QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

DIVISION OF PLANT INDUSTRY BULLETIN No. 770

EFFECT OF TEMPERATURE ON THE DEVELOPMENT OF LARVAE AND PUPAE OF THE CORN EARWORM, HELIOTHIS ARMIGERA (HÜBNER) (LEPIDOPTERA: NOCTUIDAE)

by P. H. TWINE, M.Agr.Sc.*

SUMMARY

The relation of development time of *Heliothis armigera* (Hübner) to temperature was examined using larvae reared on an artificial diet. Seven constant temperatures, ranging from 13·1 to 38·4°C were employed. Using the thermal-summation principle, a threshold temperature of 11·0°C and a thermal summation constant of 475 day degrees were estimated for development from egg hatch to adult emergence. Data were also fitted according to the model of Pradhan which indicated that the maximum rate of development occurred at 33·9°C.

I. INTRODUCTION

Heliothis armigera (Hübner) occurs as a major pest in a wide variety of horticultural and agricultural crops in Australia. As a consequence, the life cycle of the insect has been well documented (Hardwick 1965). Little, however, is known of the effect of temperature on larval and pupal development. Kirkpatrick (1962) related development time to temperature by following larval development. The present work was undertaken to study the effect of temperature on development under fluctuating insectary temperatures throughout the year.

Though valuable, such studies do not provide the basic data necessary for an understanding, and hence prediction, of the effect of temperature on development and mortality of larvae and pupae of *H. armigera* and was carried out under constant temperatures at Toowoomba, Queensland in June and July 1971.

II. METHODS AND MATERIALS

A colony of *H. armigera* was established using larvae collected from maize at Wyreema, in southern Queensland, and bred in the laboratory on artificial diet (Twine 1975). Eggs less than 24 h old were each placed in a 60-ml glass jar containing 10 ml of artificial diet. Fifty larvae were held at each temperature and these were examined daily to record stage of development. Larval instars were determined on the basis of overall morphological characters—no measurements of head capsules or cast head capsules were made.

*Based on a thesis submitted to the University of Queensland for Degree of M.Agr.Sc.

The study was carried out under continuous darkness in a multi-temperature incubator giving 13·1, 18·5, 21·3, 24·6, 27·1, 33·9 and 38·4°C with an accuracy of ± 0·5°C.

Simple regression was used to determine the best linear relationship between rate of development (reciprocal of development time) and temperature according to the classical thermal summation principle. The method of Pradhan (1946) was used to determine the relationship in the form $Y = ae^{-b(c-x)^a}$ where Y = rate of development, x = temperature °C and a, b and c are constants.

