

Temperature Effects on Development and Survival of Western Spruce Budworms

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Individual western spruce budworm developmental times have a skewed, unimodal distribution for which the log-normal distribution is an adequate model. Developmental time variances are often greater within than among families (Volney et al. 1983), particularly for early instar development (Volney et al. 1984a).¹ This pattern guarantees that representatives of most families will survive whatever the degree of synchrony between the insect and host development. Synchrony between insect emergence and phenological windows in which feeding sites are established may be a major determinant of early instar survival, however. Any process, such as flowering, which effectively increases this window's size can further influence survival rates.

As temperature increases, insect developmental rates (DR) are accelerated nonlinearly at low, almost linearly in intermediate, and retarded at high temperatures; but with increases beyond the maximum DR temperature, retardation is rapid as upper lethal temperatures are approached. For western spruce budworms, temperatures at which these rate changes occur increase with the insect's physiological age (Volney et al. 1984a).¹ This pattern allows budworms to track their thermal environment which becomes warmer as they age.

Some developmental rate variation among populations in the early instars is attributable to differences between the sibling species *Choristoneura occidentalis* Freeman and *C. retiniana* (Walsingham). Early development of each species appears closely tuned to that of its principal host until they enter the sixth instar. True firs, the principal hosts of *C. retiniana*, flush first but their shoots develop slower than those of Douglas-fir, the principal host of *C. occidentalis* (Volney et al. 1984b). Coincidentally, although *C. retiniana* emerges first, its development in the early instars is slower than that of *C. occidentalis* larvae (Volney et al. 1984a).¹ Life table analyses (Volney and Waters, unpublished) indicate that high early instar survival is correlated with high population trends.

Temperature influences sixth instar, pupal, and adult coloration. Pigmented areas of insects reared at high temperatures tend to be lighter than their counterparts reared at low temperatures (Volney et al. 1983b). Males tend to be darker than females and hybrid individuals are more labile in their color response than either

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parental morph. These temperature reactions may function in thermal regulation because radiation is an important source of thermal energy in the insects' natural environments. Further, morphological plasticity would tend to stabilize insect development across forest stands with different thermal environments. Beyond the fifth instar, there are no developmental differences between species. However, brown larval morphs of hybrid families spend longer as sixth instars than their less pigmented sibs. Thermal regulation may also stabilize development of hybrids in nature.

Although temperature has a profound effect on daily male trap catch, the onset of male response to pheromone sources is earlier on cool than on warm evenings (Liebhold and Volney 1984). Thus, mating is possible on evenings when temperatures fall below male flight thresholds at sunset.

In both species there is some value in a protracted Spring emergence but synchronized adult development becomes paramount for mating. Variation in total development time may be reduced by selection of individuals emerging in the phenological window which allows feeding site establishment. But budbreak is an unpredictable event and selection in any one season would render the population maladapted for subsequent seasons. Significant negative correlations between development times at different life stages is one way in which early developmental variation can be conserved while reducing variation in moth eclosion dates (Volney et al. 1984a).¹ The similarity in developmental controls of the two budworm species studied suggest that similar mechanisms may operate in other *Choristoneura* spp.

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¹Volney, W.J.A.; Liebhold, A.M. 1984a. Post diapause development of sympatric *Choristoneura occidentalis* and *C. retiniana* (Lepidoptera: Tortricidae) populations and their hybrids (In preparation).

PART I

Spruce Budworms

Volney, W.J.A.; Liebhold, A.M.; Waters, W.E. 1983b. Effects of temperature, sex, and genetic background on coloration of *Choristoneura* spp. (Lepidoptera: Tortricidae) populations in south-central Oregon. Can. Entomol. 115:1583-1596.

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Recent Advances in Spruce Budworms Research

Proceedings of the CANUSA Spruce Budworms Research Symposium

Bangor, Maine
September 16-20, 1984

Editors:

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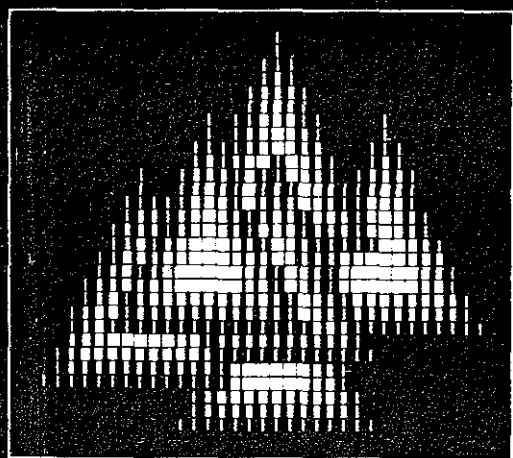
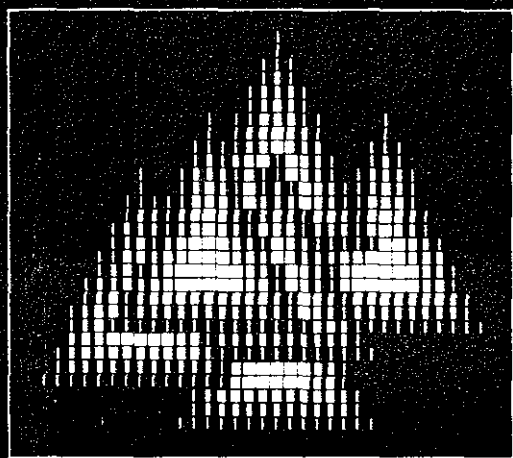
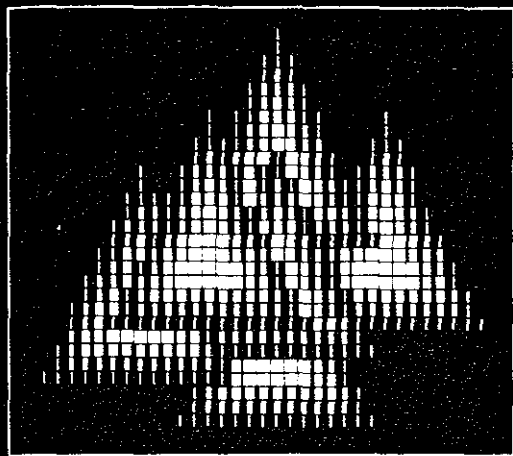
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Ottawa, Ontario 1985



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Catalog No. Fo18-5/1984

ISBN 0-662-14202-0

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