



United States
Department of
Agriculture

Forest Service

Northeastern
Station

General
Technical
Report NE-85

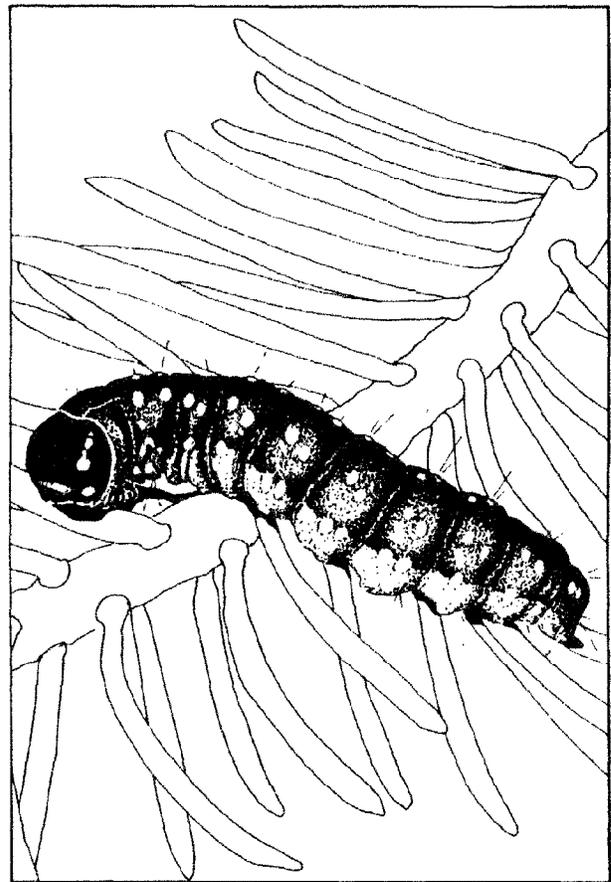
1983



canusa

Proceedings

Forest Defoliator - Host Interactions: A Comparison between Gypsy Moth and Spruce Budworms



FOREWORD

The Canada/U.S. Spruce Budworms Program in cooperation with the Center for Biological Control of Northeastern Forest Insects and Diseases of the Northeastern Forest Experiment Station co-sponsored this Forest Defoliator-Host Interaction Workshop. This invitational workshop was limited to investigators of the spruce budworms and gypsy moth in the Forest Service, Canadian Forestry Service, and the University sector. The primary purpose of this workshop was to foster communication between researchers having a mutual interest and active research projects designed to understand the relationships between the host plant and forest defoliator feeding behavior, growth, and reproduction.

This Workshop was a follow-up to two previous meetings on host-insect interaction. In 1980, Dr. W. Mattson hosted a CANUSA-sponsored meeting at the North Central Forest Experiment Station, St. Paul, MN. This informal gathering brought together CANUSA Program investigators from the US and Canada for the purpose of sharing preliminary information and data on host-insect interactions. The second meeting took place in the fall of 1982. CANUSA(E) sponsored a Symposium on Spruce Budworm-Host Interaction at the Eastern Branch Meeting of the Entomological Society of America, Hartford, CT. The current Workshop developed from this Symposium. We found that participants were raising question concerning the similarity or differences between the spruce budworm and gypsy moth host interaction systems.

These Proceedings resulted from a three-day Workshop held in April 1983 at the Park Plaza Hotel, New Haven, CT. The structure of the Workshop allowed each participant a period for a presentation followed by lengthy discussion. These discussions were lively, friendly technical exchanges clarifying or elaborating on points raised by the speaker. Frequently, these exchanges were thought-provoking and often provided avenues for further detailed discussions and in some cases, future cooperative efforts.

The papers that make up these Proceedings were submitted at the Workshop as camera-ready copy. As a result, the participants did not have the benefit of reappraising their work in light of the discussions that followed their presentations or other ideas that developed at the Workshop.

Since the Workshop was planned late in the life of the CANUSA Program, we asked each investigator to be especially aware of the implications of these interactions on population dynamics of the insect in relation to forest management potential. When possible, we also asked that future research needs and direction be mentioned.

As technical coordinators for this Proceedings, it was our task to arrange and more effectively focus material so that papers provide a smooth transition of ideas and research

activities on insect-host interactions for the spruce budworms and gypsy moth.

