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EFFECT OF TEMPERATURE AND RESIN ON HATCH OF EGGS OF THE MOUNTAIN PINE BEETLE (*DENDROCTONUS PONDEROSAE*)

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Abstract *Can. Ent.* 102: 617–622 (1970)

Effects of temperature and resin on hatch of mountain pine beetle eggs were investigated. Per cent hatch was related to total degree-hours above 40°F, the average being 5113 for 50% hatch under field conditions. Average supercooling point was 1.3°F. Higher temperatures in the freezing range were lethal with long exposure. Atmosphere saturated with volatiles from liquid resin had very little effect on egg hatch, but direct contact with liquid resin greatly reduced egg hatch.

Introduction

Factors affecting the survival and hatch of eggs of mountain pine beetle, *Dendroctonus ponderosae* Hopkins, are not well known. In some years egg survival is low, unfavourable temperatures and resin soaking of galleries being suspect. The effect of these factors on egg survival and hatch is reported in this paper.

Studies were done mainly in the years 1966 and 1967, utilizing eggs from insect populations established in lodgepole pine, *Pinus contorta* var. *latifolia* Engelmann, forests near Radium, B.C. Information relating to the biology and behaviour of the mountain pine beetle is reported elsewhere (Evenden *et al.* 1943; Reid 1962*a, b*; Reid *et al.* 1967).

Methods

Collection of Eggs

Eggs were removed from galleries in the bark peeled from logs infested 10–14 days previously. The eggs were stored on moist blotter paper in petri dishes at 41°F and 100% relative humidity as recommended by Reid (1969).

Eggs were arbitrarily classified into four easily discernible stages of development which corresponded approximately to their age. Stage I eggs were 1–2 days old and homogeneously opaque in appearance; stage II, 2–3 days old and clear at one end; stage III, 3–4 days old and clear at both ends; stage IV, 4–5 days old, possessed a clearly defined head capsule, and were within 2 days of hatching at room temperature.

Effects of Temperature on Incubation Period

In the laboratory disposable petri dishes 10×10 cm square were used to hold the eggs during experiments. Moistened blotter paper was placed on the bottom. A plastic sheet 4 mm thick and slightly less than 10 cm square, possessing 50 holes of 4 mm diameter, was pressed firmly onto the blotter paper. Two eggs were placed in each hole.

Eggs were incubated at eight constant temperatures which ranged at 9° intervals, from 41° to 104°F $\pm$ 0.5°. Four hundred stage I eggs were incubated at each temperature.

In the field, every 2 weeks from May to September, 100 stage I eggs were placed in a Stevenson weather screen adjacent to a hygrothermograph. The eggs were examined daily and the hatch recorded.

Effects of Temperatures upon Survival

In a study designed to determine the effect of a moderately low temperature upon egg survival, 400 in each stage were conditioned at 32°F for 3 days then stored at 14°F. After 2 days at 14°F, 200 eggs of each stage were removed and incubated at room temperature. The remaining eggs were kept at 14°F for an additional 5 days, and then removed and incubated at room temperature.

The supercooling point of insects and eggs has been used as an index to describe resistance to low temperatures (Salt 1961; Sullivan and Green 1964; Sullivan 1965). The low temperatures required for this study were obtained by use of a thermo-electric apparatus. It was purchased in kit form from Frigistor Ltd., Montreal, and modified to suit our needs.

The test chamber for the eggs consisted of a copper pipe-cap $^7/_8$ in. in diameter and $^1/_2$-in. deep. This chamber was seated upon the heat transfer bar of the thermo-electric apparatus. The whole unit was imbedded in styrofoam 1 in. thick.

Eggs were placed upon a nylon mesh raised $^1/_{16}$-in. above the bottom of the chamber. The thermocouple junction for temperature sensing was electrically welded and secured within the nylon mesh. Three inches of thermocouple wire were coiled within the chamber to reduce heat conduction from the outside. Thirty-gauge copper-constantin thermocouple wire and a Rubicon potentiometer were used for temperature sensing.

Supercooling points of approximately 700 eggs were determined, one half held at room temperature and the remainder at 23°F. Eggs in both groups were separated into the four age categories.

Effect of Resin on Egg Hatch

One hundred eggs in each of the four stages were completely covered with liquid resin by rolling them once over a film of resin. They were then moved onto moist blotter paper. A comparable set of eggs was submerged to one half their diameter in drops of resin. All eggs were incubated at room temperature in an atmosphere near 100% relative humidity.

