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# Effects of temperature on population growth and intake of food by the army worm, *Mythimna separata* (Walker)

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**Abstract**—Population life tables of the army worm, *Mythimna separata*, were constructed and nutritional parameters of food for the larvae were examined at 5 temperatures from 16°C to 32°C. The temperature suitable for growth and reproduction of the insect ranged from 20°C to 28°C with the optimum of 24°C. Their survivalship and fecundity were much poorer at 32°C than at 16°C. Indices of population trend of the insect at these temperatures could well fitted with the parabolic curve which theoretically indicated that the population density would multiply by some 660 after one generation circle at the optimal temperature, 22.6°C, and it would decline at temperatures higher than 32.9°C or lower than 12.3°C. Larval food intake and their AD tended to go up while their ECI and ECD to go down with a rise in temperature. These alterations in population size and feeding behavior caused by temperature would exert an important effect on their damage to crops.

**Keywords:** temperature; army worm (*Mythimna separata*); life table; nutritional parameters.

The army worm, *Mythimna separata*, is a species of economically important pest insect, mainly attacking the plants of grass family in China. The adult population of the insect migrates from south to north along east part of China during early summer and returns to south during late autumn for overwintering. The larvae eat a lot and could cause a great loss in crop yield in some areas through an oversight in monitoring. There have been several papers concerning growth and development of the army worm in relation to temperature (Li, 1958; Ponds, 1960; Wu, 1964; Helm, 1975; Smith, 1984; Su, 1986), however, most of them only involved one or a few special stages. The data of food nutritional parameters for the larvae are unavailable at present.

This project aims at systematically investigating effects of temperature on the army worm in the form of life table and on utilization and conversion efficiencies of food by the larvae.

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## MATERIALS AND METHODS

### *Insect and food*

An army worm colony was established from some moths collected at Beijing suburb and had been reared on the artificial diet (Table 1) for one generation before tested. The same diet was used in present experiments.

**Table 1** Composition of the artificial diet provided

| Component | Amount, g | Component | Amount, g |
|---|---|---|---|
| Corn leave powder | 30.0 | Sorbic acid | 2.0 |
| Wheat germ | 110.0 | Methyl parahyoxy-benzoate | 4.0 |
| Yeast | 34.0 | | |
| Agar | 18.0 | Linoleic acid | 10.0 (drops) |
| Ascorbic acid | 2.0 | Distilled water | 800.0 (ml) |

### *Methods*

The 5 constant temperatures from 16°C to 32°C were established with the same R.H. (80–90%) and photoperiod (9 hrs. light). The experiments began with the eggs laid within 12 hrs. Soon after hatching, the larvae were transferred on the diet in beakers of 25ml, 10 worms per container. From the 3rd instar they were separately placed on the diet in each of glass tubes (2.5×8.0 cm). Matured larvae were picked out and put into tubes with some moistened soil for pupation. Couples of adult moths with the same age were separately kept in each of glass jars (10×10 cm) covered with gauze and provided with 10% honey solution. Development and survivalship during immature stage and performance of adult moths were monitored. The adults examined at the highest and the lowest temperatures came from the larvae raised at 28°C and 20°C, respectively, because of poor survivalship or ununiformity in adult emergence under these conditions. Population life tables of the insect were constructed following routine procedure (Southwood, 1966; Morris, 1970; Varley, 1970; Wu, 1978). Digestion and utilization efficiencies of food by the larvae during their 5th instar were measured on basis of dry weight (Waldbauer, 1968).

## RESULTS AND DISCUSSION

### *Effects of temperature on development and survivalship*

Table 2 shows that developmental times of eggs and larvae shortened with a rise in temperature up to 28°C. Their periods at 32°C were equal to or longer than those at 28°C, indicating this temperature is unsuitable for them. Both egg viability and larval survival rates at 5 temperatures could well fitted with the parabolic curves (Table 3) with the lowest values for egg stage at 16°C and for larval stage at 32°C (Fig.1).

Table 2 Periods of various stages of the army worm (days)*

| Temp., °C | 16 | 20 | 24 | 28 | 32 |
|---|---|---|---|---|---|
| Eggs | 8.9±0.2 | 6.2±0.1 | 4.0±0.0 | 3.2±0.1 | 3.2±0.1 |
| Larvae | 52.9±0.8 | 32.9±0.4 | 21.6±0.4 | 18.5±0.2 | 19.5±0.5 |
| Pupae | 33.7±0.2 | 17.3±0.2 | 11.5±0.1 | 9.1±0.1 | 8.8±0.2 |
| Adults | 21.3±1.8 | 20.1±1.5 | 15.8±1.0 | 14.6±1.0 | 9.4±0.7 |
| Total | 116.8±0.7 | 76.5±0.6 | 52.8±0.4 | 45.4±0.3 | 40.6±0.4 |

*Values represent means with standard errors ($M \pm SE$).