Lastly, we would like to acknowledge the support and confidence expressed by the following:

Denver P. Burns, Director, Northeastern Forest Experiment Station

Melvin E. McKnight, Program Leader, CANUSA

William E. Wallner, Director's Representative, Hamden, CT

August 1983 Robert L. Talerico, Broomall, PA

COVER SKETCH

Left, gypsy moth larva; right, spruce budworm larva.

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PROCEEDINGS,

forest defoliator--host interactions:

A comparison between gypsy moth and spruce budworms

New Haven, Connecticut, April 5-7, 1983

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Sponsored jointly by the
Canada/United States Spruce Budworms Program
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GYPSY MOTH HOST INTERACTIONS: A CONCEPT OF ROOM

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The influence of host type and condition on the bioecology of gypsy moth are discussed from the viewpoint of room and board. Larval establishment was higher on preferred hosts; less than 5% migrated off them. Nonpreferred hosts lost 10-25% of larvae. Susceptibility of gypsy moth larvae to nucleopolyhedrosis virus increased following 1 or 2 years of defoliation. Survival value of insect resting locations on the host tree and in the litter are discussed in connection with risk of predation.

"And what does it live on?"
"Weak tea with cream in it."
"Supposing it couldn't find any?" she suggested
"Then it would die, of course."
"But that must happen very often,"
Alice remarked thoughtfully.
"It always happens," said the Gnat.

Lewis Carroll, Through the Looking Glass

When attempting to describe the bioecology of gypsy moth, one cannot dissociate this ubiquitous insect from its host(s). While one tends to relate host-insect interactions to herbivory (board), other functions of the host (room) are inextricably linked with behavior and survival of the gypsy moth.

Fully embryonated eggs overwinter in masses containing from 250 to 1,000 eggs. Eclosion occurs from mid-April to early May, depending upon geographic location and spring weather, usually in synchrony with host budbreak; asynchrony may occur, however, in previously defoliated hosts, which tend to break bud later than normal. Most eggs in a mass hatch within 3 to 5 days; masses on a site may hatch over a period of 2 to 3 weeks, depending upon their location in the stand and exposure to solar radiation. First-stage larvae may remain on the mass for several days if conditions are unfavorable (rain, temperatures <40°F). Otherwise, they move to the top of trees in response to light, initiate feeding or suspend themselves on silk, which fractures, permitting the larvae to disperse over several hundred meters (Mason and McManus 1981). Redispersal undoubtedly occurs and although the events that trigger it are unknown, it is believed to be related to the vigor of the larvae and means of host selection (Capinera and Barbosa 1976). Gypsy moths feed on more than 300 species of trees and shrubs and these have been grouped loosely into preferred, intermediate, and nonpreferred or rejected species (Bess et al. 1947, Houston 1979). Species of oak rank among the most preferred.

Once settled, first-stage larvae confine their feeding to the inner perimeter of the upper leaf surface. Second-stage larvae feed in inner leaf perimeter holes, whereas third-stage larvae feed on holes that expand their feeding activity to leaf margins. Larvae remain in the canopy; first-stage larvae rest on the lower leaf surface and second- and third-stage larvae rest on the undersides of twigs, branches, or bole; fourth- to sixth-stage larvae feed on the leaf margins (Leonard 1970). Normally, males have five instars, females six. Feeding activity is concentrated in the outer and upper crown and proceeds downward as foliage is removed by browsing. Dramatic behavioral change accompanies molting to the fourth stage; larvae feed nocturnally and migrate down to resting locations. Where defoliating populations are dense, larvae remain in the canopy, have intermittent feeding bouts day and night, and refrain from migrating to resting locations. This change in behavioral and feeding strategy is not understood, but it may be related to effects of crowding, necessity to maintain moisture balance, or abandonment of resting locations whose integrity has been destroyed by increased radiation due to defoliation.

Defoliation is usually a 1- to 2-year phenomenon, with outbreaks being terminated abruptly by starvation, desiccation, virosis, or a combination of factors. Forest stands on moist sites that are repeatedly defoliated tend to become more resistant to defoliation. This stems from the fact that preferred tree species, which are consistently defoliated more heavily, are more likely to die (Campbell and Sloan 1977).

