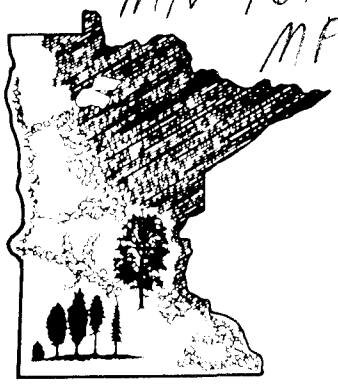

Minnesota Forestry Research Notes

No. 259
January 1977

TEMPERATURE SCHEDULES FOR OVERWINTERING YELLOWHEADED SPRUCE SAWFLY COCOONS IN THE LABORATORY

Mark W. Houseweart, D. E. Rau, and H. M. Kulman *

ABSTRACT

Twenty-four overwintering temperature schedules for cocoons of the yellowheaded spruce sawfly Pikonema alaskensis (Rohwer) were analyzed using simple and multiple regression. Groups of 100 cocoons were given various combinations of 25, 15, 8 and 0° C temperatures during a 3 to 7 month period. The treatment with a 7 month duration, with 3 months at 0°C produced the best emergence of adult insects (70%). Temperatures of 0 and 8° C had nearly equal effects.

The yellowheaded spruce sawfly, Pikonema alaskensis (Rohwer), is a serious defoliator of young white spruce, Picea glauca (Moench) Voss, growing in open areas. Ornamentals, shelterbelts, nurseries, and young plantations are most susceptible. The biology and instar determination has been studied by Nash (1939) and VanDerwerker and Kulman (1974). Adults emerge in late May and oviposit in the newly developing needles of white spruce trees. The larvae feed on the foliage for approximately 45 days, drop to the ground in mid-July and spin cocoons. These prepupal larvae remain in the ground for nearly 10 months. Pupation occurs about a week prior to adult emergence.

During our studies on the yellowheaded spruce sawfly, we needed an optimal laboratory overwintering schedule to obtain adult sawflies for winter experiments and to determine parasitism. This paper deals with the various temperature schedules used and the resulting emergence.

* Respectively, Research Assistants and Professor, Dept. Entomology, Fisheries, and Wildlife, Univ. of Minn. Respective addresses of the first two authors are School of Forest Res., University of Maine, Orono, Maine 04473; and State Office Bldg., St. Paul, MN 55101.

Methods

In July 1974, 2400 late 5th instar yellowheaded spruce sawfly larvae were collected from white spruce plantations near Grand Rapids, Minnesota. The larvae were reared on fresh white spruce foliage in 3-gallon cardboard cartons with screen tops. A 1:1 sand-sawdust mixture was provided as a cocooning medium. Cocoons were retrieved by sifting. There were 24 temperature schedules, each applied to 100 "normal" cocoons. Pairs of cocoons were placed in ½ dram vials which were stoppered with cigarette filters. All treatments were kept in environmental chambers at various combinations of 15, 8, and 0° C with a relative humidity of 60-65%. Depending on the schedule, temperatures were changed at 1 month intervals. Most treatments started and ended with 15° C since this simulated field temperatures.

The number of adult sawflies, pupae, live and dead prepupal larvae, and parasites were tabulated in each treatment 15 days after the final month at 15° C. Cocoons which did not exhibit adult emergence were dissected. Simple and multiple regression analyses were performed on the data to determine which factors (e.g. duration at 0° C) explained most of the variability in adult emergence.

Results and Discussion

Table 1 shows the 24 treatment schedules, survival percentages, and development of various stages grouped according to total treatment duration. Group A consisted of 7 months with no variation in temperatures. All other groups had a cold treatment, but total treatment duration varied as follows: group B, 7 months; group C, 6 months; group D, 5 months; group E, 4 months; group F, 3 months; and group G, 4 months but initiated with 8° C temperature instead of 15°C. Treatment group A, without cold

Published by the School of Forestry, University of Minnesota, St. Paul, Minnesota 55101, cooperating with the Division of Forestry, Minnesota Conservation Department, and Forest Industries of Minnesota

temperatures resulted in 97-100% mortality of the prepupal larvae. This rate of mortality was almost 3 times as great as any other treatment. Evidently, this sawfly requires at least some cold treatment to break diapause.

The pupal stage lasts approximately 6 days (Nash, 1939) and since there was very little mortality in this stage, adult sawflies, pupae, and sawfly parasites were pooled for the Y component in the regression analysis. Adult insects (Y) was the goal or measure of success in these overwintering schedules.

