THE EFFECTS OF TEMPERATURE ON THE EMERGENCE OF SECOND-INSTAR SPRUCE BUDWORM LARVAE

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ABSTRACT

Emergence of second-instar spruce budworm (*Choristoneura fumiferana* (Clem.)) larvae from hibernacula appears to be affected by at least three factors; an adequate cold treatment, the accumulation of heat units, and a sufficiently high temperature for actual emergence from hibernacula. Data on the emergence sequence of larvae under controlled conditions in the laboratory suggest that a fourth factor is also involved.

Résumé

Il semble que l'émergeance des larves de Tordeuse des bourgeons de l'épinette (*Choristoneura fumiferana* (Clem.)) au deuxième stade de leur développement, depuis des hibernacles, soit affectée par au moins trois facteurs: une froidure adéquate, l'accumulation d'unités de chaleur, et une température suffisamment élevée pour permettre l'émergeance des larves depuis leur hibernacle. Selon la séquence des émergeances alors que l'auteur les suivaient en laboratoire, il semble qu'un quatrième facteur entre aussi en jeu.

INTRODUCTION

The emergence of spruce budworm (*Choristoneura fumiferana* (Clem)) larvae from hibernacula in 1974 showed sufficient variation to indicate that not all the larvae were responding to the emergence stimuli in the same way. These observations suggested that the differences between individuals may be large enough to indicate different physiological morphs in any one population. In 1975, detailed studies on the emergence of second-instar larvae were conducted.

MATERIALS AND METHODS

Mid-crown branches of balsam fir trees in a 30-40-year-old stand near Fredericton were collected on 7 February, 27 March, and 25 April, 1975. Within four days of being collected, these branches were tied in small bundles, wrapped in paper towelling, and hung in heated rooms with a 24 hr photoperiod. The foliage was saturated with water once a day. Second-instar larvae emerged from hibernacula and were removed from the towelling at frequent intervals each day. Four temperature regimes were used and the temperatures were recorded on thermographs. The areas beneath the curves were measured using a planimeter and were converted to degree-days. Larval emergence was related to heat units, degree-days above 5.6°C (Miller *et al.* 1971).

The treatment and yield from each foliage collection was as follows:

Foliage Collected	Laboratory Temperature °C Min	Max	Emergence No. of Larvae	Period
7 February 1975	0	32	1808	24 Feb - 21 Mar
27 March 1975:				
Treatment 1	19	22	6137	5 - 25 April
Treatment 2	24	33	6946	5 - 17 April
25 April 1975	7 (16 hr)	21 (8 hr)	1614	30 Apr - 23 May

The relationship between larval emergence and accumulated heat units was plotted on probability paper to detect any heterogeneity in each sample.

RESULTS

The emergence of larvae from the foliage collected on 25 April was a straight line relationship between 0.1 and 95% when plotted on probability paper against accumulated heat units (Fig. 1), indicating that the sample was part of a single normally distributed population. However, the graphs showing emergence of larvae from foliage collected on 27 March and 7 February had distinct inflexions (Fig. 1), at 68.5% emergence for the March collection, and at 43% emergence for the February collection. The scattering of points beyond the 95% level is typical of budworm data and can be ignored in the present study.

The data from each of the four temperature regimes were separated into two groups based on the evidence in Fig. 1. Those larvae having the greatest sensitivity to heat, i.e. the first 95% of the

