EFFECT OF TEMPERATURE ON OVIPOSITION AND BROOD DEVELOPMENT OF *PISSODES STROBI* (COLEOPTERA: CURCULIONIDAE)

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Abstract

Can. Ent. 108: 1167–1172 (1976)

The effects of temperature on rates of oviposition and development of immature stages of *Pissodes strobi* from Sitka and white spruce were investigated in the laboratory. Maximum rate of oviposition occurred at 20° to 26°C. Brood development from egg to emergence took 888 and 785 degree-days above a threshold of 7.2°C for the weevil from Sitka and white spruce, respectively.

Résumé

L'auteur étudia en laboratoire les effets de la température sur les taux de ponte et sur le développement de *Pissodes strobi* sur l'Epinette de Sitka (*Picea sitchensis*) et l'Epinette blanche (*Picea glauca*). La ponte maximale se produisit à 20 à 26° C. Le développement de la progéniture depuis l'oeuf jusqu'à l'émergence dura 888 et 785 degrés-jours au-dessus d'un seuil de 7.2°C chez l'Epinette de Sitka et l'Epinette blanche, respectivement.

The terminal weevil, *Pissodes strobi* (Peck), a pest of pine and spruce in the northern United States and Canada, was known as three species (*P. strobi*, white pine weevil, *P. engelmanni* Hopk., Engelmann spruce weevil, and *P. sitchensis* Hopk., Sitka spruce weevil). Smith and Sugden (1969) placed *P. engelmanni* and *P. sitchensis* in synonymy with *P. strobi*. The weevil kills the terminal leader, causing crooked and multiple stems and growth loss. It is a serious pest of eastern white pine, *Pinus strobus* L., in eastern U.S.A. and Canada (Belyea and Sullivan 1956) and of Sitka spruce, *Picea sitchensis* (Bong.) Carr., in coastal British Columbia and northwestern U.S.A. (Silver 1968; Wright 1960). It also damages white spruce, *P. glauca* (Moench) Voss, and Engelmann spruce, *P. engelmanni* Parry, in the interior of British Columbia and in Alberta (Stevenson 1967).

Differences in damage intensity on Vancouver Island and the lack of damage on the Queen Charlotte Islands suggested that differences in hazard existed (Harris *et al.* 1968). More detailed data from areas of regeneration suggested that temperature might be one of the factors involved. Two ways in which temperature might affect the insect are: (*a*) effect on rate of oviposition, and (*b*) effect on rate of brood development. This study was undertaken to determine these effects under laboratory conditions for the weevils from Sitka spruce and from white spruce.

Methods

Rates of oviposition and brood development were studied in constant and diurnally fluctuating temperature regimes.

Adult weevils were collected from leaders of Sitka spruce in the San Juan and Nitinat areas and from leaders of white spruce in the Aleza Lake area in the central interior of British Columbia; they were sexed and held at 10°C on freshly-cut host material until used. The host material used in the study consisted of large laterals (Sitka spruce) or leaders (white spruce) with the previous 2 years' internodes. Tests were initiated within 1 week of collection of adults and host material.

In the oviposition tests, two female and two male adults were caged on each of 10 branches in each temperature regime. After 4 days in the regime, the numbers of dead adults were recorded, and the branches were held at 1°C until examined, usually within 1 week. The number of oviposition punctures on each branch and the number of eggs in each oviposition puncture were recorded.

In the brood development study, adult weevils were caged on the host material for 5 or 6 days at 25° or 20°C to obtain oviposition. Branches with oviposition punctures were then placed in the temperature regimes. Four or more branches were removed from each regime after intervals of 10, 15, and every 10 days thereafter (up to 65 days for Sitka spruce and 95 days for white spruce) and held at 1°C until examined (usually within 1 week). All living individuals of each developmental stage and number of emergence holes were recorded. Larvae were stored in 70% ethanol and later assigned to instars on the basis of the distribution of head-capsule widths.

