The Great Lakes Entomologist

Volume 24
Number 4 - Winter 1991 *Number 4 - Winter 1991*

Article 10

December 1991

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EFFECT OF TEMPERATURE ON DEVELOPMENT RATE AND SURVIVAL OF *NOMOPHILA NEARCTICA* (LEPIDOPTERA: PYRALIDAE)

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ABSTRACT

Development of *Nomophila nearctica* was studied under six constant temperatures in controlled temperature cabinets. Developmental threshold temperatures for egg, larval, and prepupal-pupal stages were 8.9, 11.5, and 9.2°C. The overall mean developmental threshold temperature for all stages was 9.9°C. Degree-day summations, based on the above threshold temperatures, averaged 50, 304, and 181 DD for the egg, larval, and prepupal-pupal stages, respectively. Total heat units of 535 DD are required for development from oviposition to adult emergence. Head capsule measurements indicated six larval instars.

Nomophila nearctica Munroe (Lepidoptera: Pyralidae) is mainly distributed throughout North and Middle America (Munroe 1973). Recently, *N. nearctica* was recognized by Munroe (1973) as a New World species and *N. noctuella* Schiff. as an Old World species. Literature references made to North American populations of *N. "noctuella"* before 1973 were in fact *N. nearctica* including MacKay's (1972) description of the larva of *N. nearctica*. Little has been published on its life stages, host preference, and seasonal abundance.

Felt (1893) observed *N. nearctica* in a grass and clover pasture in New York, noting that larvae fed mainly on legumes, purslane, mustard, and cinquefoil. Flint (1922) reported that newly seeded fields of sweet clover on the Illinois Agricultural Experiment Station farm at Urbana were damaged by *N. nearctica*. According to Flint (1922), its chief larval food plants are red and sweet clovers, and alfalfa, but may also feed on soybeans and white clover. Smith (1942) reported *N. nearctica* in alfalfa fields and grasslands in Kansas. Drake and Decker (1927) noted that *N. nearctica* is an occasional pest of minor importance to legumes, bluegrass, foxtail, celery, corn, and a number of other plants. Flint (1922) and Smith (1942) both stated that this species has feeding and webbing habits similar to the crambids or "sod webworms."

We have observed that *N. nearctica* is one of the most common summer moths found in grassy and turf areas in central Illinois. However, data about its biology and pest status are unclear. We have noted that to the untrained eye of the homeowner and turf manager, the larval stage and webbing habits of *N. nearctica* may often be confused with sod webworm (*Pediasia* spp.) larvae. Because of its abundance and rather broad host range, it is possible that feeding damage observed in

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grassy or turf areas attributed to the sod webworm (*Pediasia* spp.) may be in fact due to *Nomophila nearctica*.

To facilitate prediction of seasonal abundance of field populations of *N. nearctica*, we present results here of a laboratory study to determine the temperature-related development of *N. nearctica*.

MATERIALS AND METHODS

During the summer of 1986, female moths were collected from lawns and grassy field borders in Champaign, Illinois and placed in empty 11 mm glass vials with a moistened cotton plug. Females were held overnight at ca. 21°C and monitored for oviposition on the inside surface of the vial. Within 5–6 hours of oviposition, the vials with 3–4 egg masses of 15–30 eggs each were randomly placed in temperature cabinets set at one of six constant temperatures: 10°C, 15°C, 20°C, 26°C, 29°C, and 33°C. Cabinets had a 16:8 (L:D) photoperiod and 50–60% RH. Only the time required for egg hatch was recorded at each of the respective temperatures; no attempt was made to record egg mortality.

After eclosion, the first instar larvae were carefully removed from the vials, placed on beet armyworm (*Spodoptera exigua* [Hubn.]) diet (Shorey and Hale 1965) in 30 ml plastic cups sealed with a paper lid, and randomly assigned to a given temperature regime. Thirty first instar larvae were used for each of the six temperature regimes. Data collection commenced when the first instar larvae were placed on the artificial diet and terminated at adult emergence. We made daily observations of mortality, molting, pupation, and adult emergence.

Head capsules were removed from the diet cups after each molt and preserved in 70% ethanol for future measurements. Width of all pooled (N = 180) head capsules from all six temperatures was recorded with a binocular microscope fitted with an ocular micrometer.

Threshold temperatures for development were estimated using the X-intercept method (Arnold 1959). Average days at each stage were converted to percent development per day and plotted against respective temperatures (Rubenstein et al. 1986). Extrapolation of the computed regression line to the X-intercept provided an estimation of the temperature at zero rate of development. This temperature is assumed to be the developmental threshold (X-intercept method). Centigrade degree-days for egg, larval, and prepupal-pupal stages were calculated according to Arnold (1959). The equation $C = D(T-K)$ was used where C = degree days (°C), D = developmental time (days), T = experimental constant temperature (°C), and K = threshold temperature (°C) (King et al. 1985). Data was analyzed with the Solo Statistical System, Version 2.0. (Jandell Scientific).