TABLE I

Total degree-hours above 40°F and number of days required for 50% hatch of mountain pine beetle eggs under field conditions

Rearing dates	No. of days	Mean temp (°F)	Total degree-hours above 40°F
29 May — 10 June	13	55.0	4598
14 June — 23 June	10	59.0	4573
30 June — 10 July	11	59.5	5181
17 July — 26 July	10	60.0	4754
31 July — 9 Aug.	10	62.0	5300
24 Aug. — 2 Sept.	10	64.5	5891
8 Sept. — 20 Sept.	13	57 5	5492

To assess the effect of resin volatiles on egg hatch, 250 eggs in each of the four stages were incubated in an atmosphere saturated with resin vapour. Resin for this study was a mixture obtained from 20 lodgepole pines. Care was taken during collection to reduce the loss of volatiles.

Results and Discussion

Effect of Temperature on Incubation Period

The minimum threshold for egg hatch, 40°F, was determined from field data using the equation $K = Y(t - a)$, where K is a constant, Y is the incubation period in days, t is the mean temperature during the incubation period, and a is the thermal threshold (Tripp 1965). Field data are summarized in Table I. A threshold temperature of 39.1°F was calculated from these data, which, for practical purposes, was raised to 40°F. In previous observations, development within the egg had been detected at temperatures lower than 40°F but hatch was rare. Different threshold temperatures for development and for hatch were described by Lin *et al.* (1954) in eggs of *Tribolium.*

In the field the total degree-hours above 40°F required for 50% hatch ranged from 4598 to 5891 degree-hours with a mean of 5113 (Table I). In the laboratory, the range was from 4440 at 77°F to 6120 at 50°F, with a mean of 5385 (Table II).

At a constant temperature of 41°F in the laboratory only 13% of the eggs hatched in a 90-day period; in the field, only 25% hatched during a 30-day period when the average temperature was 46°F. Results from the present study suggest that optimum constant temperatures for hatch are in the range 68° to 77°F as the minimum heat units were recorded in that range.

Mountain pine beetles will oviposit at temperatures as low as 35°F (Reid 1962*b*), but our results suggest few eggs will hatch at that temperature. Flight

TABLE II

Total degree-hours above 40°F required for 50% hatch of mountain pine beetle eggs at five constant temperatures

Temp. (°F)	Total degree-hours above 40°F
50	6120
59	5472
68	5376
77	4440
86	5520

TABLE III
Hatch of mountain pine beetle eggs in per cent and total degree-hours above 40°F

% hatch	Total degree-hours	Range
10	3842	3250–4750
20	4141	3450–4900
30	4400	3700–5100
40	4633	4000–5250
50	4850	4300–5450
60	5108	4650–5600
70	5350	4900–5750
80	5633	5250–5950

periods of the beetle vary in different years (Reid 1962*b*). When they occur in late August there may be insufficient heat units remaining in that season for complete egg hatch before freezing temperatures are a daily occurrence. The data in Table III permit estimations of per cent egg hatch when the degree-hours above 40°F are known from time of oviposition. These data were interpolated from field study hatch curves.

Effect of Temperature on Egg Survival

No hatch occurred among eggs incubated at 104°F and only 5% hatched when incubated at 95°F. However, between 50° and 85°F approximately 85% of the eggs hatched. Eggs of mixed age stored for long periods at temperatures lower than 41°F exhibited reduced hatchability when incubated at room temperature. Only 220 of 400 eggs stored 3 months at 41°F hatched whereas fewer than 100 of 400 eggs stored at 23°F for 1 month hatched. When eggs were separated into the four stages and subjected to 14°F for 2 and 7 days, differences in cold resistance were evident. Eggs in stages III and IV were not greatly affected whereas mortality in the two younger stages was considerable (Table IV).

Eggs not conditioned to low temperatures supercooled and then froze at an average temperature of 1.3°F whereas eggs conditioned at 23°F supercooled and froze at —0.6°. Age of the eggs had no apparent effect. Data from the supercooling studies are illustrated in the form of mortality curves (Fig. 1).

Results indicate eggs of the mountain pine beetle do not have a high tolerance to freezing temperatures. Although they can, on the average, survive brief exposure to temperatures as low as 1.0°F, tolerable exposure time varies inversely with temperature. Since freezing temperatures during winter months are common in most regions where mountain pine beetle populations are established,

TABLE IV
Survival of mountain pine beetle eggs stored at 14°F and incubated at room temperature

Egg stage	Survival (%) at 14°F	
	2 days	7 days
I	59	46
II	69	48
III	84	80
IV	75	70

