The Effects of Rearing Temperatures on Certain Aspects
of the Biology of Corcyra cephalonica (Stainton), the Rice Moth[*]

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The rice moth, Corcyra cephalonica (Stainton) is an important
lepidopteran pest of stored products, especially in the tropics. It infests a
wide range of products, such as rough and milled rice, sorghum, millet,
groundnuts, cocoa (Rao 1954) and coffee (Bitram and Oliveira 1978). The
development of C. cephalonica has been studied on some grains, processed
cereals and oilseeds. Cox et al. (1981) reared C. cephalonica on wheat feed
at temperatures and relative humidities likely to be encountered in Britain.
Russel et al. (1980) determined the development on millet and sorghum at 28°C
and different relative humidities. Kamel and Hassanein (1967) reared the moth
on cornmeal at 27.2 and 18.2°C with 55.4 and 56.8% RH, respectively. Rao
(1954) reared the moth on many cereals, oilseeds and spices without control
over temperature and RH. Ayyar (1934) presented an account of the life cycle
of C. cephalonica but did not indicate the experimental conditions.

The objective of this research was to study the biology of C. cephalonica
at three temperatures near the optimum for this moth, and to determine whether
small differences in temperature near the optimum affect the life cycle of
this insect significantly enough to change population growth characteristics.

MATERIALS AND METHODS

A stock culture of C. cephalonica was obtained from the USDA
Stored-Product Insects Research and Development Laboratory at Savannah,
Georgia in 1981. The moth was maintained at 27±1°C and 68±2%RH with a 14L:10D
photoperiod on a rearing medium composed of the following (by volume):

cornmeal	4 parts
whole wheat flour	4 parts
Purina Lab Chow dog food	2 parts
rolled oats	1 part
brewer's yeast	1 part
honey	1 part
glycerine	1 part
wheat germ	0.5 part

To prevent unwanted infestation and/or pathogens, the first four ingredients
were mixed and autoclaved. After cooling for approximately an hour, the
mixture was stored in a cold room (4.5°C) until required. Immediately before
use, the other ingredients were admixed.

A standardized rearing method was used throughout the experiment.
Cultures were started initially with 25 mg of 12 ± 12-hr-old eggs per quart
jar containing 150 g of medium. Before eggs were introduced, the medium was

conditioned under the respective experimental conditions for three days. Pupation sites, which consisted of corrugated cardboard rolls, were placed on the surface of the medium. Jars were closed using lids with brass screen and filter paper.

The three temperatures for these experiments (28 ± 1, 30 ± 2 and 32 ± 1°C) and one relative humidity (68 ± 2%) were maintained at 3 different sites. Hygrothermographs in each site were initially synchronized at 28 ± 1°C and 68 ± 2% RH. At all sites the light cycle was 14L:10D.

Observations were made at each temperature on the following parameters: incubation period, egg fertility, larval development period, number of larval instars, pupal period, number of adults emerged, percent survival from egg to adult, longevity of paired and unpaired males and females, fresh body weight of females, pre- and post-oviposition period, fecundity and the total life cycle. Observations were also made on the handling effects of rearing C. cephalonica in the laboratory.

The incubation period was determined by placing 100 (12 ± 12-hr-old) eggs in petri dishes and by observing daily hatch. Percent hatch was determined separately for 20 replicates of 50 eggs placed in each petri dish.

The number of larval instars was determined by measuring head capsules. Using a fine camel hair brush, 50 neonatal larvae were transferred into a pint jar with 100 g of medium. A total of 150 jars were prepared, 50 for each temperature. Starting on day one and continuing until no larvae could be found, 20 larvae were randomly selected from each jar. Jars from which larvae had been previously selected, were discarded. Larvae were frozen for approximately one hour, then head capsules were measured using an ocular micrometer in a binocular microscope.

Pupal periods were determined by taking daily radiographs of cocoons from 15 days after hatch until eclosion. Cocoons were cut individually from pupation papers and radiographed with Kodak Industrial X-ray Film, Type M, on a General Electric grain inspection x-ray unit. The exposure time was 2.5 min at 20 kilovolts and 5 milliamps.

The longevity of adults was determined by placing sexed pupae individually in 4.5 x 4.5 cm plastic containers ventilated by wire gauze glued into the lid. Fifty adults of each sex, paired or unpaired were observed daily until death (200 adults total).

Fresh body weight was determined for 80 newly-emerged, unmated females frozen for one hour before weighing. Fifty newly-emerged males and females were paired, individually, in 4.5 x 4.5 cm plastic containers and eggs of each pair were counted daily. Pre-oviposition, oviposition and post-oviposition periods were noted.

The total life cycle was determined by averaging the number of days each individual took to develop from oviposition to adult emergence. Cultures for this observation were inoculated with 20 mg of eggs (500 eggs) in a quart jar with 150 g of medium. Three replicates were set up for each temperature. Cultures were undisturbed until emergence was completed.

