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THE EFFECTS OF TEMPERATURE ON ADULT SURVIVAL, OVIPOSITION AND THE INTRINSIC RATE OF INCREASE OF *PLUTELLA XYLOSTELLA* (L)

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RINGKASAN

Kajian dijalankan di makmal bagi memastikan kesan suhu ke atas kehidupan dewasa, peneluran dan kadar peningkatan yang hakiki, (r_m) *Plutella xylostella* (L).

Keputusan telah menunjukkan bahawa suhu memainkan peranan yang berkesan ke atas kadar kehidupan, peneluran dan tempoh generasi. Berdasarkan kadar peningkatan yang hakiki (r_m) yang diperolehi, suhu yang paling sesuai untuk populasi *Plutella* ialah dalam lingkungan 30°C. Pertalian antara jangkamasa hidup dan suhu didapati sesuai dalam persamaan logistic tetapi pertalian antara peneluran dan r_m dengan suhu didapati sesuai dalam persamaan polinomial.

INTRODUCTION

Investigation on the seasonal abundance of the diamond-back moth, *Plutella xylostella* (L) (= *maculipennis,* Curt) (HARDY, 1938; HARCOURT, 1963; ABRAHAM and PADMANABHAN, 1968; SACHAN and SRIVASTAVA, 1972) revealed that its numbers were influenced by weather conditions, *viz.,* temperature and rainfall. That temperature affects *P. xylostella* activity by favouring development, egg oviposition and adult survival as indicated in studies by HARDY (1938).

The growth rate of insect populations in the field and the processes regulating it can generally be estimated from lifetable parameters using simple and general inductive models as shown by various scientists (MAY, CONWAY, HASSELL and SOUTHWOOD, 1974; SOUTHWOOD, 1978; VARLEY and GRADWELL, 1960; 1963). One such parameter which describes the population growth potential is the intrinsic rate of natural increase (r_m) (BIRCH, 1948; MESSENGER, 1968).

This paper describes studies on the effects of temperature on r_m, adult survival rates and egg oviposition of *P. xylostella* under laboratory conditions. Such information can give a better understanding of the population dynamics and behaviour of the moth in the field.

MATERIALS AND METHODS

Laboratory procedure

The *P. xylostella* used in this study was obtained from cultures maintained in the laboratory. All experiments were conducted in bioclimatic chambers maintained at different constant temperatures of 15°C, 20°C, 25°C, 30°C, 35°C and 40° centigrade. Temperatures were maintained within ± 1°C and the relative humidities between 70% and 80% for all the temperatures. A daily 12 h photophase was provided using a combination of incandescent and fluorescent lights.

To determine the age specific oviposition and survival rates, pairs of freshly emerged adults were placed in glass breeding jars (24 cm x 10 cm) and fed with an aqueous solution of 10% honey. Leaves of *Brassica juncea* with stalks immersed in glass tubes of water were used as the oviposition substrate. The numbers of eggs laid and adult surviving were recorded daily for 20 pairs of adults for each temperature throughout their lifespans.

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The survival rates of the immature stages were estimated using a known cohort of eggs laid by five females over 24 hours. These one-day-old eggs were kept in the six temperature regimes until the adult appeared.

Analytical methods

Adult survival rates

Adult survival rates may be described by an age specific survivorship function which is based on the premise that the adults have age specific probabilities of daily survival. These probabilities p(j) represent the likelihood of an adult surviving to age (j). A parametric distribution which defines the p(j)s can be employed quantifying these probabilities (BIRLEY, 1977; BELLOWS, 1982). The function is a discrete form of the cumulative normal distribution truncated at zero:

$$p(j) = 1 - (k\sigma\sqrt{2\pi})^{-1} \int_{-\infty}^{j} \exp[-(t-\mu)^2/2\sigma^2]\, dt \quad (1)$$

where μ is the mean adult duration which may be approximated to $\bar{x}$, and σ^2, the variance, approximated by s^2 and k is a constant. As pointed out by BELLOWS (1982) this is only an approximation as the age index, (j) is not permitted to be negative. The approximation is more precise when $\mu \gg \sigma^2$. The constant k is required to ensure that the sum of p(j)s over the range of (j) required is unity.