Group B gave the best mean emergence of 60 adult insects. Within group B, additional 15° C temperatures before the cold treatment decreased the number of emerging adults in a linear trend. Group C averaged 32, while groups D, E, F, and G yielded nearly zero emergence. However, since dissections of cocoons were made 15 days after the terminal 15° C temperature, it is not possible to ascertain whether diapause had been broken or not, or whether the low emergence and high values in live prepupal larvae were simply the result of short treatment duration. In comparing means of live prepupal larvae in groups E (77.2) and G (78.6), both with 4 months duration, there seems to be little difference whether the treatments started with 15° C or 8° C. Wetzel et al. (1973) refer to unpublished data showing that the length of the warm period before cold exposures did not affect the utilization of yoke in pharate larvae of the forest tent caterpillar, Malacosoma disstria Hübner.

Comparing individual treatments within groups, no clear differences are evident between the effects of 0° vs. 8° C since survival of prepupal larvae was about equal in treatment groups D, E and F with all combinations of 0° and 8° C cold treatments. However, in assuming equal effects of 0° and 8° C, we cannot ignore the possibility that the number of adults might have been different if the post cold period had been longer than 1 month.

All of the parasites completed development by the end of the study in all treatment groups except A, F, and G. The rate of parasitization could not be determined before the study was started since the larvae were collected in the field. Mean parasitism per group was as follows: groups A, F, and G, 0.0; group B, 3.0; group C, 2.0; group D, 7.5; group E, 3.75. There were 8 Syndipnus gaspesianus (Provancher), 3 S. rubiginosus Walley, and 4 Rhorus sp., all ichneumonids; 3 Ichneutes pikonematis Mason, a braconid, and 48 undetermined immature hymenopterous parasites.

Regression Analysis:

Results of regression analyses are shown in table 2. Initially all 24 treatments were used in simple and multiple regressions with Y, the dependent variable, being the sum of sawfly adults, pupae, and parasites. The following is a list of the independent variables (X) and their derivation:

X_1 = Total time (duration of the treatment in months)

X_2 = Day degrees of the first 2 months (°C of first month x 30 + °C of second month x 30)

X_3 = Degree difference during first 2 months (°C of first month - °C of second month)

X_4 = Day degrees of the last 2 months (same calculation as X_2)

X_5 = Degree difference during last 2 months (°C of last month - °C of penultimate month)

X_6 = Duration at 0° C (number of months at 0° C)

From table 2, using all treatments, total time (R^2=46.6%) and duration at 0° C (R^2=27.2%) are the most important variables accounting for the variability in Y. In the multiple regression analysis, although all variables were significant if (V_1) total time was included, only (V_6) duration at 0°C was retained since it contributed 14% in explaining the variability in Y. Again total time (X_1) and duration at 0° C (X_6) accounted for the most variability in the model (60.6%).

Results of the analyses using all treatments showed that the speed at which cocoons are cooled and warmed and the severity of the reduction or increase in temperature, on a monthly basis, are less important than total time and duration at 0° C.

In additional regression analyses group A was excluded, since the temperatures were not varied, which gave more emphasis to 0° and 8° C. We used the same dependent variable (Y) but the independent variables were as follows:

X_1 = Total time

X_2 = Duration at 0° C

X_3 = Duration at 8° C

X_4 = Duration at 0° + 8° C

Correlations between the independent variables become evident since all include duration. Total time was correlated with duration at 0° + 8°C, R^2 = .87; while both duration at 0°C (X_2) and duration at 8°C (X_3) were

correlated with duration at 0° + 8° C (X_4) R^2 = .61. With such high correlations between independent variables (X), it can be seen from the multiple regression analyses (group A removed) that after total time (X_1) is included in the model the other variables, although significant, do not contribute substantially in explaining the variability in Y.

While total time is the most important variable with group A removed, it is again evident that length of time (7 months) in group A (table 1), with no decrease in temperature, yields poor emergence.

Conclusions

The 4 best treatments, on the basis of total number of adult insects were: 3, 4, 5, and 8. Of these, treatment 3 gave the most favorable combination of high emergence and low mortality under the conditions of 1 month temperature sequences.

Within the treatment time periods in this study, we can infer that (1) exposure to temperatures below 15° C for 1 month are required for the survival of the prepupal larvae and parasites; (2) either 0° C or 8° C are satisfactory cold temperatures for the survival of the overwintering prepupal larvae and parasites; (3) 7 months are required for the development of 48-70% of the sawflies; (4) this period probably can be shortened by omitting the pre-chill temperature of 15° C prior to the cold period; and (5) that parasites can develop after 1 month of exposure at 15° C followed by 2 or more months of cold exposure before the post-chill temperature of 15° C.

In reference to conclusion (2) above, subsequent laboratory rearings indicate the 0° C is better than 8° C for the cold exposure period. Sawfly development occurs at 8° C, making prediction of emergence time difficult.