Similar life cycle data were obtained by totalling the number of days required for each developmental stage in the previous experiments. By comparing these two techniques, handling effects were determined.

RESULTS

The highest temperature (32°C) tended to shorten incubation, larval, pupal and oviposition periods, total life cycle and the longevity of unpaired males and females of C. cephalonica. The pre-oviposition and post-oviposition period increased with temperature. A variable effect of temperature was seen in the fertility, percent egg to adult survival, fecundity and fresh body weight of females.

Eggs

The incubation period was one day longer at 28°C than at 30° and 32°C (Table 1). Fertility was not affected by these temperatures.

Table 1. The effect of temperature on development of Corcyra cephalonica from egg to adult.

Development[1]	Temperature (°C) at 68 ± 2% RH		
	28 ± 1	30 ± 2	32 ± 1
Incubation period (days)[2]	6.2 a	5.2 b	5.2 b
Fertility (%)[3]	35.4 c	38.7 c	33.1 c
Larval period (days)[4]	23.8 d	22.6 e	19.6 f
Pupal period (days)	9.8 g	8.3 h	8.5 h
Total adult emergence[5]	168.0 i	156.0 i	186.0 i
% Survival[6]	31.8 j	30.8 j	36.7 j

[1] Means across columns followed by the same letters were not significantly different at 5% level, Duncan's multiple range test.

[2] Average of 100 eggs.

[3] Average of 20 replicates, 50 eggs each.

[4] Average of 173 ± 24 larvae.

[5] Cultures undisturbed from inoculation to adult emergence, 3 replicates.

[6] Number of adults completing development from the eggs.

Larval and Pupal Period and Instars

The duration of the larval stage showed a significant difference among temperatures (Table 1). Larval period shortened as temperature increased.

The larvae of C. cephalonica were found in six instars at all three temperatures (Table 2). Temperature influenced the range of days larvae were found as a particular instar. Generally, as temperature increased the length of each stadium decreased and also occurred earlier. The first instars at 28°C were found up to 5 days after hatch, at 30° only up to 3 days, and at 32° up to 2 days. Fifth instars were found during day 13-16, 11-13, 9-11 after hatch, from the lowest to the highest temperature, respectively.

The pupal stadium at 28°C averaged 9.8 days (Table 1), significantly longer than at the higher temperatures (P 0.05).

Table 2. The effect of temperature on larval instars of Corcyra cephalonica.

Temp. (°C)	Instar	Days instar found[1] (after hatch)	Size of head capsule (mm)		No. of larvae
			Range	Average	
28	1	1-5	0.168 - 0.218	0.195	48
	2	3-6	0.252 - 0.286	0.266	54
	3	6-9	0.353 - 0.403	0.383	54
	4	8-12	0.504 - 0.672	0.576	68
	5	13-16	0.739 - 0.958	0.851	68
	6	15-28	1.008 - 1.529	1.299	267
30	1	1-3	0.168 - 0.202	0.197	43
	2	3-7	0.235 - 0.286	0.260	60
	3	5-9	0.336 - 0.403	0.373	61
	4	8-10	0.487 - 0.638	0.534	36
	5	11-13	0.739 - 0.857	0.805	56
	6	14-28	1.042 - 1.510	1.210	273
32	1	1-2	0.168 - 0.202	0.194	39
	2	2-4	0.235 - 0.286	0.265	41
	3	5-8	0.353 - 0.454	0.391	38
	4	7-8	0.538 - 0.605	0.576	38
	5	9-11	0.689 - 0.874	0.812	60
	6	12-24	0.991 - 1.478	1.270	223

[1] Days larvae were found in an instar.

Adults

Different temperatures did not cause significant differences in numbers of adults emerged from undisturbed cultures (Table 1) or disturbed cultures. Undisturbed cultures were not handled at the various stages of the life cycle. The fresh body weight of females were significantly different at all 3 temperatures. Unmated females and males lived significantly longer (13.1 and 15.9 days) at 28°C than at the higher temperatures (11.0 days).

The oviposition period at 32°C (2.58 days) was significantly shorter than the oviposition periods at 28°C and 30°C (Table 3). At 32°C the pre- and post-oviposition periods were longer. The three temperatures studied had a variable effect on the fecundity of C. cephalonica (Table 3). The range of eggs laid was 14-323. The longevity of paired adults was not affected.

The small difference in temperature had a significant effect on the total life cycle (oviposition to adult) of C. cephalonica (Table 4). Moths reared (undisturbed) at 28°C had the longest life cycle (40.7 days) compared with 34.5 at 30°C and 31.3 at 32°C..