A computer programme coded in FORTRAN was developed to generate p(j) values from the mean ($\bar{x}$) and variance (s^2) of adult survival rates. In this programme a numerical approximation (DAVIES, 1972) of the normal distribution given by Hastings was used.

Intrinsic rate of increase, r_m

Tables of age specific oviposition (m_x) and survival rates (l_x) were developed for each age interval (x) of one day using the method described by BIRCH (1948). The values of m_x were obtained based on the assumption that the sex ratio was 1:1. The intrinsic rate of increase was then computed using the equation of BIRCH (1948):

$$\sum_{x=0}^{\infty} e^{-r_m x} l_x m_x = 1 \quad (2)$$

The values of r_m were determined by an iterative method using the computer. The net reproductive rates (R_0) and mean generation times (T) were also computed for the various temperatures.

Significance tests

Standard analysis of variance was used to test for significance of mean oviposition and longevity among treatments and the Duncan's multiple range test was used to compare means in those tests which showed significance. Tests of independence of adult numbers was made using the G test (SOKAL and ROHLF, 1969).

RESULTS

Adult survival

The mean adult longevities at the various temperatures were found to be significantly different ($P<0.05$). Generally, adult longevity increased as temperatures decreased within the range of temperatures observed *(Figure 1)*. The date was fitted to a logistic equation:

$$Y = \frac{1 + \exp(a - bt)}{K} \quad (3)$$

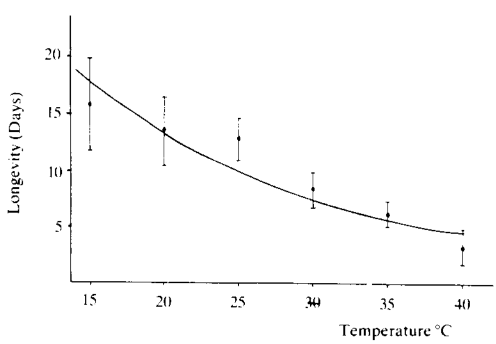

*Figure 1. Relationship between **Plutella xylostella** adult longevity ($\bar{x} \pm$ s. e.) and temperature.*

where Y = mean adult longevity; t = temperature and a, b and K are constants. This relationship was similar to the one described by DAVIDSON (1944).

Figure 2 shows the daily survival rates p(j) of the adult female at different temperatures. The solid lines in the figure were generated using equation (1) with the respective $\bar{x}$ and s values. From the examination of the residual (DRAPER and SMITH, 1966), the data fitted the model reasonably well.

Egg Oviposition

As shown in *Figure 3,* the largest number of eggs were laid at 25° centigrade. The relationship between egg oviposition per female and temperature can be reasonably described by a polynomial equation (F = 56.9; $P<0.05$);

$$Ye = 46.09t - 0.918t^2 - 365.55 \qquad (4)$$

where Ye is mean eggs oviposited per female.

The daily egg oviposition patterns at various temperatures do not appear to be fixed *(Figure 4).* At 15°C, the daily oviposition appears uniformly spread out throughout its life-span. For the other temperatures, however, oviposition is more concentrated in the first few days of the adult life.