RESULTS AND DISCUSSION

Developmental time rates for all stages at the six temperature regimes are presented in Tables 1 and 2. Between 15°C and 33°C, mean developmental time (days) decreased for all stages. Overall stage-specific survivorship from larval eclosion through adult emergence ranged from 0.0% at 10°C to 73% at 29°C (Table 3). In our study, it appears that 29°C is the optimum developmental temperature for *N. nearctica* (Table 3).

Developmental rates for the egg stage are presented in Table 1. At 10°C, egg hatch occurred, but no larvae lived past the second stadium (Tables 1–3). Low egg survival at 10°C in this study is similar to results obtained by Heinrichs and Matheny (1965) in which only 3% of sod webworm, *Pediasia trisecta* (Walker) eggs survived at 10°C.

Table 1. — Development period (days) of *N. nearctica* reared on artificial diet at six temperatures under a 16:8 (L:D) photoperiod, N=30.

	Mean Duration in Days (± S.D.)		
Temp. (°C)	Egg	Larva	Prepupa-Pupa
10	16.0 (0.51)	–	–
15	11.2 (0.50)	76.1 (3.71)	33.0 (0.71)
20	4.8 (0.74)	37.4 (1.62)	16.4 (1.09)
26	3.3 (0.60)	24.2 (1.84)	10.2 (0.89)
29	2.8 (0.64)	15.4 (0.89)	9.4 (1.17)
33	1.9 (0.63)	14.6 (0.91)	7.6 (1.06)

Table 2. — Duration of development period (days) of *N. nearctica* larvae reared on artificial diet at six temperatures under a 16:8 (L:D) photoperiod, N=30.

	Mean Duration in Days (±S.D.) Instar					
Temp. (°C)	1st	2nd	3rd	4th	5th	6th
10	11.8 (1.79)	14.7 (5.54)	–	–	–	–
15	11.2 (0.37)	10.9 (0.13)	10.1 (1.21)	11.2 (1.27)	10.7 (0.78)	22.0 (2.83)
20	4.5 (0.51)	7.5 (0.51)	5.0 (0.52)	6.2 (1.36)	6.2 (1.96)	8.0 (0.76)
26	2.4 (0.40)	2.5 (0.52)	2.1 (0.51)	5.6 (0.56)	6.0 (0.82)	5.6 (0.96)
29	2.2 (0.50)	1.8 (0.51)	1.9 (0.52)	2.4 (0.53)	3.6 (0.51)	3.5 (0.68)
33	2.4 (0.53)	1.9 (0.51)	2.0 (0.52)	2.1 (0.82)	3.1 (1.03)	3.1 (1.16)

Table 3. — Percent survival of *N. nearctica* stages reared on artificial diet at six temperatures under a 16:8 (L:D) photoperiod, N=30.

	Instar[a]							
Temp. (°C)	1st	2nd	3rd	4th	5th	6th	Prepupal-Pupal	% Surv. to Adult[b]
10	16.6	13.3	0.0	0.0	0.0	0.0	0.0	0.0
15	36.6	16.6	16.6	16.6	16.6	16.6	13.3	6.6
20	100.0	100.0	53.3	43.3	43.3	43.3	43.3	43.3
26	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.3
29	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3
33	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3

[a]Percent stage-specific survivorship is the quotient of the number of individuals entering that particular life stage and the sample size x 100 (N=30).
[b]Percent survivorship to adult is the quotient of the total number of adults that emerged and the sample size x 100 (N=30).

Extrapolation of the regression equation ($y = -17.371 + 1.9464x$) for egg development vs. constant temperature indicated a X-intercept developmental threshold of 8.9°C (Table 4). The thermal requirement for egg development, averaged over all constant temperatures with 8.9°C as a base, was 49.6 DD. We recognize that this linear relationship is due to the limited number of temperatures used in our study. Extensions of the temperature range below 10°C and above 33°C would have

Table 4. — Regression equations for the development rate of *N. nearctica* immature stages in relation to temperature.

	LDT[a]	$\bar{X}$ DD[b]	Regression Equation	r^2
Egg	8.9	49.6	y = -17.371 + 1.9464x	0.96
Larva	11.5	303.7	y = -3.7446 + 0.32661x	0.96
Pupa	9.2	181.4	y = -5.1125 + 0.55522x	1.00

[a]LDT = Lower Developmental Threshold
[b]DD = Degree Days

probably resulted in a non-linear developmental curve, which is common with most insects (Howe 1967, Wagner et al. 1984).

Larval development at the five constant temperatures is summarized in Tables 1–2. With the exception of 10°C, in which larvae did not survive past the second stadium, survival ranged from 16.6% at 15°C to 73.3% at 29°C (Table 3).

