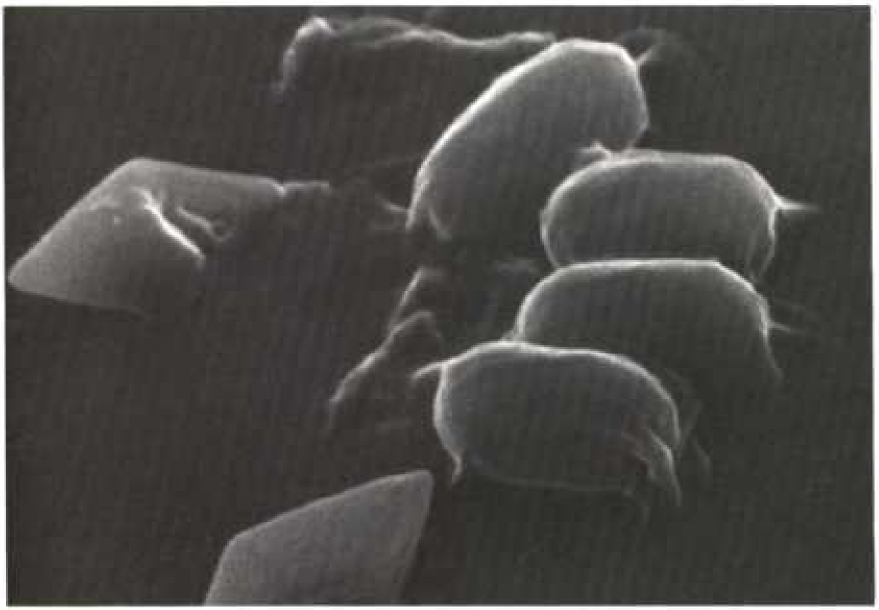

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Interestingly, one bacterial species that is relatively unimportant in natural regulation of the pest has been found to be effective as a microbial insecticide. This microorganism, *Bacillus thuringiensis* (*Bt*) (fig. 13), has been commercially available for several years and is effective against many insect pests, including the gypsy moth. Unlike some of the other bacteria, *Bt* is not harmful to man or wildlife. However, it is not as specific as the nucleopolyhedrosis virus and does affect certain other insects.

Bt kills only the larval stage of the gypsy moth, in a manner quite different from the other bacteria mentioned. *Bt* normally lives in the soil, and at a certain stage in its life cycle it produces a spore and a crystal (fig. 14). The spore is a protective stage that allows the bacterium to survive under harsh environmental conditions, while the crystal is believed to be a waste product of the cell. It is the crystal that is very toxic for gypsy moth larvae. Within a few days of ingesting a mixture of spores and crystals that have been sprayed on foliage, gypsy moth larvae cease feeding and die. The crystal, which is a large protein complex, breaks down into smaller toxic substances that cause paralysis of the larva's gut. The larva then cannot feed and soon dies of starvation (fig. 15).

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Figure 13.—A stained smear of a larva killed by *Bacillus thuringiensis*, showing the large, rodlike cells of this bacterium.

Figure 14.—A scanning electron micrograph of spores and the toxic diamond-shaped crystals of *Bacillus thuringiensis*.

Figure 15.—A gypsy moth larva killed by *Bacillus thuringiensis*.

The gypsy moth is also susceptible to at least three species of pathogenic fungi: *Beauvaria bassiana, Paecilomyces farinosus,* and *Aspergillus flavus* (figs. 16–18). The combined mortality caused by these three microorganisms is usually less than 1 percent in natural gypsy moth populations, but like the bacteria, they can at times cause significant mortality within a small area.

Spores of fungi are usually the infection units. They are airborn and often are trapped in the hairs on the surface of a gypsy moth larva. If temperature and humidity are right, the spore will germinate and with the help of enzymes penetrate the integument of the larva. Once in the hemocoel, the fungus grows to produce threadlike structures called mycelia. During growth, the fungus may produce toxins that cause death or it may simply multiply until it virtually fills the larva with mycelia. After death of the larva, the fungus may grow back through the integument to produce spores on the outside of the insect (fig. 19).

Unfortunately, environmental conditions that cannot be controlled (particularly humidity) are so critical to the initiation of fungal disease as to make these microorganisms difficult to use as microbial control agents. More importantly, many of the fungi produce toxins that affect man and other life forms, so their use in pest management programs could present some risk that probably would not be offset by their effectiveness.