Intrinsic Rate of Increase (r_m)

The r_m values increased to a maximum at 30°C, followed by a decline. At 40°C it could not be calculated because of high mortality in the larval stages. The r_m values fitted a polynomial equation (F = 447; $P<0.05$) extremely well:

$$r_m = 0.463 - 0.071\,t + 0.004\,t^2 \qquad (5)$$

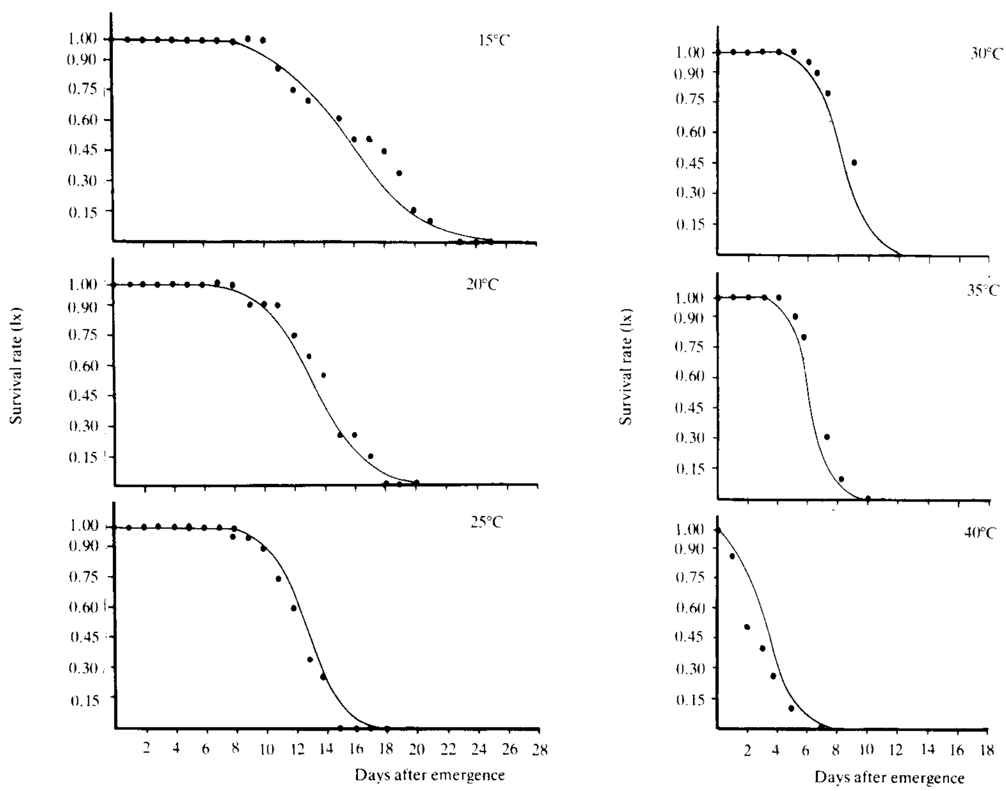

Figure 2. Daily survival rates of ***Plutella xylostella*** *at various temperatures.*

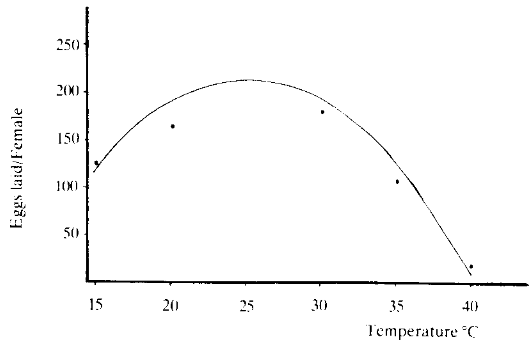

Figure 3. Relationship between egg oviposition per female ($\bar{x}$) and temperature in ***Plutella xylostella***

Other lifetable parameters such as the finite rate of increase (λ),the net reproductive rate (R_0), the mean generation time (T) and the doubling time (D.T.) were also calculated *(Table 1)*.

DISCUSSION

It is evident from this study that temperature has significant effects on adult survival, oviposition rates and generation time. The temperature most favourable for *Plutella* populations appears to be 30° centigrade. At this temperature r_m was the highest.