The pupae rarely died at the temperatures below 28°C while two thirds of them failed to become moths at 32°C. Survival rate during whole immature stage also followed a parabolic curve. The equations describing relationship between survival rate during various stages of the insect and temperature are given in Table 3.

Table 3 Survival rates and egg production of the army worm in relation to temperature

| Stage | Equation | Optimal * temp., °C | Maximal value* |
|---|---|---|---|
| Eggs | $Y = 3.0443 + 7.0565X - 0.1379X^2$ | 25.6 | 93.3 |
| larvae | $Y = 42.4657 + 4.7446X - 0.1022X^2$ | 23.2 | 97.5 |
| Egg→adult | $Y = -231.4897 + 28.9791X - 0.6475X^2$ | 22.5 | 92.7 |
| Mean eggs laid | $Y = -2537.1630 + 356.1492X - 7.9144X^2$ | 22.5 | 1469.5 |

*Theoretical values calculated according to the respective equations.

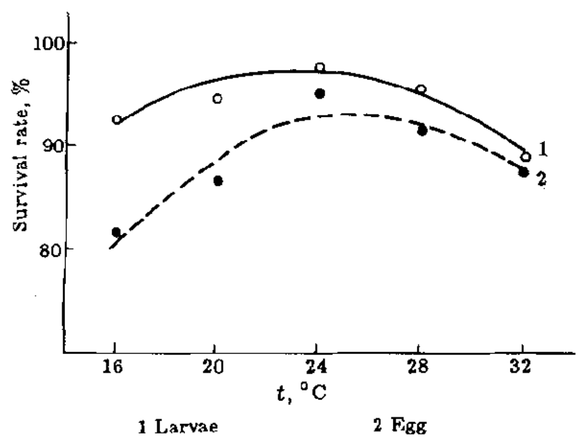


**Fig.1** Survival rates of eggs and larvae in relation to temperature

*Effect of temperature on reproduction*

Mean egg production varied between 1300 and 1450 at middle temperatures (Table 4). Female fecundity reduced slightly at 16°C while numbers of egg they had and laid decreased by about 50% at 32°C in comparison to those at 24°C. The relationship between adult fecundity and temperature tended to be a parabolic curve (Table 3).

**Table 4** Effect of temperature on reproduction of the army worm*

| Temp., °C | 16 | 20 | 24 | 28 | 32 |
|---|---|---|---|---|---|
| Eggs laid | 1196.0[a] | 1296.8[b] | 1456.4[c] | 1347.2[d] | 696.0[e] |
| | ±124.6 | ±115.0 | ±76.9 | ±138.2 | ±114.8 |
| No. eggs | 43.3 | 2.2 | 8.9 | 16.6 | 64.7 |
| remained | ±16.1 | ±1.1 | ±2.3 | ±5.8 | ±14.5 |
| Total | 1239.3 | 1299.0 | 1465.3 | 1363.8 | 760.7 |
| | ±113.8 | ±114.8 | ±76.7 | ±135.0 | ±106.0 |
| % Eggs-laid | 96.5 | 99.8 | 99.4 | 98.8 | 91.5 |

*15 couples of moth were examined in each group. Values followed by different letters differ significantly at $P < 0.05$.

*Population life tables of the insect*

Combining the data mentioned above, life tables of the army worm at the temperatures tested were constructed. In Table 5, sex ratio of 1:1 was assumed for all treatments. Estimative survival rate during immature stage was calculated by the equation in Table 3. Predicted egg number of next generation equaled the product of estimated number of female adult multiplied by estimative mean egg production. The equations for these calculations can be found in Table 3, too. Index of population trend referred to the number of times the egg population multiplies after one generation. Fig.2 shows these indices in relation to temperature, which could be well expressed by the following equation:

