SCIENTISTS FIGHT GYPSY MOTH SPREAD WITH INTENSIFIED ATTACK

By John Kerr, Associate Editor

"It is hard to describe if you haven't seen it," says Bill Rae, an arborist in the Boston Area. It defoliated 5.1 million acres of urban and rural forest in 1980. It will likely eat much more foliage in 1981 as it spreads south and west.

The gypsy moth, *Lymantria dispar*, the nation's number one shade tree insect, persists and thrives in the heavily infested Northeast. Scientists, diversifying their attack on the hungry insect, have stepped up their efforts as it multiplies. Arborists have attempted to use scientific research to counter one of the most challenging problems they have faced. Homeowners, in a state of entomophobia, are locking their windows and shuddering as caterpillars drop like hailstones on their rooftops.

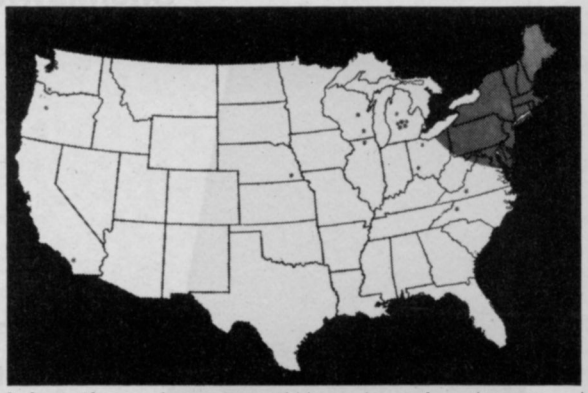
Rae has had to refuse orders since March. Other arborists are inundated with calls. "People will do anything to get rid of them," Rae says. "Even people who don't believe in spraying are now doing it."

Although professional arborists and the U.S. Forest Service have become extremely cautious from environmental pressures, the problem has become so severe that it has solidified forces against the insect. Since the beginning of this century, millions of dollars have been spent in efforts to control gypsy moth populations.

Early outbreaks occurred only in New England; today the insect threatens nearly half the states in the U.S. Excitement has reached a pitch because the gypsy moth, unlike agricultural pests that consumers seldom see, directly affects homeowners, campers, and nature lovers.

Traditionally, management of such a pest has been accomplished through pesticides. At a minimum of $5 an acre, the cost of spraying millions of acres questions its practicality. Charles Schwalbe, director of the Otis methods development center with the Animal and Plant Health Inspection Service (APHIS), thinks both cost and a feeling of helplessness contribute to negative reactions toward spraying. Schwalbe says, "I think that more people are beginning to feel that when the gypsy moth reaches these peak populations, the best action is inaction—let nature take its course."

More than cost and fear though, researchers and field applicators believe that pesticides can not do the complete job. A management approach integrating pesticides with biological agents and natural elements and predators pervades the minds of the leaders in the scientific and industrial communities. Integrated pest management (IPM) has become not only a popular concept, but a necessity.



Infestations of gypsy moth have been found scattered throughout the United States.

Man's role

More than any other insect problem, gypsy moth thrives under man's domain. Defoliation often occurs in populated areas, especially where homes and developments are located in previously forested land. Spruce budworm is an extremely bad problem in the northern U.S. and Canada; the Douglas fir tussock moth, found mainly in the western U.S., infests thousands of forest land acreage. But these two insects attack contiguous stands of conifers, mainly overmature trees.

The gypsy moth feeds on many types of trees, although it prefers oaks, and has a tremendous capacity to adapt to different regions. It has been found in Japan, China, Australia, and Europe. In the past year, infestations in the United States have been discovered in Washington, Oregon, California, Nebraska, Minnesota, Wisconsin, Indiana, Illinois, Michigan, Ohio, West Virginia, Virginia, and North Carolina. This spread southward and westward happens because of man's activities.

Campers, firewood, nursery stock, and anything else that moves or is moved from parts of the Northeast may contain gypsy moth. The federal government is trying to regulate this movement, but it is not an easy task. The state of Virginia inspects thousands of vehicles every summer. Officials try to inform Christmas tree growers and nurserymen that if their area becomes infested, it must be kept under quarantine.

All nursery stock in the Northeast is being closely watched for infestations of gypsy moth. APHIS monitors the stock being shipped and if any of it is infested, the owner is required to use some type of control program.