Extrapolation of the regression equation (y = -3.7446 + 0.32661x) for larval development vs. constant temperature revealed a developmental threshold of 11.5°C (Table 4). A mean degree day summation, using 11.5°C as a base temperature was calculated to be 303.7 DD (Table 4).

Prepupal-Pupal development is presented in Table 1. Survival for the prepupal-pupal stage ranged from 13.3% at 15°C to 73.3% at 29°C (Table 3). The X-intercept linear regression equation (y = -5.1125 + 0.55522x) resulted in a developmental threshold of 9.2°C (Table 4). The mean degree day summation for the prepupal-pupal stage was 181.4 DD using 9.2°C as a base threshold.

Developmental thresholds for the egg, larval, and prepupal-pupal stages were averaged to obtain an overall mean developmental threshold of 9.9°C. Total heat units of 534.7 DD are required for development from oviposition to adult emergence.

In general, the number of days spent by *Nomophila nearctica* in each immature stage in this study, conducted under laboratory conditions, are comparable (6 days or less) with data gathered on *N. nearctica* from field observations and field insectary studies in Kansas conducted by Smith (1942) and in Illinois by Flint (1922) (Table 5). However, since no specific temperature data were reported by Smith (1942) nor by Flint (1922), weather data for the summers (May–August) of 1940–1941 and 1919–1920 were obtained from the Weather Data Library at Kansas State University, Manhattan and the Midwest Climate Center at the University of Illinois, Urbana, respectively. Smith (1942) commented that in mid-summer (July–August) larval development in the field took one month (Table 5). Mean temperature for July-August 1940 and 1941 at Manhattan, Kansas was ca. 27°C. In our study, larval developmental time at 26°C was 24.2 days (Table 5). However, a noticable difference was observed in larval developmental time under field insectary conditions in which Smith (1942) reported that during May and June, larval developmental time was ca. 17 days (Table 5). No specific year was mentioned, but in May–June 1940–1941, weather records indicate an overall mean temperature of 21°C. In our study, larval development took 37.4 days at 20°C (Table 5). According to Flint (1922), during the seasons of 1919 and 1920, the average period from adult to adult was 50 days and the average egg period was six days; average larval period 30 days; average pupal period 10 days (Table 5). Mean temperature for June–August 1919–1920 was 23°C. At mean developmental times for 20°C and 26°C, results from our laboratory study are comparable to Flint's (1922) for the egg, larval, and prepupal-pupal life stages (Table 5).

We realize that any comparison between our study and those of Smith (1942) and Flint (1922) is weakened by neither author reporting field rearing temperature

Table 5.—Comparison of field observations, field laboratory rearing and laboratory rearing studies of *N. nearctica.*

FIELD OBSERVATIONS

Stage	Mean no. Days in Each Stage Smith (1942) (27°C)[a]	This study (26°C)
Egg	3–4	3.3
Larval	30	24.2
Prepupal-Pupal	–	10.2

FIELD INSECTARY STUDIES

Stage	Mean no. Days in Each Stage Smith (1942)[b] (21°C)	Flint (1922)[c] (23°C)	This Study (20°C)	(26°C)
Egg	3.0	6.0	4.8	3.3
Larval	17.2	30.0	37.4	24.2
Prepupal-Pupal	10.5	10.0	16.4	10.2

[a]$\bar{X}$ temperature 27°C for July-August 1940–1941, obtained from Weather Data Library Kansas State University, Manhattan.
[b]$\bar{X}$ temperature 21°C for May-June 1940–1941, obtained from Weather Data Library Kansas State University, Manhattan.
[c]$\bar{X}$ temperature 23°C for June-August 1919–1920, obtained from Midwest Climate Center, Urbana.

Table 6.—Head capsule width of larval *N. nearctica* reared on artificial diet at six temperatures under a 16:8 photoperiod.

Instar	$\bar{X}$ Headcapsule width (mm.)	(±S.D.)
I	0.2496	0.0059
II	0.3717	0.0277
III	0.5119	0.0555
IV	0.7553	0.0654
V	1.1421	0.1525
VI	1.7677	0.0610

data nor host plants used during the rearing study, whereas larvae studied in our experiments were reared under constant temperatures and on artificial diet.

A summary of head capsule meaurements for the instar classes for all temperature regimes is presented in Table 6. These measurements indicate six larval instars. No overlap occurred between successive instars. Head capsule widths are comparable with measurements taken by Smith (1942) on field reared larvae in Kansas.

Additional study is needed to determine seasonal abundance of *N. nearctica* and to better understand host plant feeding preferences as it relates to potential economic damage in turf management and production.

ACKNOWLEDGMENTS

We express our sincere appreciation to D. Mahr, University of Wisconsin, K. Eastman and G. Godfrey, Illinois Natural History Survey, and R. Weinzierl, University of Illinois for their review of the manuscript.

Special thanks are due to E. Brewer, Illinois Natural History Survey, and the staff of the Weather Data Library, Kansas State University for their assistance in procuring weather data.

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