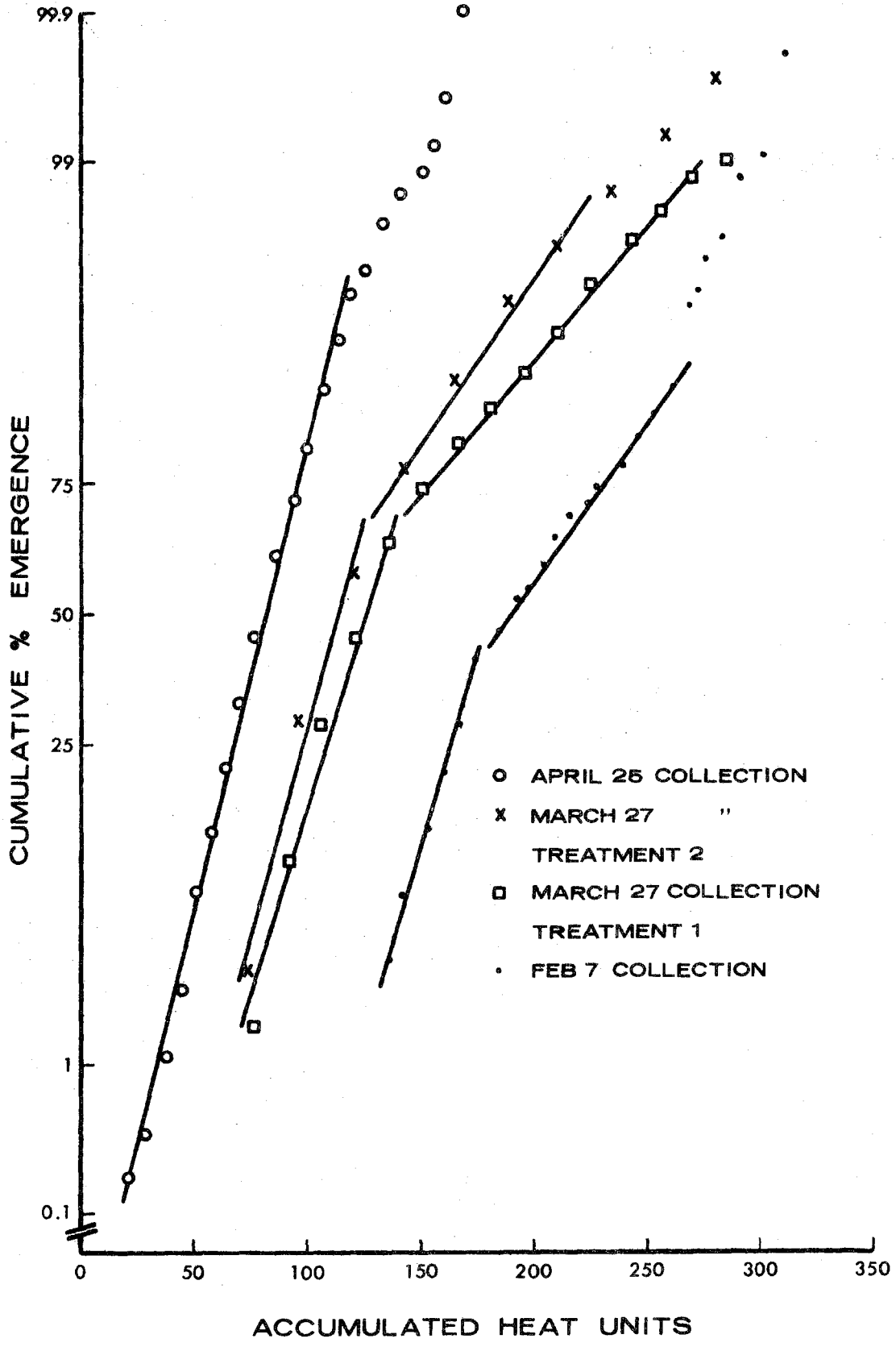

Fig. 1. Cumulative percentage frequency curves for emergence sequence of second-instar larvae from balsam fir foliage.

25 April collection, the first 69% of each treatment of the 27 March collection, and the first 43% of the 7 February collection, were considered as one group (Fig. 2) while those larvae having less sensitivity to heat, i.e. the remaining larvae, were considered as the other group. In Fig. 2 the probit lines are parallel indicating that each of these populations was responding to heat in an identical manner. The four populations in the second group were more varied than those in the first group, partly because they contained the 5% tail of each sample. The probit lines were not parallel indicating that the larval response was not identical. Nevertheless it was possible to estimate 50% emergence for each of the populations in this second group. The heat units required for 50% emergence are summarized in Table 1. It can be seen in the 27 March collection that there were greater similarities between equivalent groups of each treatment than between groups within treatments.

Table 1. Heat unit requirements for 50% emergence of second-instar larvae from balsam fir foliage under controlled conditions in the laboratory.

Collection Date	Heat Units Required for 50% Emergence		
	Larvae with high sensitivity to heat	Larvae with low sensitivity to heat	Total Population
7 February	160	230	192
27 March			
Treatment 1	112	195	124
Treatment 2	103 av. 108	155 av. 175	116
25 April	78	130	80