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The Minnesota Department of Agriculture last year prohibited importing trees supplied by three Connecticut nurseries after MDA officials confirmed that at least three shipments were heavily infested with gypsy moth egg masses. The prohibition remains until state and federal officials can certify their stock as disease and pest free. The Department's Division of Plant Industry has sent questionnaires to nurserymen and persons involved in government tree planting programs asking for the sources of tree stock planted in 1979 and 1980.

APHIS has used 75,000 to 100,000 traps a year to monitor gypsy moth populations in the Northeast. Campers and hikers have cooperated distributing the traps and picking them up at the end of the year. These programs have become particularly important to the states where populations have not reached outbreak proportions. Low levels of gypsy moth once detected can be localized and often eradicated. Homeowners can be warned to clean up yards, fences, and treehouses where the gypsy moth likes to rest during the day.

Egg mass hatching in the early spring shows the buff-colored larvae, which have rencently emerged, and the darker, older larvae.

At extremely high densities, (right) the gypsy moth caterpillars apparently do not use resting places at all until they are ready to pupate. Rather, they remain on the foliage, feeding continuously both day and night.

The professional arborist

Active pursuit by the National Arborist Association of a healthy and profitable IPM program is encouraging members and associates to expand their thinking. The high visibility of the industry to the public helps emphasize the importance of good planning and cultural practices. Much of these practices—monitoring, inspections, horticultural spray oils, *Bacillus thuringiensis (Bt)*, the use of parasites, predators, and resistant hosts—work in an attack against the gypsy moth. Many of these techniques, still in their infancy stages, must be refined and presented to the homeowners in an educated manner.

"Nothing is a complete, total panacea," says William Wallner, Forest Service project leader for the ecology and management of northeastern forest insect pests. "We must recognize all the alternatives. To expect a singular management approach to permanently solve such a complex problem as gypsy moth is naive."

The gypsy moth, because of its visibility, could not only promote IPM, but could help the arborist attain a position of extreme value. "It is a great opportunity for the professional arborist to assert himself in the public eye," says Erik Haupt, president of The Haupt Tree Co. in southwestern Massachusetts. High sell manufacturers will be advertising quick solutions to the problem. "They will be like the old medicine men," says Haupt, "selling a product if people need it."

Arborists agree that timing is a vital factor against the gypsy moth. Careful attention is being paid to egg mass hatching and proper time for treatment. This lets the arborist obtain maximum control with minimum treatment.

Haupt says some of his clients insist on biological control no matter how much he explains its limited effectiveness. This fact is another lesson to the arborist: you have to provide what the customer wants. Whether he's a property owner, golf course operator, or park superintendent, the customer desires and demands according to his own needs and wants. These desires are basis enough for an IPM program against the gypsy moth.

Since trees become more susceptible to disease and insect damage when they are weak, the arborist must keep them as healthy as possible before infestation occurs. Trees stressed with too little or too much water, frosts, leaf diseases, or herbicides are likely to suffer more drastically from gypsy moth defoliation than healthy, nonstressed trees. Unfortunately, even healthy trees can suffer from defoliation if enough of their leaves are removed in successive years.

The U.S. Department of Agriculture

Three USDA agencies—the Animal and Plant Health Inspection Service, Science and Education Administration (SEA), and Forest Service—coordinate federal-state efforts in regulatory, survey, control and eradication, research and development, and information and education programs.

APHIS, through its Plant Protection and Quarantine Programs, and state agencies from Maine to Maryland enforce regulations to prevent spread of the gypsy moth caused by people. In their regulatory work, APHIS and the states work closely with SEA, the Forest Service, and the Interior and Defense Departments. They also keep contact with such industrial organizations as the American Association of Nurserymen, Association of American Railroads, American Trucking Association, moving companies, airlines, the pulp and paper industry, the National Campers' and Hikers' Association, and other outdoor and travel groups.

Along with their work distributing thousands of traps, APHIS and the states conduct aerial surveys. These help identify the location and severity of defoliation and help predict where next year's damage will occur.

Control programs are designed to protect high-value recreation areas, forested communities, and timber resources from serious damage and spare homeowners the nuisance of crawling caterpillars in heavily infested areas. The Forest Service initiates control programs on federally-owned lands. On state and private lands, the Forest Service may participate but only at a state's request. Cost-benefit and biological evaluations must first be made and environmental effects of alternatives carefully considered.