The intrinsic rate of increase, r_m which is the growth constant in the exponential and logistic equations describing population growth, is a weighted measure of the rate of development, rate of reproduction (m_x) and the survival rate (l_x) (ANDREWARTHA and

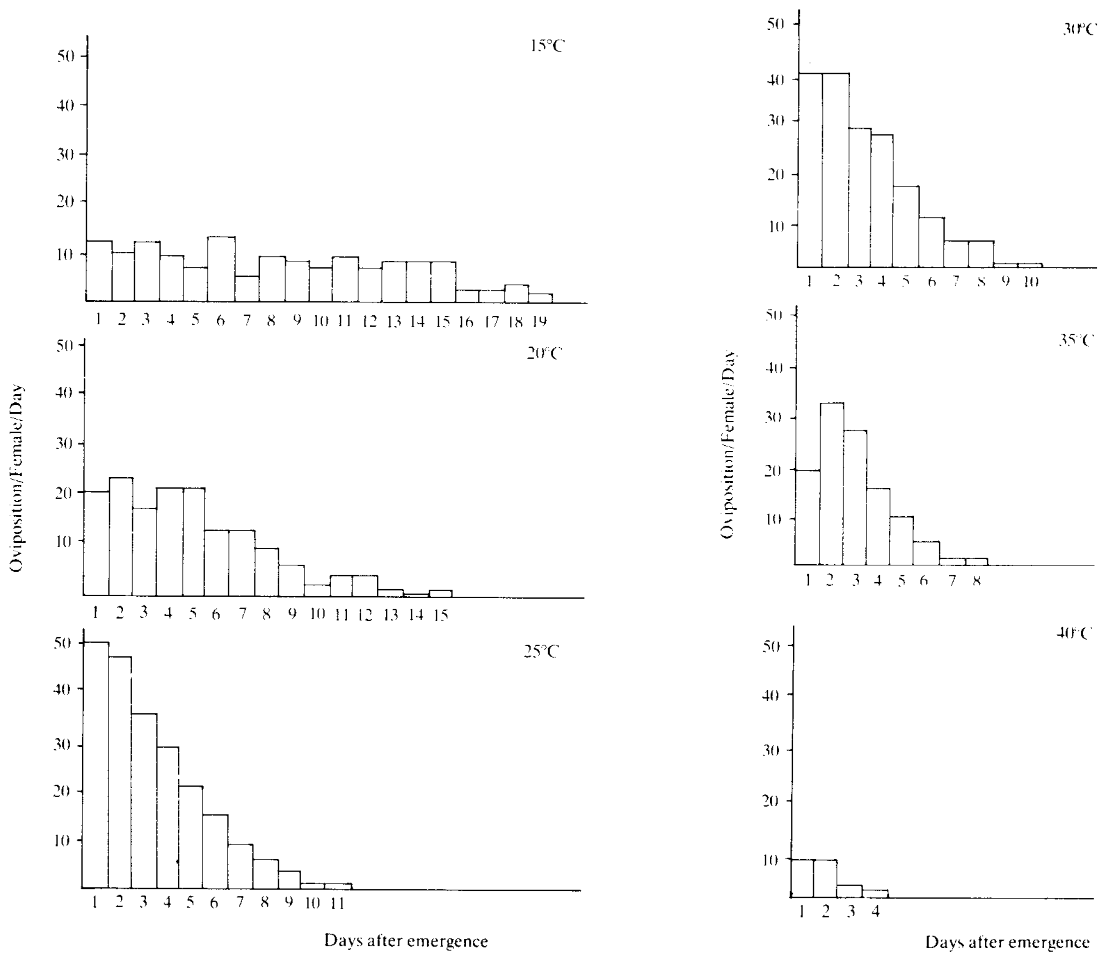

Figure 4. Daily egg oviposition patterns of ***Plutella xylostella*** *at various temperatures.*

Table 1. Effect of temperature on the lifetable parameters of *Plutella xylostella*