Accumulated heat, measured in degree-days above a developmental threshold temperature, was determined in the following way. The percentage occurrence of each developmental stage was calculated at each examination date for each temperature regime. An estimate of the time required for 50% to reach each stage in each regime was determined by interpolation between the two points closest to 50%. In addition to the time in the temperature regimes, the time during the oviposition period was included. A developmental threshold temperature was roughly estimated from the data. Day equivalents of the oviposition period were estimated for each regime as one-half of $D(T_o - T_d)/(T_r - T_d)$ where D = days for oviposition, T_o = oviposition temperature, T_d= threshold temperature, and T_r= regime temperature. These were added to the time for 50% occurrence in the regime. The rates of development for each stage were calculated with standard regressions ($Y = a+bX$, where Y = reciprocal of the number of days for 50% to reach the stage and X = temperature minus the threshold). These lines were compared with lines through 0 ($Y = b'X$) (Freese 1964). Degree-days and days required for development were calculated from these lines.

The temperature regimes were obtained in styrofoam-lined plywood boxes with holes drilled in the bottom, and placed over water trays. The branches were placed in the holes so that the cut base was always in water. All units were supplied with light (about 860 lux) from the top. The diurnally fluctuating temperatures, we well as the light, were operated on a 16 h day, 8 h night cycle. Each regime was monitored with a hygrothermograph, and temperatures were measured to the closest 0.5°C. Approximately a 1½ to 2 h lag occurred between minimum and maximum temperatures in the diurnally fluctuating regimes. The five constant and six diurnally fluctuating temperature regimes, along with approximate relative humidities for the tests, are shown in Table I.

Table I. Temperature regimes in oviposition and development studies (°C)

Regime		Sitka spruce			White spruce		Approx. relative humidity (%)
		Oviposition					
No.	Type*	Test 1	Test 2	Dev.	Ov.	Dev.	
1	C	–	10.6	10.6	10.6	10.6	90
2	,,	14.4	14.4	14.4	13.9	14.2	85
3	,,	20.0	21.1	22.2	21.7	21.7	65
4	,,	26.1	28.9	26.1	26.1	26.1	75
5	,,	31.1	31.7	31.7	32.8	32.8	60
6	DF	4.4–15.6	4.4–15.6	4.4–15.6			90–70
7	,,	5.6–18.9	5.6–18.9	5.6–18.9			90–65
8	,,	5.6–22.2	5.6–26.7	5.6–26.7			90–60
9	,,	10.0–15.6	10.0–15.6	10.0–15.6			80–70
10	,,	10.0–20.6	10.0–20.6	10.0–21.1			80–60
11	,,	10.0–25.6	10.0–26.7	10.0–26.7			80–45

*Abbreviations: C, constant; DF, diurnally fluctuating.

Results and Discussion

(a) *Oviposition*

The results of the oviposition studies are shown in Table II. The means indicate the same pattern for the weevil from both white and Sitka spruce. Oviposition activity (expressed by eggs/female and oviposition punctures/female) rose to a maximum at about 20° to 26°C, then levelled off or dropped. Further interpretation of the results is difficult because of the large variation and mortality of the females. The data do suggest that little difference occurs in the oviposition activity patterns related to temperature of populations of *P. strobi* from different hosts. Sullivan (1960) and Gara *et al.* (1971), working in Ontario on white pine and in Washington on Sitka spruce, respectively, found maximum oviposition activity at higher temperatures (29° to 33°C). However, the variation evident in the results presented here precludes any suggestion of a real difference.

(b) *Brood Development*

A total of 330 Sitka spruce laterals removed from the temperature regimes had 5177 living progeny at the time of observation. An additional 87 young adults had emerged. Mortality was high at 31.7° and only six progeny developed beyond the fourth instar. In the study of the weevil from white spruce, 174 leaders had 1760 living progeny at the time of observation and an additional 480 young adults had emerged.