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Figure 16.—Colonies of the fungus *Beaavaria bassiana.*

Figure 17.—The fungus *Paecilomyces farinosas.*

Figure 18.—A giant colony of *Aspergillus flavus.*

Figure 19.—A gypsy moth larva killed by *Beaavaria bassiana.*

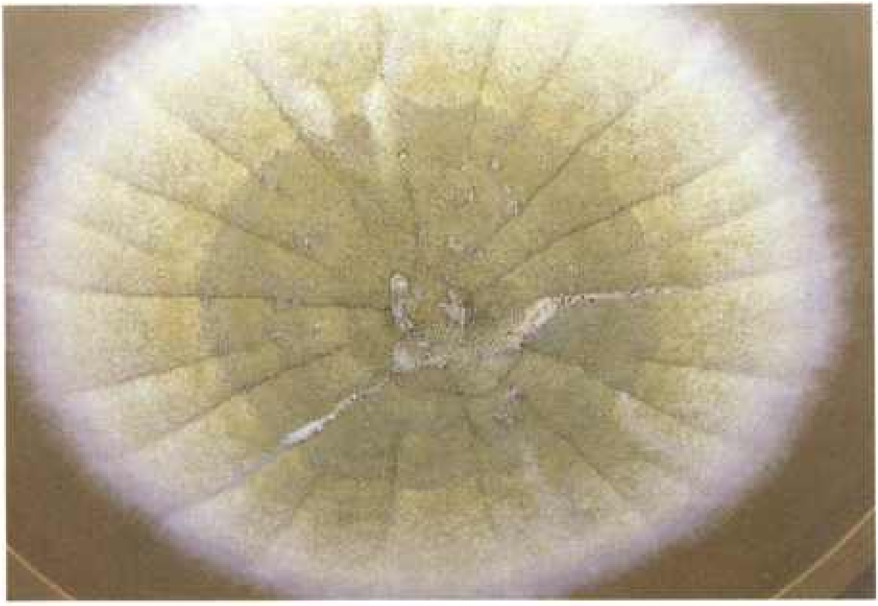

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Figure 20.—Healthy (left) and starved fourth-stage gypsy moth larvae.

After gypsy moth NPV, the noninfectious diseases account for the bulk of the gypsy moth mortality (35 percent on the average) in dense populations of the insect. Unfortunately, very little is known about these diseases, principally because little is known about the genetics and normal physiology of the gypsy moth. These two areas of study have not been developed to the point where baseline information on healthy insects is available for comparison to insects that are diseased. Therefore abnormal physiological conditions are very difficult to diagnose and identify accurately.

Most noninfectious diseases of the gypsy moth are undoubtedly related to weather factors, nutritional factors, or heredity.

Unseasonably cold or warm temperatures in the winter or spring may result in gypsy moth eggs hatching either at a time when the weather is not favorable for the development and survival of the larvae or at a time that puts larvae out of phase with the development of their food source. This often results in larvae dying on the egg mass.

Poor nutrition is probably responsible for most of the noninfectious disease seen in natural gypsy moth populations. Insects that are severely limited in food supply simply starve (fig. 20). Larvae that feed on low-quality foliage or on nonpreferred hosts may die during the molting period or, if they survive, become subpar pupae and adults.

Genetics undoubtedly plays a role in noninfectious disease occurrence. It is known that larvae develop tumors (fig. 21) and teratologies, although these are rare. There are probably many genetic-related diseases of this insect that have yet to be discovered.

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Figure 21.—Gypsy moth larva showing a tumor in the thoracic region behind the head.

How to Recognize Gypsy Moth Diseases

Careful observation of disease in gypsy moth populations may indicate how much of a problem the insect will be in future years. This knowledge can help in the planning of control measures to use against this pest.

Probably the gypsy moth disease that is most easily recognized in the field is nucleopolyhedrosis. As mentioned earlier, and seen in figure 3, dead insects characteristically hang in an inverted "V" position from bark and leaves. Dead larvae are moist looking and dark in color and may ooze a brownish ill-smelling fluid that stains leaves and bark. The widespread occurrence of virus-killed larvae indicates that the population is in decline and that in the next generation there will be fewer insects, and less defoliation, to contend with.

Bacterial disease symptoms are variable; discoloration of the integument, cessation of feeding, paralysis, vomiting, diarrhea, and larval shortening are common symptoms. Larvae infected with *Serratia marcescens* show a characteristic rose coloration on the underside of their bodies (fig. 12). Bacterially killed larvae are found more often on the ground than on trees.

Larvae afflicited with fungal disease often display restless behavior and may become spastic in their movements. They may choose to settle on the undersides of leaves. Living or dead larvae may be covered with mycelia (fig. 19).

Noninfectious diseases are the most difficult to recognize, because their symptoms at times resemble those of infectious disease, particularly bacterial diseases. For instance, larval shortening is a common symptom of both starvation and the disease caused by *Streptococcus faecalis*. Without some laboratory tests, it is difficult to know what is being dealt with. However, in a situation where a number of dead, shortened larvae are found in the midst of complete defoliation, starvation can be suspected. On the other hand, if there is obviously enough food available for the insects, suspect bacterial disease. If a number of dead, first-stage larvae are present on the egg mass, physiological disease related to weather or hereditary factors is probably the cause. If this condition is widespread, it could very well be an indication that the gypsy moth population is not healthy and may be in a decline phase.

In closing this discussion, it must be remembered that infectious and noninfectious diseases are not the only gypsy moth killers. There are a number of parasitic insects as well as some small mammals that kill gypsy moth larvae and pupae. The collective action of all of these mortality agents—disease, parasites, and predators—is what controls the gypsy moth life system. When it is better understood how these factors operate in natural gypsy moth populations, it will be easier to deal with this pest and minimize its harmful effects.

Acknowledgments

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