Pheromones

The main method APHIS uses for trapping and monitoring the gypsy moth is sex pheromones. Pheromone traps have shown better success in low level infestations than in higher populations, where taking egg mass surveys can provide a better gauge. Spraying the gypsy moth pheromone, disparlure, into infested areas confuses the males who are seeking to mate with the non-flying females.

Excitement over the use of pheromones to control the gypsy moth problem has diminished in recent years. A leader in the research, Penn State University's Alan Cameron, has dropped his efforts after 10 years of study. "It is useful and valuable as bait for detection," Cameron says. "I'm satisfied we can't use it to reduce population in heavily infested areas." He bases his results on applications which are made to prevent mating after the damage has been done in a summer. If the application is effective, it would show lower populations the following year. This has not been proven.

Disparlure has been combined with biological agents, viruses, parasites, and chemicals and the gypsy moth has been eradicated. "I would not claim that the disparlure was responsible," says Cameron. "I also can't say it was not a part of the elimination."

Cameron thinks pheromones can be very useful as monitor tools, particularly in fruit orchards, to help get away from the calendar approach to spraying. In agriculture also, where a high dollar crop produces immediate returns on a spraying investment, an effective pheromone program could justify its cost.

The complexity of the gypsy moth's mating process leads Cameron to believe that other factors, such as visual and tactile senses, are involved. "There are too many factors to manipulate the population," he says. Even reducing the mating success 30 to 60 percent may not help when one egg mass may produce up to 1,100 eggs. "Their reproductive capacity is very high, particularly with new invading populations."

Cameron believes he knows disparlure's limitations. "The research was good in advancing the science, but frustrating because we are not much farther ahead than ten years ago."

Other ways of monitoring

When the gypsy moth hits its late third and early fourth instars (the male has five instars, the female six), it becomes active from its original

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resting spot underneath a leaf's surface. It begins to migrate from the foliage it feeds upon at night to resting locations on the tree's trunk or on signs, treehouses, stone walls, and other ground sites during the day. In the evening, it moves back up the tree.

Bark flaps of burlap or other materials wrapped on a tree trunk make a suitable resting spot and thus a trap for the gypsy moth. Here they can be collected and either killed or monitored. Research on the use of bark flaps for estimating populations, determining larval behavior, and aiding biological controls is being investigated by Wallner of the Forest Service in Connecticut.

Chemicals

Scientists now agree, as do most arborists, that pesticides are only a piece of the puzzle for total gypsy moth control. However, spraying insecticides is still the most thorough method of control and they cannot be ignored at this time to treat the gypsy moth.

If a trapping program in Virginia shows an isolated infestation, the Forest Service uses an intense spray program to wipe it out. According to John Weidhaas, extension specialist in entomology at Virginia Tech, the Forest Service will use Dimilin, an insect growth regulator, because it is highly specific to caterpillars. It is not approved for populated areas. Spraying occurs in the second or third week of May. Hitting the gypsy moth in its early instars is vital for any chemical to give maximum effectiveness. The application of Dimilin has been cut in half under acceptable weather conditions and then sprayed a second time in June.

Many chemicals are available, often limited by state regulations and to licensed applicators. The following chemical insecticides are registered: carbaryl (Sevin), trichlorfon (Dylox), acephate (Orthene), Imidan (a phosphate-type insecticide), Bidrin (a toxic insecticide used by injection), Malathion, and Methoxychlor. Diflubenzuron, (Dimilin), which prevents the gypsy moth from molting, is only registered for forest treatment.

At the Otis methods development center, where Charles Schwalbe directs the research, insecticide screening is a large project. The center screens biological and chemical compounds from industry to determine their toxicity to the gypsy moth.

Schwalbe describes the work like this: "We take registered insecticides and try to define their use patterns. We use the minimum efficient dose to receive the desired control. We improve formulations so they work better, concentrating on microbial insecticides. When you spray one, it doesn't last long; ultraviolet light breaks it down and rain washes it off. This is the main reason for erratic results."