Parameters	Temperature (°C)					
	15	20	25	30	35	40*
% immature survival	0.35	0.31	0.25	0.28	0.22	None survived
Oviposition rate (eggs/day)	8.23	11.20	18.24	20.91	18.45	7.51
Oviposition period (days)	19	17	14	10	8	4
Net reproductive rate, R_o	21.82	24.29	31.07	24.11	11.65	na*
Mean generation time, T days	41.21	25.56	17.57	14.38	12.69	na*
Intrinsic rate of increase, r_m	0.077	0.128	0.200	0.233	0.196	na*
Finite rate of increase, λ	1.080	1.136	1.221	1.263	1.217	na*
Doubling time, D.T. days	4.024	2.510	1.510	1.370	1.560	na*

*At 40°C immatures were unable to survive.

BIRCH, 1954). Any extrinsic factor of environment that affects any of the factors would also affect r_m and the higher the r_m value, the more favourable are the environmental circumstances within which the population resides (MESSENGER, 1976). However, consideration of r_m values as true measures of rates of population growth may be unrealistic for most species in nature because r_m is based on the assumption that the population is increasing in an unlimited environment and has attained a stable age distribution, conditions which rarely occur in nature (SIDDIQUE and BARLOW, 1972). Thus real rates can be much lower than computed rates as shown for the aphid *Therioaphis maculata* (MESSENGER, 1964) and the granary weevil, *Ptinus teetus* (HOWE, 1953). However, r_m which assumes a stable age distribution, still serves as the only quantitative index reflecting the relative effects of different environmental factors on population growth.

Although, *Plutella* showed a lower net reproductive rate (R_o) and oviposition rate at 30°C but larger r_m as compared to corresponding maximum values at 25°C, this larger r_m was related to shorter developmental time (HARDY, 1938) and the mean generation times at 30° centigrade. LEWONTIN (1965) showed that the effects on r_m to changes in developmental time was greater than the effects produced by proportional changes in other parameters of population growth. However, it is not implied that a high relative oviposition excludes the possibility of a high r_m but rather that at 25°C the high oviposition is distributed over a longer period (14 days at 25°C and 10 days at 30°C), resulting in the relatively lower r_m. Further, *Plutella* showed the highest finite rate of increase and the lowest doubling times at 30° centigrade.

The diamond-back moth is a cosmopolitan species occurring wherever *Brassicas* are grown (HARDY, 1938; C.I.E., 1967; SALINAS, 1972). According to HARDY (1938), the main climatic factor which limits the occurrence of *Plutella* is temperature and that the optimum temperature favourable for its development lies around 30° Centigrade. This was also observed in our studies. In Malaysia, *Plutella* can occur in areas of different temperature regimes. In the lowlands, the average monthly temperatures remain within the range of the optimum temperature, naturally favouring the build-up of the moth. In the highlands where cooler temperatures in the range of 20°C to 24°C are experienced, the build-up of *Plutella* is complemented by the intensive crop cultivation and direct effects of indiscriminate pesticide usage.

Limitations in the use of constant temperatures to interpret the responses of insects to climate had been discussed (MESSENGER and FLITTERS, 1959). Nevertheless, our studies showed that r_m was highly associated with temperatures. This is further supported by field observations which indicate that *Plutella* occurs in relatively higher numbers during hotter periods of the year ranging from 24°C to 32°C (ABRAHAM and PADMANABHAN, 1968; SACHAN and SRIVASTAVA, 1972).

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SUMMARY

Laboratory studies were conducted to determine the effects of temperatures on the adult survival, oviposition and intrinsic rate of increase, r_m, of *Plutella xylostella* (L).

Results showed that temperature had significant effects on adult survival and oviposition rates and generation time. Based on the intrinsic rate of increase (r_m) obtained, the temperature most favourable for *Plutella* populations was found to be around 30°C. The relationship between longevity and temperature was found to fit a logistic equation whilst relationships of oviposition rate and r_m with temperature were found to fit polynomial equations.

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