Is gypsy moth capricious? If so, does larval behavior reflect this penchant? Host type influences rates of development, survival, and fecundity (Hough and Pimentel 1978) but larval distribution and movement within a forest stand are poorly understood.

In 1980, I selected a mixed hardwood stand classified as susceptible to gypsy moth defoliation, and determined that there were 22 egg masses within a 1/2-ha study area (considered a sparse population). All trees >3 inches DBH were burlap-banded and larvae marked under bands every other day with a different color acrylic paint for each of eight tree species. The assumption was made that each tree had an equal chance of receiving dispersing or redispersing larvae, and that host selection was made by instar I and II larvae. Larval abundance was related to gypsy moth host preference; the greatest numbers of larvae/ft² of basal area of host were found on oak, hickory, and aspen; the fewest on red maple, dogwood, and black birch (Table 1). Once larvae reached the third stage, they usually remained on the same host. Less than 5% of the larvae left preferred hosts. Some redistribution is expected since larvae can be dislodged from foliage to the ground by wind, rain, parasites, or predators. They then head for the nearest vertical object and climb it. Least preferred hosts lost more instar III larvae than preferred hosts, which lost none. Additionally, 10 to 25% larval outflux of instars V and VI occurred on least preferred hosts (Table 2). Redistribution appeared random but certain preferred hosts (aspen)

Table 1.--Number of gypsy moth larvae captured and egg masses counted/ft.² basal area of host. North Stonington, CT, 1980

<u>Instar</u>	<u>Quaking aspen</u>	<u>Black oak</u>	<u>White oak</u>	<u>Hickory</u>	<u>Black birch</u>	<u>Red maple</u>	<u>Dogwood</u>
III	2.5	5.0	2.3	7.9	3.7	1.9	0.4
IV	32.4	14.3	12.7	26.1	16.7	12.2	2.6
V	118.7	43.1	41.0	60.6	58.6	36.6	14.8
VI	82.2	33.1	38.3	37.0	48.5	17.9	9.9
# Egg masses	48.1	27.7	53.6	21.8	30.4	11.3	1.4

Table 2.--Percent marked gypsy moth larval movement/ft.² basal area by instar and host. North Stonington, CT, 1980

<u>Instar</u>	<u>Quaking aspen</u>	<u>Black oak</u>	<u>White oak</u>	<u>Hickory</u>	<u>Black birch</u>	<u>Red maple</u>	<u>Dogwood</u>
<u>Percent larval outflux</u>							
III	0	0	0	0	3.9	7.7	0
IV	3.6	2.0	4.6	1.7	5.2	4.7	1.9
V	3.3	3.0	3.2	4.3	10.1	14.6	7.8
VI	5.6	3.5	2.3	3.5	2.7	25.8	4.8
<u>Percent larval influx</u>							
III	22.2	0.3	0	0.6	0	0	0
IV	6.0	2.3	2.5	1.2	2.5	3.2	11.5
V	5.6	3.8	4.9	3.0	10.2	6.3	7.4
VI	6.1	2.2	4.5	3.2	8.3	11.8	8.1

gained more marked larvae from other hosts than they lost. In general, there was little evidence of consistent host-switching on preferred or intermediate hosts.

Utilization of the burlap bands increased with each instar reflecting that larval migration down the tree is influenced by the size and abundance of resting locations. Burlap bands are considered highly attractive as resting locations, and egg mass abundance was correlated with the numbers of stage VI females. Only white oak had more egg masses than sixth instars. No evidence of preferential movement from other hosts to white oak was disclosed by our larval marking procedure. Perhaps white oak provided the ideal room and board through preferred foliage and abundant refuges above our burlap bands which precluded the need by all larvae to migrate down the bole where they could be marked.

Pupae are usually found in those resting locations used by larvae that offer the most protection from predators (Campbell et al. 1975). Although this symposium focuses largely on the tree as board for the herbivore, the host may provide room for gypsy moth by providing refuges more secure than others.

The Traveller that is struck by
Lightning, seldom gets home to
Tell his widow.