Until recently, Schwalbe says, there has not been the concern of these two factors affecting insecticide residual. Research information has made manufacturers more willing to accept the results. The Otis laboratory has made significant progress with stickers to counter the wash effect

Gypsy Moth Food Plant Preferences

Most Preferred	Intermediate		Least Preferred
OAK	MAPLE	SOURWOOD	ASH
HAWTHORN	BUCKEYE	PINE	HOLLY
PAPER BIRCH	HICKORY	COTTONWOOD	MULBERRY
GRAY BIRCH	RED BUD	CHERRY	YELLOW POPLAR
APPLE	HACKBERRY	HEMLOCK	SYCAMORE
SWEETGUM	DOGWOOD	ELM	LOCUST
TAMARACK	PERSIMMON	SERVICEBERRY	FIR
ASPEN	BEECH	BLACK WALNUT	SPRUCE
WILLOW	MAGNOLIA	SASSAFRASS	RHODODENDRON
BASSWOOD	TUPELO	WITCHHAZEL	MOUNTAIN LAUREL

of rain. Ultraviolet penetration is a tougher problem.

Sterilized males

Another project Schwalbe's team deals with is rearing large quantities of sterile male gypsy moths. Cobalt 60 gamma radiation is used. It is important to get the right amount of radiation at the right development of the gypsy moth.

This research is now in its fourth year and is still preliminary. Last year, the first field tests were done in Michigan and they will be continued there this year. Schwalbe expects that the tests at low level populations will show how well the sterilized males mate and how they move in the field.

FEEDING RESPONSE OF 3rd INSTAR GYPSY MOTH LARVAE TO FOLIAR EXTRACTS OF VARIOUS PLANTS FROM NORTH AMERICA

STIMULANT	NEUTRAL	DETERRENT
DOUGLAS FIR	OLIVE	VIBURNUM
HONEY LOCUST	ROYAL PALM	GUMBO LIMBO
COTONEASTER	ELDER	MANGROVE
FORSYTHIA	SEA GRAPE	EUCALYPTUS
GINKGO	PAW PAW	ANDROMEDA
GIANT SEQUOIA	RASPBERRY	CAMELLIA
DEODOR CEDAR	BALD CYPRESS	LIME
THOMPSON SEEDLESS GRAPE	EUONYMUS	CAJUPUT TREE
CRAPEMYRTLE	WAX MYRTLE	PISTACIO
ALMOND	BLUEBERRY	CALIFORNIA LAUREL

Biological agents

Two entomologists, William Yendol from Penn State and Frank Lewis, principle insect pathologist at the Northeastern Forest Experiment Station, gathered sufficient data from studies to help get *Bacillus thuringiensis (Bt)* registered with the Environmental Protection Agency. After this success, they did the necessary research to register a gypsy moth virus, nucleopolyhedrosis (NPV), named Gypchek. "We did research and development of these microbials for control and utilization in IPM programs for gypsy moth management," says Lewis.

Bacillus thuringiensis, a spore-forming bacteria, comes in many strains, one of which is registered and produced under the names Dipel, Thuricide, and Bug Time. It kills the gypsy moth in its larval stage. When the insect eats the mixture of spores and crystals, the larva's gut is paralyzed. Ultimately, the insect starves to death or the bacteria grows and kills the insect by septicemia, or multiplication of the bacteria in the blood.

"We have mainly tried it (*Bt*) by itself," says Lewis. "We need much more work integrating these things, trying to substitute microbials for pesticides. We present it as an option. *Bt* works better when applied from the ground than the air."

The most devastating disease of the gypsy moth is that caused by the specific nucleopolyhedrosis that affects the larval stages of the insect. It is entirely specific to the gypsy moth. Like *Bt*, NPV is slow acting and harmless to the environment.

An insect becomes infected by eating foliage that has been contaminated with virus-containing polyhedral inclusion bodies (PIB's). The PIB's dissolve in the gut of the insect and release virus rods which first cross the gut wall and then infect blood cells. The disease progresses to the fat body and finally to cells of the integument (outer skin). 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 larva usually die within 9 to 11 days and hang from foliage of bark in an inverted "V" position.

Dr. Yendol says present research is dealing with different forms of Gypchek and its mode of action. This year it will be studied in an attempt to improve the application technology, including aerial application rates, dosages, and its most effective ways to treat egg masses. Work focuses on incorporating the virus into pest management with pheromones, parasites, and insecticides.

Infectious diseases caused by bacterial pathogens are also important in gypsy moth regulation. 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.

Parasites

Another program to halt the rampage of gypsy moth is occurring in New Jersey under APHIS control. William Metterhouse is running the program which involves field evaluation and monitoring of gypsy moth parasites. Started in 1963, the field and laboratory studies have helped to introduce seven parasites and one predacious beetle into the population in New Jersey and New England.