$$Y = -2530.2850 + 282.1893X - 6.2407X^2.$$

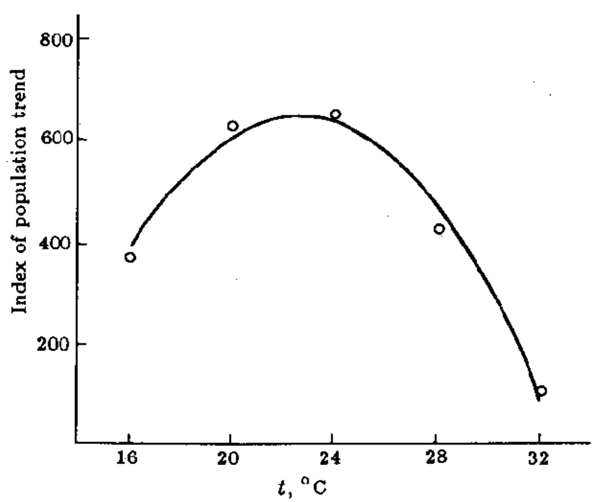


**Fig.2** Relationship between index of population trend and temperature

Table 5 Population life tables of the army worm at different temperatures

| Temp., °C | 16 | 20 | 24 | 28 | 32 |
|---|---|---|---|---|---|
| Eggs tested | 100 | 100 | 100 | 100 | 100 |
| % hatch | 81.7 | 86.0 | 95.7 | 91.9 | 87.5 |
| Larvae hatched | 81.7 | 86.0 | 95.7 | 91.9 | 87.5 |
| % survival, younger larvae | 95.0 | 96.2 | 98.0 | 97.7 | 100.0 |
| Larvae of 4th instar | 77.6 | 82.6 | 93.6 | 89.8 | 87.8 |
| % survival, older larvae | 97.9 | 98.4 | 100.0 | 98.4 | 89.0 |
| Prepupae | 76.0 | 81.4 | 93.8 | 88.4 | 77.9 |
| % survival | 97.8 | 100.0 | 98.0 | 98.4 | 57.3 |
| Pupae | 74.3 | 81.4 | 91.9 | 87.0 | 44.6 |
| % survival | 96.7 | 96.7 | 97.9 | 96.7 | 60.8 |
| Adult moths | 71.8 | 78.7 | 90.0 | 84.1 | 27.1 |
| Females | 35.9 | 39.4 | 45.0 | 42.1 | 13.6 |
| % survival, immature stage observed | 71.8 | 78.7 | 90.0 | 84.1 | 27.1 |
| Estimated | 66.4 | 89.1 | 91.0 | 72.3 | 32.8 |
| Eggs of next generation predicted | 37685.0 | 63336.0 | 66052.0 | 44468.0 | 12386.0 |
| Index of population trend | 376.9 | 633.4 | 660.5 | 444.7 | 123.9 |

Results calculated according to the equation indicated that population density of the insect from one generation to the next would increase at the temperatures ranged from 12.3°C to 32.9°C with the greatest index, about 660, at 22.6°C. The population would maintain constant at 12.3°C or 32.9°C, and the lower or higher temperatures would reduce its size.

*Food ingestion, utilization and conversion by the larvae*

Ingestion of food during the final two instars of larvae usually accounted for more than 90% of total food consumption by them in *Lepidopterous* insects. In present experiment 5th instar larvae of the army worm were chosen to investigate effect of temperature on nutritional parameters of the diet for them because the last instar involves prepupal stage during which a series of profound change in physiological and biochemical processes will take place.

Table 6 shows that larval ingestion and egestion increased with rising temperature up to 24°C and then gradually decreased at the higher temperatures. Digestion, utilization and conversion efficiencies of the diet by the larvae varied at the temperatures tested. It was a general trend that a rise in temperature promoted approximate digestibility(AD), and reduced efficiencies of conversion of ingested and digested food (ECI and ECD, respectively), although unusual lower AD and ECI were determined at 20°C which seemed not resulting entirely from measuring error and are yet to be explained.

**Table 6** Ingestion, digestion and utilization of food by the 5th instar larvae

| Temp., °C | 16 | 20 | 24 | 28 | 32 |
|---|---|---|---|---|---|
| Ingestion, mg | 27.2±2.4 | 32.3±2.0 | 40.9±4.4 | 38.1±2.8 | 37.2±3.3 |
| Egestion, mg | 13.4±1.4 | 17.4±1.1 | 19.7±2.2 | 15.3±1.3 | 13.6±1.4 |
| AD, % | 51.03[a] ±2.14 | 45.94[b] ±1.42 | 53.52[c] ±1.84 | 55.35[d] ±2.25 | 63.04[e] ±1.77 |
| ECI, % | 30.91[a] ±1.37 | 22.72[b] ±0.92 | 26.78[c] ±1.10 | 27.81[c] ±1.36 | 28.88[d] ±0.90 |
| ECD, % | 62.69[a] ±3.81 | 52.39[bc] ±3.27 | 50.84[bc] ±2.18 | 51.94[bc] ±4.77 | 46.76[d] ±2.40 |

We consider that the results described here indicate a strong possibility that climatic change caused by human activities, especially various industrial activities, would influence not only population dynamics of the army worm but also their food consumption. These alteration in density of the pest insect and their feeding behavior would exert an important effect on their damage to crops. The present experiment was conducted with the artificial diet at constant temperatures. It is necessary for such work to extend to a wider range of pest species with their host plants at varied temperature to assess the overall importance of abnormal climate-pest infestation-crop yield interactions in field.

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