Table II. Oviposition punctures, eggs, and female mortality during 4 days at various temperatures (°C) for *Pissodes strobi* from Sitka and white spruce

	Sitka spruce						White spruce		
	Test 1			Test 2					
Regime No.	Mean*	S.E.	Mort. (%)	Mean	S.E.	Mort. (%)	Mean	S.E.	Mort. (%)
				Oviposition punctures/female					
1	–	–	–	0.50	0.20	0	1.20	0.56	0
2	3.00	0.73	0	1.70	0.69	0	2.70	1.21	0
3	5.95	1.65	5	7.45	1.75	0	7.30	1.43	0
4	6.35	2.06	10	5.80	1.89	35	6.85	1.57	10
5	5.80	2.36	40	5.85	1.95	30	7.35	2.77	40
6	1.75	0.52	5	0.60	0.24	10			
7	2.30	0.71	10	0.75	0.29	15			
8	5.55	1.09	5	0.78	0.47	35			
9	2.55	0.77	0	2.05	0.49	0			
10	4.55	1.41	5	2.40	0.62	25			
11	4.00	0.94	10	1.23	0.36	25			
				Eggs/female					
1	–	–		1.40	0.55		1.41	0.72	
2	4.85	1.39		3.75	1.31		3.30	1.57	
3	11.90	3.18		15.55	3.70		9.00	2.19	
4	10.75	3.00		10.95	3.33		11.20	2.93	
5	10.10	3.37		10.15	3.48		8.95	3.43	
6	3.05	0.99		1.00	0.48				
7	3.65	1.12		1.45	0.54				
8	10.25	1.81		2.00	1.24				
9	4.40	1.36		3.70	0.90				
10	9.15	2.58		5.30	1.36				
11	7.85	2.02		2.70	0.87				

*Based on number of females at beginning of test.

Again mortality was severe at the highest temperature (32.8°C) and, although fourth instar were present as early as 10 days, none developed beyond this stage. Data for these high temperatures are not included in the following discussion.

The ranges of head-capsule size were similar to those obtained by Silver (1968) and Stevenson (1967) for the weevil from Sitka spruce and Engelmann spruce, respectively. No effect on size due to different rearing temperatures was evident.

The number of days for 50% of the progeny to reach each stage was plotted over average temperature in Fig. 1. Fluctuating temperatures appeared to have no different effect than constant temperatures on the development of the progeny. The minimum temperatures were in effect for only 8 h daily and the results suggest that they were so close to the threshold temperature that their effect was not evident.

The statistics for the regressions of the reciprocal of days required on temperature minus the threshold are shown in Table III. The regression coefficients for all lines with three or more points were significant, except the one for emergence for the weevil from Sitka spruce. This line, however, is based only on three points which follow a pattern similar to the corresponding points for the young adult stage.

Estimates of the developmental threshold temperature, based on the x-intercepts, averaged 7.4° and 7.8°C for Sitka and white spruce, respectively. Nevertheless, the y-intercept of none of the lines was significantly different from zero. Therefore, 7.2°C, the original rough estimate, is accepted as the developmental threshold.

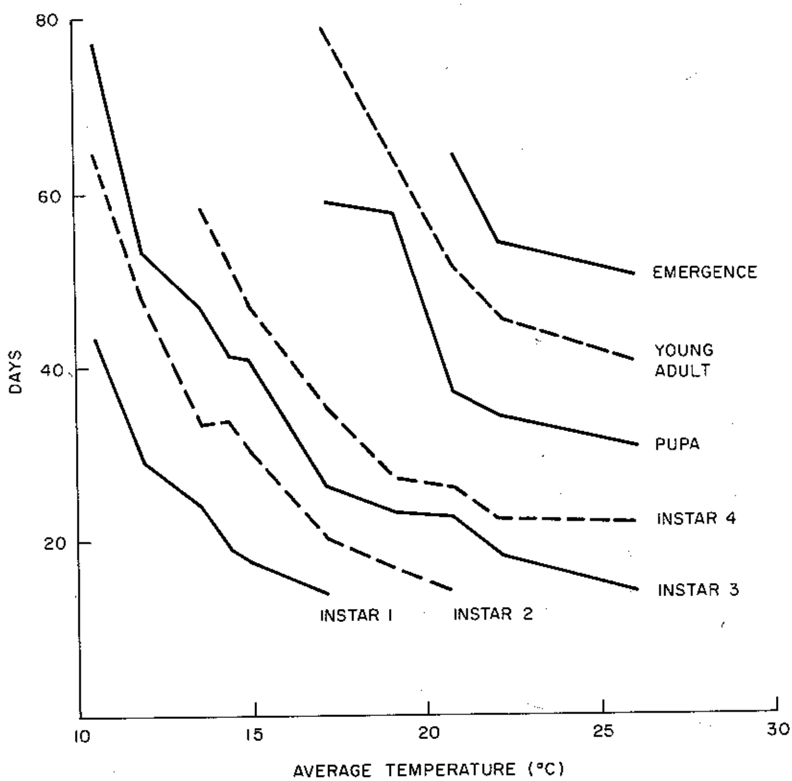

FIG. 1 Number of days including the day equivalents of the oviposition period for 50% of individuals of *Pissodes strobi* reared in Sitka spruce laterals to reach each stage of development at various average temperatures.