Ben Franklin's Wit & Wisdom

Analogously, predators can strike quickly and preferentially kill larvae or pupae. The tree provides a number of resting locations (room) each having an associated level of risk to the larva or pupa occupying it. Smith (in press) reported that the type of resting location influenced pupal mortality from predators. Pupae have higher survival when the host provides refuges off the ground that are more secure from predation (Table 3). Forest stands susceptible to gypsy moth defoliation can be classified on several factors including the abundance of these structural features (Houston and Valentine 1977).

The abundance of gypsy moth in Eurasia and East Asia is cyclic and predictable. In North America it is considered episodic, and outbreaks are unpredictable. The consistent level of nonpathogenic mortality reported by Campbell and Podgwaite (1971) in sparse to moderate densities gives credence to the notion that a general decrease in physiological dysfunction

Table 3.--Percent survival of gypsy moth pupae within different resting locations

Density per acre	Location	Eaten by predators		Died (other causes)	Emerged
		Vert.	Invert.		
1000	Flap	13	19	15	52
	Bole	14	17	17	52
	Litter	45	22	8	25
300	Flap	7	15	11	68
	Bole	22	19	11	49
	Litter	42	25	7	26
100	Flap	2	13	6	78
	Bole	3	14	8	76
	Litter	9	37	3	52

From Smith, 1983

among larvae could signal the initiation of an outbreak. A number of authors have speculated on host foliar condition relative to the abundance of other tree defoliators; nitrogen (White 1974), tannins (Feeny 1970, Schultz and Baldwin 1982), and wound-induced proteinase inhibitors (Green and Ryan 1972). Gypsy moths reared on trees that had been artificially defoliated to simulate insect defoliation took longer to develop, suffered more nonpathogenic mortality, and developed into smaller pupae than those on undefoliated hosts (Wallner and Walton 1979). Foliar analysis for nutritional changes which occurred in conjunction with this study (Valentine et al. 1983) indicates that foliar sugar concentration may influence gypsy moth growth and fecundity.

There are subtle secondary effects that are scientifically appealing but elusive to document. One, increased susceptibility to a pathogen as a consequence of declining host constituency, was examined in the course of our study on the effect of artificial herbivory on gypsy moth. Larvae were constrained on host trees receiving 1, 2, or no defoliations and permitted to develop to adults, from which eggs were obtained by within-treatment matings. Larvae from eggs from each of these 3 populations subjected to different defoliation regimens were challenged with the nucleopolyhedrosis virus (NPV) (Lewis et al. 1981) and LC₅₀ values were determined (Fig. 1).

Only those larvae from eggs produced on trees defoliated for 2 consecutive years were significantly more susceptible to NPV than those from undefoliated trees. However, larvae from once-defoliated trees tended to be more susceptible to NPV than those from either the primary standard or undefoliated trees. This suggests that host condition can influence the resistance of the insect to a pathogen. NPV assays traditionally have been variable, depending upon the geographic source of gypsy moth, its past defoliation history, bioassay methodology, etc.; hence this one test should be viewed as only identifying a potential area for further research.

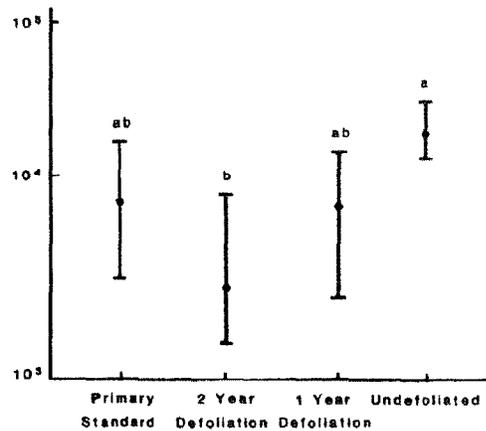


Figure 1--LC₅₀ and 95% confidence limits of gypsy moth mortality challenged with 1976 K standard gypsy moth NPV. Larvae emanated from eggs produced by field reared insects on trees subjected to different defoliation treatments.

The host mediates gypsy moth development, behavior, physiology, and survival within the concept of room and board. It cannot be viewed as a static relationship but a dynamic one, a theme which should be evident throughout this workshop. Are gypsy moth and spruce budworm host relationships iterative processes such that--

The food that to him is as luscious as locusts, shall be to him shortly as bitter as coloquintida.

William Shakespeare, *Othello*

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