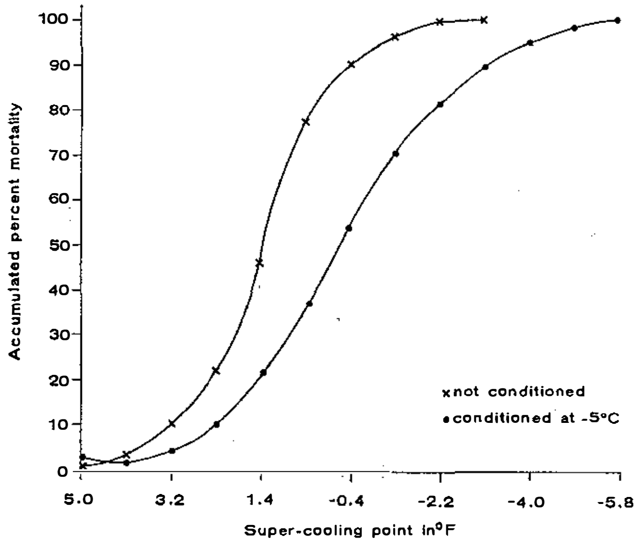

FIG. 1. Supercooling points expressed as mortality curves for eggs of the mountain pine beetle.

and temperatures lower than 1.0°F are frequently maintained for several months, complete mortality occurs in the overwintering eggs.

In contrast, larvae of the mountain pine beetle are more resistant than eggs to low temperatures. Sômme (1964) found late stage larvae of this insect were able to withstand temperatures near —29°F for prolonged periods.

Beal (1933) reported temperatures of near —4°F had no effect on eggs of the southern pine beetle, *D. frontalis* Hopkins, but were lethal to larvae. The same investigator reported eggs of the western pine beetle, *D. brevicomis* Hopkins, suffered heavy mortality at that same temperature (Miller and Keen 1960).

Effect of Resin on Egg Hatch

Suffusion of resin into tissues surrounding eggs and galleries is a part of the resistant mechanism exhibited in varying degrees by the host tree (Reid *et al.* 1967). Even in trees showing no outward sign of resistance it is common for the first few inches of egg gallery to become resin soaked.

In this study mortality was practically complete among all stages when eggs were completely covered by a thin layer of resin. When mature embryos developed, or were already present, they appeared unable to break through the hardened resin coating. Mortality was near 40% when eggs were only half covered (Table V).

TABLE V

Survival in per cent of mountain pine beetle eggs in contact with liquid resin

	% hatch		
Egg stage	Control	Completely covered by film of resin	One half covered by film of resin
I	80	4	59
II	88	0	56
III	86	0	44
IV	80	0	51

Volatiles from fresh resin had only a slight effect on egg hatch. The per cent hatch in the terpene saturated atmosphere was 3% less than in the controls. The age of an egg had no apparent effect. Results from these studies suggest egg mortality in resinous tissue occurs only when eggs are in direct contact with the resin. The greater the amount of resin contact, the greater the mortality.

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References

Beal, J. A. 1933. Temperature extremes as a factor in ecology of the southern pine beetle. *J. For.* **31**: 329–336.

Evenden, J. C., W. D. Bedard, and G. R. Struble. 1943. The mountain pine beetle, an important enemy of western pines. *U.S. Dep. Agric. Circ.* 664.

Lin (Sping), A. C. Hodson, and A. G. Richards. 1954. An analysis of threshold temperature for development on *Oncopeltus* and *Tribolium* eggs. *Physiol. Zoöl.* **27**: 287–311.

Miller, J. M., and F. P. Keen. 1960. Biology and control of the western pine beetle. *U.S. Dep. Agric. Misc. Publ.* 800.

Reid, R. W. 1962*a*. Biology of the mountain pine beetle, *Dendroctonus monticolae* Hopkins, in the east Kootenay Region of British Columbia. I. Life cycle, brood development, and flight periods. *Can. Ent.* **94**: 531–538.

——— 1962*b*. Biology of the mountain pine beetle, *Dendroctonus monticolae* Hopkins, in the east Kootenay Region of British Columbia. II. Behaviour in the host, fecundity, and internal changes in the female. *Can. Ent.* **94**: 605–613.

——— 1969. The influence of humidity on incubating bark beetle eggs. *Can. Ent.* **101**: 182–183.

Reid, R. W., H. S. Whitney, and J. A. Watson. 1967. Reactions of lodgepole pine to attack by *Dendroctonus ponderosae* Hopkins and blue stain fungi. *Can. J. Bot.* **45**: 1115–1126.

Salt, R. W. 1961. Principles of insect cold hardiness. *A. Rev. Ent.* **6**: 55–74.

Sômme, L. 1964. Effects of glycerol on cold hardiness in insects. *Can. J. Zool.* **42**: 87–101.

Sullivan, C. R. 1965. Laboratory and field investigations on the ability of eggs of the European Pine Sawfly *Neodiprion sertifer* Geoffroy, to withstand low winter temperature. *Can. Ent.* **97**: 978–993.

Sullivan, C. R., and G. W. Green. 1964. Freezing-point determination in immature stages of insects. *Can. Ent.* **96**: 158.

Tripp, H. A. 1965. The development of *Neodiprion swainei* Middleton (Hymenoptera: Diprionidae) in the Province of Quebec. *Can. Ent.* **97**: 92–107.

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