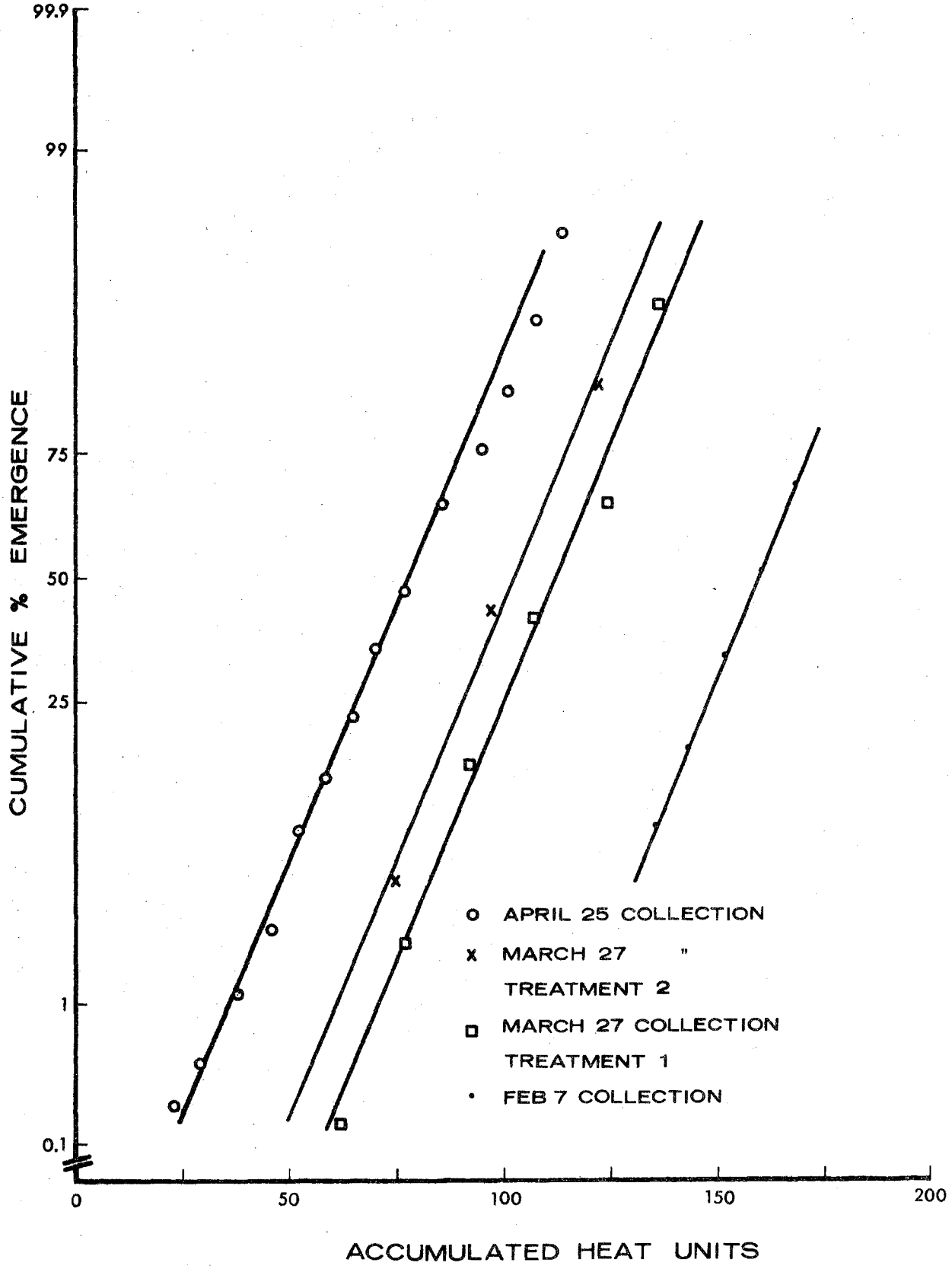

Fig. 2. Cumulative percentage frequency curves for emergence sequence of second-instar larvae from balsam fir foliage. (Larvae with high sensitivity to heat).

DISCUSSION

Based on these observations of 16,505 second-instar larvae under controlled conditions it appears that emergence from hibernacula is primarily a response to heat. I interpret the emergence of larvae from the foliage collected on 25 April to be the result of a direct accumulation of heat units, all previous requirements having been met in the field before 25 April. A difficulty arises in explaining the distinct inflexions (Fig. 1) in the emergence sequences from foliage collected before 25 April. One possible explanation is the non-completion of an adequate cold treatment. In the 7 February collection, the first 43% of the population may have had its cold requirement satisfied and began to accumulate heat units immediately; the other 57% may not have begun to accumulate heat units until later. However, the same phenomenon (an inflexion) was observed in the 27 March collection; it is difficult to imagine that by this date 31% of the population had not satisfied its cold requirement. Also, the slopes of the probit lines after the inflexions are different from the slopes before the inflexions (Fig. 1) indicating that the groups were responding to heat in different ways. The involvement of some other factor seems the most likely explanation.

Although this factor is unknown, its effect can be deduced from the behaviour of the larvae. During the spring the larvae respond to heat in such a way that they require 25 heat units for the mid-50% of the population (i.e. from 25-75%) to emerge (Fig. 2). This corresponds to 2-3 days of warm weather in early May. During the winter the larvae require 60 heat units for a similar emergence effort. The unknown factor causes the larvae to change from a low sensitivity to heat in the winter, to a high sensitivity to heat in the spring. Thus, on 7 February,

43% of the larvae had a high sensitivity to heat, by 27 March, 69%, and by 25 April, 95% of the larvae had changed.

The effect of this factor in the field appears to have been documented by Rose and Blais (1954). These authors recorded that in 1952 there were two emergence peaks of second-instar larvae; an exceptionally early emergence on 29 April and another emergence on 20 May. Temperature does not appear to have been the main factor delaying emergence of the 20 May group because they reported that by 20 May, 50% of the larvae which emerged on 29 April were in the third and fourth instars. I conclude that the larvae which emerged on 29 April 1952 correspond to the larvae, collected on 27 March 1975 in New Brunswick, which required a mean of 108 heat units for emergence (Table 1) (i.e. the group having a high sensitivity to heat) while the larvae emerging on 20 May 1952 correspond to the larvae which required a mean of 175 heat units (Table 1) (i.e. the group having a low sensitivity to heat).

The larval population responds to temperature in one of two ways. In early winter and late spring, all the larvae respond to heat as though they were a single population; in late winter and early spring the larvae respond to heat as though they were two populations. The biological significance of this behaviour is not known.

References

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Rose, A.H. and J.R. Blais. 1954. A relation between April and May temperatures and spruce budworm larval emergence. Can. Ent. 86: 174-177.