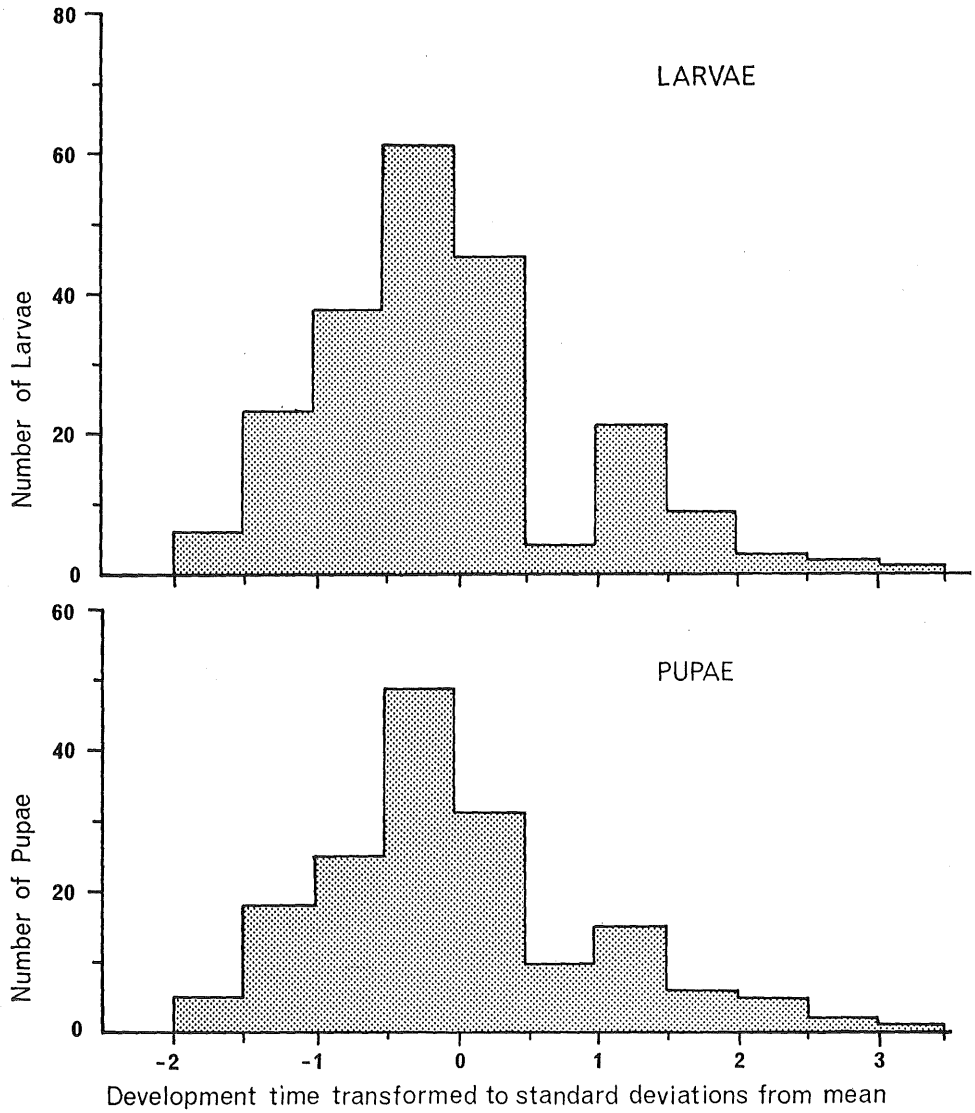

Figure 1.—Standardised frequency distribution (mean O, variance 1) for time of development of H. armigera *combined over all temperatures*

TABLE 1

DEVELOPMENT TIMES (MEAN AND STANDARD DEVIATION IN DAYS) FOR IMMATURE STAGES OF *H. armigera*

State of Development	Temperature (°C)						
	13·1	18·5	21·3	24·6	27·1	33·9	38·4
1st Instar	7·5 ± 0·8	3·0 ± 0·0	2·0 ± 0·2	1·5 ± 0·5	1·0 ± 0·0	1·0 ± 0·0	1·0 ± 0·0
2nd Instar	7·1 ± 1·2	2·9 ± 0·5	2·1 ± 0·4	1·5 ± 0·5	1·0 ± 0·0	1·0 ± 0·0	2·0 ± 0·0
3rd Instar	12·8 ± 1·2	4·0 ± 0·5	3·1 ± 0·5	3·0 ± 0·1	1·8 ± 0·5	1·1 ± 0·4	1·3 ± 0·2
4th Instar	19·0 ± 8·9	5·1 ± 0·7	3·1 ± 0·4	2·6 ± 0·5	1·9 ± 0·3	1·7 ± 0·5	5·0 ± 0·0
5th Instar	24·7 ± 5·5	6·2 ± 1·6	4·0 ± 1·0	2·0 ± 0·6	2·0 ± 0·5	1·4 ± 0·6	–
6th Instar	28·0 ± 5·9	8·3 ± 1·2	6·1 ± 1·3	5·5 ± 0·8	4·3 ± 0·8	3·5 ± 0·6	–
Pre Pupa	20·8 ± 3·9	6·0 ± 0·7	3·0 ± 0·7	2·5 ± 0·5	2·4 ± 0·5	2·0 ± 0·2	–
Larval Life	19·9 ± 9·6	35·3 ± 2·0	24·0 ± 2·2	18·5 ± 1·3	14·5 ± 1·0	11·7 ± 0·9	–
No. of Larvae	12	45	47	49	44	41	0
% Larval Mortality	76%	10%	6%	2%	12%	18%	100%
Pupal Life	–	33·9 ± 3·6	22·6 ± 2·0	15·7 ± 2·2	11·5 ± 1·6	10·0 ± 0·7	–
No. of Pupae	0	16	40	44	42	36	0
% Pupal Mortality	100%	64·4%	14·9%	10·2%	4·5%	12·2%	–
Total Life	–	69·0 ± 4·1	46·6 ± 2·2	34·2 ± 3·1	26·1 ± 1·8	21·6 ± 0·9	–

III. RESULTS

Data on the development times for immature stages at each temperature are given in table 1.

At 38°C no larvae developed to pupae though a few successfully completed the early larval instars. The rate of development of these few individuals was retarded. Stress, however, was not apparent in development of either larvae or pupae at 34°C or below. Optimal survival temperatures were 27°C for pupae (4·5% mortality) and 24°C for larvae (2·0% mortality).

Females developed more rapidly than males below 27°C but no differences between numbers of male and female moths were obtained at any temperature (table 2).

TABLE 2

DEVELOPMENT TIMES (MEAN AND STANDARD DEVIATION IN DAYS) FOR TOTAL LARVAL AND PUPAL STAGES OF MALES AND FEMALES OF *H. armigera* AT VARIOUS TEMPERATURES

Sex	Temperature (°C)			
	21·3	24·6	27·1	33·9
Males	47·5 ± 2·3	34·4 ± 2·3	26·1 ± 1·7	21·5 ± 0·9
Females	45·6 ± 2·0	33·0 ± 3·0	25·9 ± 1·8	21·8 ± 1·0
Probability of Similarity ..	15%	11%	50%	33%

Development times for all larvae at each temperature were transformed to a common mean (0). Unit variance and frequency distribution for the transformed data are given in figure 1. Distribution differed from the expected normal ($P<0\cdot005$), and the form indicated a bimodal distribution with some larvae having a longer development time. Pupal data showed a similar trend.

Results obtained using the thermal summation principle to relate rate of development to temperature are summarised in table 3.