Another method for obtaining the total life cycle was to add the number of days for the different stages in disturbed cultures. The life cycles averaged 54.6, 47.2 and 43.6 days from the lowest to the highest temperature (Table 4). Handling caused an increase in the development periods of 34, 37 and 39% over that of the corresponding undisturbed cultures at 28°, 30° and 32°C, respectively.

Table 3. The effect of temperatures on the oviposition period, fecundity and fresh body weights of females of Corcyra cephalonica.

Parameters[1]	Temperature (°C) at 68 ± 2% RH		
	28 ± 1	30 ± 2	32 ± 1
Preoviposition (days)[2]	2.6 a	2.5 a	2.9 b
Oviposition (days)[2]	3.3 c	3.7 c	2.6 d
Post-oviposition (days)[2]	2.5 e	2.9 ef	3.5 f
Fecundity (eggs/pair)[2]	83.7 g	105.4 g	94.4 g
Weight of females(mg)[3]	27.6 h	23.3 i	25.7 j

[1] Means across columns followed by the same letters were not significantly different at 5% level, Duncan's multiple range test.

[2] Average of 50 pairs.

[3] Average of 83 ± 7 newly emerged, unmated females.

Table 4. The effect of temperatures and handling on the total life cycle of
Corcyra cephalonica.

Life cycle (days)[1]	Temperature (°C) at 68 ± 2% RH		
	28 ± 1	30 ± 2	32 ± 1
Egg-adult (undisturbed cultures)[2]	40.7 a	34.5 b	31.3 c
Egg-adult (disturbed cultures)[3]	54.6	47.2	43.6
Handling effect (difference in days)	13.9	12.7	12.3

[1] Means across columns followed by the same letters were not significantly different at 5% level, Duncan's multiple range test.

[2] Cultures undisturbed from inoculation to adult emergence. Eggs (20 mg) added to 150 g standard medium (500 eggs), 3 replicates.

[3] Cultures disturbed at each stage of the life cycle.

DISCUSSION

Prediction of Population Size

Theoretically, a population size can be predicted at each temperature by using the generation time (life cycle from egg to adult minus the post-oviposition period), the % survival and the average eggs/female in undisturbed cultures. Table 5 includes the numbers of insects predicted during 105 ± 10 days at each temperature from an initial population of 1 pair of insects. There was one more generation at 32°C than at the two lower temperatures and therefore, a great difference in the possible population size. The population is potentially 40 times greater at 32°C than at 28°C in 105 days. After 120 days, an additional generation could occur at 30°C with a 30 times increase in the population size over that produced at 28°C. Teotia and Singh (1977) found that under conditions of abundant food and space, a population of C. cephalonica on sorghum (at 26.5 ± 1°C and 73 ± 1% RH) could increase more than 200 times in 2 successive generations. When food and space were limited the increase was less.

Table 5. Population prediction for Corcyra cephalonica at three near-optimum temperatures based on fecundity, survival and generation time.

Prediction	Temperature (°C) at 68 ± 2% RH		
	28 ± 1	30 ± 2	32 ± 1
Population[1] in 105 ± 10 days	4714	8553	180,079
Generations[2]	3	3	4

[1] Calculated from 1 pair on day 1 at:
   28°C: 83.7 eggs/$_+$; 31.8% survival; 38.2 days/generation
   30°C: 105.4 eggs/$_+$; 30.8% survival; 31.6 days/generation
   32°C: 94.4 eggs/$_+$; 36.7% survival; 27.8 days/generation.

[2] Life cycle from egg to adult w/o the post-oviposition period.

Biology of the Rice Moth

The differences in data of the present study from the data of other workers, was probably due to differences in strains of moths, rearing media and methodology utilized. Although none of the studies on biology of C. cephalonica reported in the literature are directly comparable to this work, Cox et al. (1981) used a rearing medium of wheat feed, glycerol and yeast in a light regime of 16L:8D. They reported that the percent hatch of eggs at 70% RH and 30°C was 41% while at 32.5°C it was 27%, similar to the 39% and 33% found here. The percent adult survival at 30°C and 70% RH was 82% and 75% for strains from Burma and Malawi, respectively. The fresh body weights of females of the Burma strain averaged 23.5 mg while a Malawi strain was heavier (29.2 mg) at the same temperature. The same authors reported that isolated males and females lived for 14 and 13 days at 30°C and 13 and 11.5 days, respectively at 32.5°C.

Russel et al. (1980) reported that the female larvae of C. cephalonica developed through seven instars and male larvae six when reared separately. Because of the technique used in this study, sex of the larvae was unknown.

CONCLUSION

At the highest temperature used (32°C), the development of C. cephalonica was not hindered. The life cycle, especially the larval period, was shortened and generation time was reduced. Fecundity and survival were not significantly changed. Therefore, it is possible for populations of moths to increase much more rapidly because of an extra generation due to a 2° or 4°C difference in average temperature over 3 to 4 months. This in part explains the pest status of C. cephalonica in the tropical regions of the world.

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