Several species of small wasps attack the various life stages of the gypsy moth. One of the

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most common species, *Ooencyrtus kuwanai*, is an egg parasite that can attack 30 percent of an egg mass and up to 90 percent of a small egg mass. *Apanteles melanoscelus* and *Phobocanpe disparis* wasps attack the larval stages. Another wasp, *Brachymeria intermedia*, stings the gypsy moth pupae but is most effective when gypsy moth populations are at defoliating levels.

Several fly parasites infect the gypsy moth. The most promising, according to Metterhouse, is *Parasetigena silvestris*. *Compsilura concinnata* attacks insects on more than 200 of their hosts. *Blepharipa pratensis*, another fly, lays its eggs on leaves and the gypsy moth caterpillar eats the eggs when it eats the leaves. A predacious ground beetle, *Calosona sycophanta*, which was imported from Europe, attacks both the larvae and adult gypsy moth.

"Parasites provide another regulating factor," says Metterhouse."The augmentation of parasites on low gypsy moth populations has become more important. More research is ongoing and all parts of the USDA are cooperating. An example of the cooperation between APHIS-SEH-Forest Service is the evaluation of parasites for vectoring microbial diseases to increase effectiveness of natural controls.

Predators

The gypsy moth's parasites are usually smaller than the host they attack and develop with a single individual. Predators usually are larger than their prey and consume many host insects during the course of their life. They are very active, live longer, and may prey upon a variety of insects, depending on what is available.

According to Harvey Smith with the Department of Agriculture's Northeast Forest Experiment Station in Hamden, Connecticut, the importance of predators has probably been underestimated because they consume their prey quickly and leave few if any remains. Woodland mammals can consume large numbers of gypsy moth larvae and pupae in forested areas. Some mammals eat only one life stage of gypsy moth, while others may eat as many as three.

Some mammalian predators of the gypsy moth include the white-footed mouse, shrews, chipmunks, moles, and squirrels. Shrews, which are often mistaken for mice, are voracious insect feeders that consume their weight in prey each day. Unfortuantely, mice and shrews are probably not important as predators in suburban settings because they are eliminated by domestic animals such as the common cat and because their natural habitat, forest litter, is frequently destroyed.

Many species of birds have been observed feeding on gypsy moth larvae or adults. Nuthatches, chickadees, towhees, vireos, northern orioles, catbirds, robins, and blue jays are proba-

bly more important in sparse gypsy moth populations. Cuckoos and flocking species such as starlings, grackles, red-winged blackbirds, and crows may be attracted to areas where the gypsy moth exists in large numbers.

Other factors

Numerous factors, often difficult to measure, contribute to the control and spread of gypsy moth. Ripe temperatures can trigger heavy infestations of the gypsy moth. An early thaw proceeded by severe freezing could reduce populations. Unfortunately for residents of the Northeast and surrounding areas, conditions appear healthy for the gypsy moth in 1981 and preliminary studies show this year may be the highest population ever.

Awareness of all facets of the gypsy moth—its life cycle, habits, and controlling agents—can make a major difference in a preventative rather than protective program. According to Dr. Cameron, "As the insect moves down through the south and west and the initial defense is beyond us, we seem to get into the situation in which we hope it doesn't get too bad. Then populations build up and we try to protect the areas threatened. It becomes a reactive program that develops over the years rather than a true management program with emphasis on prevention."

"How long it remains, no one is certain," says Dr. Lewis. "It is a cyclical insect in Europe; it subsides and reappears in Europe every seven to eight years. These cycles appear to be climate related." Barring dramatic changes in the climate, Lewis expects the insect to be at least as serious a problem in 1982.

"It will probably take more resources than we have now," Lewis says. "All our tools and tactics are being researched to collectively and selectively use for control. Our past experience of a single control has not solved the problem. Hopefully, we will have a longer term management."

Nobody is deluding himself with optimistic predictions. Dr. Cameron says, "We are a long way from broadly managing the gypsy moth in the U.S. This is part of the challenge and part of the work."

Dr. Schwalbe says, "The gypsy moth is a tremendously cosmopolitan insect. It occurs under such a variety of situations that there is just no way that within the extremely near future we will have the means to control it."

If anything positive has arisen from this devastating insect, it could be that government and industry are working together to solve the problem. The concept and activity of pest management has come alive and may soon be a household word. The gypsy moth could be the rallying force that makes IPM work. **WTT**