While these findings present a way to overwinter yellowheaded spruce sawfly larvae and rear parasites in the laboratory, they fail to delineate the minimum period required to overwinter prepupal larvae. Future studies should include: treatments which provide extended time during the post-chill period; temperature sequences of less than 1 month; and temperature and time sequence to determine if the time at 8° C reduces the required post-chill period at 15° C.

Literature Cited

Nash, R. W. 1939. The yellow-headed spruce sawfly in Maine. J. Econ. Entomol. 32:330-4.

VanDerwerker, G. K., and H. M. Kulman. 1974. Stadium and sex determination of yellow-headed spruce sawfly larvae, Pikonema alaskensis. Ann. Entomol. Soc. Am. 67:29-31.

Wetzel, B. W., H. M. Kulman, and J. A. Witter. 1973. Effects of cold temperatures on hatching of the forest tent caterpillar, Malacosoma disstria (Lepidoptera: Lasiocampidae). Can. Entomol. 105:1145-9.

The assistance of the Blandin Paper Company and Mr. C. Peterson of their staff is gratefully acknowledged.

Published as Minnesota Agriculture Experiment Station Scientific Journal Series Paper No. 1650

Table 1. The effects of 24 temperature schedules on the survival and development of yellowheaded spruce sawfly. Since each treatment used 100 cocoons, the numbers are equal to percentages. Adult insects are sum of sawfly parasites, sawfly adults and pupae.

Treatment Group	No.	Temperature (°C) by Month							Number Prepupal Larvae		Number Adult Insects
		July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Alive	Dead	
A	1	25	25	25	25	25	25	25	0	97	3
	2	15	15	15	15	15	15	15	0	100	0
B	3	15	8	0	0	0	8	15	16	14	70
	4	15	15	8	0	0	8	15	2	35	63
	5	15	15	15	8	0	8	15	32	20	48
C	6	15	0	0	0	8	15	-	37	35	28
	7	15	8	0	0	8	15	-	30	34	36
	8	15	8	0	0	8	15	-	41	11	48
	9	15	8	0	8	8	15	-	40	29	31
	10	15	8	8	0	8	15	-	27	38	35
	11	15	15	8	0	8	15	-	57	28	15
D	12	15	0	0	0	15	-	-	74	17	9
	13	15	0	0	8	15	-	-	57	31	12
	14	15	8	0	0	15	-	-	68	23	9
	15	15	8	0	8	15	-	-	73	22	5
E	16	15	0	0	15	-	-	-	72	22	6
	17	15	8	0	15	-	-	-	75	23	2
	18	15	0	8	15	-	-	-	76	19	5
	19	15	8	8	15	-	-	-	86	12	2
F	20	15	0	15	-	-	-	-	87	11	2
	21	15	8	15	-	-	-	-	86	14	0
G	22	8	0	15	-	-	-	-	86	14	0
	23	8	0	0	15	-	-	-	84	14	2
	24	8	0	8	15	-	-	-	66	34	0

Table 2. The square of the correlation coefficient (R^2) of simple and multiple regression analyses of overwintering treatments for yellowheaded spruce sawfly cocoons (Y-total adult insects) for all treatments and treatments excluding group A.

SIMPLE REGRESSION ALL TREATMENTS

Variable	R^2	F
X_1 = Total time	.466	**
X_2 = Day degrees of first 2 months	.056	
X_3 = Degree difference during first 2 months	.074	
X_4 = Day degrees of last 2 months	.003	
X_5 = Degree difference during last 2 months	.059	
X_6 = Duration at 0 C	.272	**

SIMPLE REGRESSION EXCLUDING GROUP A

Variable	R^2	F
X_1 = Total time	.799	**
X_2 = Duration at 0 C	.194	*
X_3 = Duration at 8 C	.277	**
X_4 = Total time at 0 + 8 C	.631	**

MULTIPLE REGRESSION ALL TREATMENTS

Variable #	R^2	F
All (1, 2, 3, 4, 5, 6)	.708	**
$V_{1, 3, 4, 5, 6}$	.703	**
$V_{1, 4, 5, 6}$	.675	**
$V_{1, 4, 6}$	.650	**
$V_{1, 6}$	.606	**

MULTIPLE REGRESSION EXLUDING GROUP A

Variable #	R^2	F
$V_1 + V_2$	.800	**
$V_1 + V_3$	.799	**
$V_1 + V_4$	.800	**
$V_1 + V_2 + V_3$	.800	**
$V_1 + V_4 + V_2$	.800	**
$V_1 + V_4 + V_3$	.800	**

** F significant (.01) * F significant (.05) # Subscripts same as in simple regression