Table III. Statistics of regressions of the reciprocal of days required for 50% of the brood to reach each stage of development (Y) on temperature minus 7.2°C (X) for *P. strobi* from Sitka and white spruce

Stage	n	b (1×10^{-4})	a (1×10^{-4})	r	$S_{y.x}^2$ (1×10^{-4})	b'† (1×10^{-4})
			Sitka spruce			
Instar 1	6	72.52	−17.60	0.993**	0.050	70.10
Instar 2	8	53.39	−53.49	0.992**	0.065	47.74
Instar 3	10	35.81	− 5.90	0.991**	0.065	35.32
Instar 4	8	25.00	26.80	0.967**	0.095	27.09
Pupa	5	19.20	−22.71	0.924*	0.096	17.64
Young adult	4	13.38	3.88	0.969*	0.024	13.64
Emergence	3	7.14	66.97	0.894	0.019	11.28
			White spruce			
Instar 1	2	77.78	11.56	–	–	79.76
Instar 2	3	57.14	−11.57	0.999*	0.053	56.00
Instar 3	3	47.58	−24.48	0.998*	0.066	45.28
Instar 4	4	36.62	−25.77	0.991**	0.177	34.81
Pupa	3	24.11	−39.65	0.998*	0.014	21.50
Young adult	3	16.36	− 5.00	0.998*	0.006	16.03
Emergence	2	14.26	−25.43	–	–	12.74

*,**Significant at 95 and 99%, respectively.
†Slope of line through zero.

Those regressions available for testing (instars 2 to 4, pupa, and young adult) showed significant differences ($p \leq .05$) in either slope or level between the two groups of insects (Freese 1967). The slopes were consistently higher (Table III), although not always significantly so, for the weevil from white spruce. These differences suggest that this group utilizes heat more efficiently for development, perhaps a climatic adaptation.

Estimates of the number of days required for development to each stage and the duration of each stage at 20°C, and the number of degree-days above 7.2°C required, based on lines through zero, are shown in Table IV.

No pupae were found at 15°C or lower by 65 days for the weevil from Sitka spruce, but emergence occurred by 95 days and pupation occurred by 55 days for the weevil from white spruce at 14.2°. Unfortunately, 65 days was the maximum time the Sitka

Table IV. Number of days required for development to each stage and duration of stage (days) at 20°C and number of degree days above 7.2°C required for *P. strobi* from Sitka spruce and white spruce based on b′, Table III

	Source of weevils					
	Sitka spruce			White spruce		
Stage	Days to stage	Duration of stage	Degree-days	Days to stage	Duration of stage	Degree-days
Egg	–	11.1	–	–	9.8	–
Instar 1	11.1	5.3	142	9.8	4.1	126
Instar 2	16.4	5.7	210	13.9	3.3	178
Instar 3	22.1	6.7	283	17.2	5.3	221
Instar 4	28.8	15.6	369	32.5	13.9	288
Pupa	44.4	13.1	568	36.4	13.4	465
Young adult	57.5	11.9	736	49.8	11.5	636
Emergence	69.4	–	888	61.3	–	785

spruce material was left in the temperature chamber. However, Carlson (1971) found that at 15.6°, development of the weevil from Sitka spruce did not proceed beyond prepupal larvae which had formed pupal chambers.

Conclusion

The rate of oviposition by the weevil from both Sitka spruce and white spruce was similar, with maximums at 20° to 26°C. The rate of development was faster for the weevil from white spruce, requiring about 785 degree-days above 7.2°C, compared with 888 degree-days for the weevil from Sitka spruce. Examination of weather records should indicate if weather would preclude successful oviposition during May and June, the oviposition period, and whether enough summer heat is present to allow development of the insect.

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(Received 26 November 1975)