TABLE 3

RELATIONSHIP BETWEEN RATE OF DEVELOPMENT AND TEMPERATURE FOR LARVAE AND PUPAE OF *H. armigera* USING THERMAL SUMMATION PRINCIPLE

Development Stage	Regression Equation	Coefficient of Determination	Threshold Temperature °C	Thermal summation Constant (day degrees)
Larvae	Y = 0·0385x—0·041	0·975	10·6	260
Pupae	Y = 0·00473x—0·054	0·930	11·4	211
Larvae + Pupae ..	Y = 0·00209x—0·023	0·960	11·0	475

The following equations were calculated using the formula of Pradhan:

$$\text{Larvae} \quad .. \quad .. \quad \hat{Y} = 0\cdot0847\, e^{-0\cdot00567\,(32\cdot79-x)^2}$$

$$\text{Pupae} \quad .. \quad .. \quad \hat{Y} = 0\cdot00627\, e^{-0\cdot00627\,(32\cdot75-x)^2}$$

$$\text{Total Life} \quad .. \quad \hat{Y} = 0\cdot0466\, e^{-0\cdot00501\,(33\cdot80-x)^2}$$

where $\hat{Y}$ = rate of development (days^{-1}) and x = temperature (°C).

Observed development time has been compared with times estimated by the thermal summation formula and Pradhan formula (table 4). Absolute errors were largest at the lowest temperature where development times were longest.

TABLE 4

DEVELOPMENT TIMES (OBSERVED AND ESTIMATED DAYS) OF *H. armigera*

Temperature (°C)	Larval Life			Pupal Life			Total Life		
	Observed	Estimated		Observed	Estimated		Observed	Estimated	
		Thermal Summation	Pradhan		Thermal Summation	Pradhan		Thermal Summation	Pradhan
13·1	119·9	106·0	106·3	..	..	..	..	..	..
18·5	35·3	33·1	37·5	33·9	29·9	35·0	69·0	63·8	69·4
21·3	24·0	24·4	24·9	22·6	21·4	22·3	46·6	46·5	47·0
24·6	18·5	18·6	17·3	15·7	16·0	14·9	34·2	35·2	32·8
27·1	14·5	15·8	14·1	11·5	13·5	12·0	26·1	29·7	26·9
33·9	11·7	11·2	11·9	10·0	9·4	9·9	21·6	20·9	21·5

IV. DISCUSSION

The development times recorded in this work were generally similar to those recorded by Kirkpatrick (1962) under fluctuating insectary temperatures though no direct comparison is possible. The bimodal distribution of the development times is consistent with the occurrence of an additional instar in portion of the population (Twine 1975).

Several workers including Baker and Miller (1974) have found that with a large amplitude in temperature, as commonly found under field conditions, the model of Pradhan (1946) explains observed reactions to temperature more accurately than the thermal summation principle. Data using this model are presented for this reason.

However, the thermal summation principle provides a convenient means of incorporating the effects of fluctuating temperatures into population models. The fit of observed data to this simple model was adequate though wider differences could be anticipated with temperatures outside the observed range. The current data indicate a threshold of 11·0°C and a thermal summation constant of 475 day degrees for the combined larval and pupal stages of *H. armigera*. These results are comparable with the values of 12·6°C and 383 day degrees established by Mangat and Apple (1966) for the closely related species *H. zea*. Despite its known limitations the thermal summation principle was considered by Wigglesworth (1972) to be acceptable for practical use.

V. ACKNOWLEDGEMENT

Thanks are extended to Professor D. S. Kettle, Entomology Department, University of Queensland for the interest and guidance offered and for his helpful discussion and criticism of the work throughout its progress.

REFERENCES

BAKER, C. R. B. AND MILLER, G. W. (1974).—Some effects of temperature and larval food on the development of *Spodoptera littoralis* (Boisd.) (Lep., Noctuidae). *Bull. ent. Res.* 63 (3): 495-512.

HARDWICK, D. F. (1965).—The corn earworm complex. *Memoirs of the Entomological Society of Canada* No. 40. 247 pp.

KIRKPATRICK, T. H. (1962).—Notes on the life histories of species of *Heliothis* (Lepidoptera: Noctuidae) from Queensland. *Qd J. agric. Sci.* 19: 567-570.

MANGAT, B. S. AND APPLE, J. W. (1966).—Corn earworm development in relation to temperature. *J. econ. Ent.* 59: 1005-1006.

PRADHAN, S. (1946).—Insect population studies. IV. Dynamics of temperature effect on insect development. *Proc. natn. Inst. Sci. India* 12: 385-404.

TWINE, P. H. (1975).—Some aspects of the natural control of larval *Heliothis armigera* in maize. M.Agr.Sc. Thesis, University of Queensland. pp. 82.

WIGGLESWORTH, V. B. (1972).—'The principles of insect physiology'. 7th edition. Chapman and Hall: London. pp. 827.

(Received for publication 12th April, 1977).

The author is an officer of Entomology Branch, Queensland Department of Primary Industries, stationed at Toowoomba, 4350. He is presently on study leave at the University of California, Riverside, U.S.A.