Asian Journal of Agricultural Research 2 (1): 25-31, 2008
ISSN 1819-1894

Influence of Varying Temperature on the Development and Fertility of *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae) on Cabbage

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Abstract: A laboratory study was conducted to find out the development and fertility of *Plutella xylostella* at varying temperatures (20±1, 25±1 and 20/25±1°C, coupled with 70±5% RH and 12 h L: 12 h D). The observations of two successive generations revealed that *P. xylostella* registered maximum life span of 33.13±1.494 days at 20±1°C, followed by 30.75±1.513 days at 20/25°C and 28.84±1.847 days at 25±1°C. When, a comparison was made between the developmental stages of *P. xylostella* at different temperature, it ranged from 3.0-4.0, 8.0-13.0, 1.0-1.5, 4.0-6.0 and 5.0-15.0 days at egg, larval, prepupal, pupal and adult stage, respectively. Although, the minimum temperature (20±1°C) influenced the highest natality (11 days) of the female, it also persuades highest fecundity of 104.42 eggs/female against the lowest of 78.26 eggs/female at 25±1°C. Similarly, mean length of generation of *P. xylostella* also attained high value of 27.92 days at 20±1°C and the low of 24.70 days at 25±1°C. However, *P. xylostella* exhibited a markable variation in different rates of increase (intrinsic, finite and annual) at different temperatures; it scheduled high value at fluctuating temperature (20/25±1°C) in comparison to constant temperature (20±1 and 25±1°C). Likewise, a high carrying capacity (26.57 female/female/day) was also observed at fluctuating temperature (20/25±1°C), against the low (18.52 female/female/day) at 25±1°C. Therefore, the temperature is a crucial abiotic factor, governs the certain biological attributes of various insects. Both minimum and fluctuating temperatures favor the development and survival of *Plutella xylostella* on cabbage under controlled condition.

Key words: Diamondback moth, development, female fertility, temperature, cabbage

INTRODUCTION

Cabbage, *Brassica oleracea* var. *capitata* is one of the important cruciferous vegetable crops in the world. The most important factor limiting cabbage production is the presence of pests especially insects that cause regular quantitative as well as qualitative losses in diverse ecological conditions. This crop attacked by number of insect-pests at different developing stages. Among them diamond back moth, *Plutella xylostella* (L.) is the most destructive one (Mahla *et al*., 2005; Kumar *et al*., 2007). In India this pest has national importance on cabbage, causing 50-80% annual loss in marketable yield (Devjani and Singh, 1999; Ayalew, 2006).

Although, this insect is believed to have originated in the Mediterranean area and now it is the most universally distributed pest of all lepidopterans (Hemchandra and Singh, 2005). The purpose of present investigation is to provide detailed information of life table of *Plutella xylostella* and generates simple but more informative statistics that giving the comprehensive description of the survivorship, development and reproduction of this insect. Therefore the study was aimed to find out development and female fertility of diamondback moth, *Plutella xylostella* at varying temperatures.

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MATERIALS AND METHODS

To maintain the culture of *P. xylostella*, larvae were collected from cabbage plants grown in experimental fields of the Department of Plant Protection, Aligarh Muslim University, Aligarh, during late January and early February, 2007. They were released in batches of 50 in broad mouthed plastic jars (diameter 15 cm and height 25 cm) for obtaining pupae at different temperatures (20±1, 25±1 and 20/25±1°C, coupled with 70±5% RH and 12 h L: 12 h D) in BOD incubator. The bottom of each plastic jar was lined with sphere of blotting paper. The mouths of the jars were covered with muslin cloth. Fresh leaves of cabbage were provided as food to the larvae, daily. The lower end of the cabbage leaf was wrapped with cotton swab to maintain the turgidity. The pupae collected from each of jars from respective temperatures were kept again in separate plastic jars of the same size as above for emergence of adults. After emergence of adults, they were sexed and paired (20 pairs) in each of egg laying jars. There were four replications of each egg laying jars were kept at different temperatures. After adult emergence, the egg laying jars were provided with cabbage leaves to obtain eggs. The leaves were removed daily and examined, using hand lens for finding out the eggs. The eggs were removed with the help of soft wet camel hair brush. Counted number of same age old eggs obtained from the adults of *P. xylostella* were placed over the wet blotting paper in petridishes and allowed to hatch at different temperatures. Egg hatch percentage was recorded from each aliquot and subsequently adjusted, so that life table commenced with 100 eggs.

Fluctuating temperature (20/25±1°C) was maintained by transferring the rearing jars from one constant temperature (20±1°C) to another (25±1°C) at an interval of 12 h and L:D of 12:12 h. From hatched eggs, one hundred 0-10 h old larvae were collected with the help of soft wet camel hair brush. Larvae were individually reared in plastic vials (5×10 cm) on fresh cabbage leaves. Initially, fresh leaves provided as food, were changed after three days of larval feeding. Thereafter, the food was changed daily. The longevity and mortality of each larval instars, prepupal, pupal and adult stage was recorded daily at respective temperatures.

To record fecundity, ten pairs of adult moths of different age group were released individually in plastic jars (15×25 cm) along with leaves and 10% sugar solution, soaked in cotton swab, as food for adults. The sugar soaked cotton swab was hanged with a thread 15 cm below from the mouth of the jar. The egg laying jars along with individually paired moths of different age group were kept at different temperatures (20±1, 25±1 and 20/25±1°C) for obtaining eggs. Black paper sheet was lined along the inner surface of each of the jars. Since, moths not only laid the eggs on leaves but also on the surface of the paper, therefore, black paper sheet as well as leaves were examined daily, using hand lens to count the number of the eggs laid by a single female of different age group. Fresh leaves and black paper sheet were used daily until the egg laying of each of the females was completed at different temperatures. Longevity of female was also recorded in each of replications. This way the observations for the survival and fertility of female were recorded and the table was constructed with the following assumptions:

- The survivorship rates were assumed to be the same for both the sexes, as it was not possible to identify the sexes prior to the adult stage.
- The sex could not be identified at the egg stage. Therefore a sex ratio of 1: 1 was considered in each batch of eggs (Birch, 1948; Southwood, 1978).

The table was constructed on the suggestions made by Birch (1948) and Southwood (1978). It consisted of following columns:

x = Pivotal age of the class in days.

l_x = Number of females alive at the beginning of the age interval × (as fraction of initial population of one).
m_x = Average number of eggs laid per female in each age interval assuming 50:50 sex ratio and computed as:

$$m_x = N_x/2$$

Where, N_x = Total natality per female off springs in each age.
Following parameters were also calculated for survivorship and fertility table:

- **Net Reproductive or Replacement Rate (R_o):** This is also referred to as the carrying capacity of insect. The information on the multiplication rate of a population in one generation is obtained from it. It is denoted as,

$$R_o = l_x.m_x$$

- **Mean length of Generation (T):** It is defined as the mean period between the birth of the parent and the birth of their off springs. This period is a weighed approximate value since the progeny is produced over a period of time and not at a definite time. Calculation followed the method suggested by Dubin and Lotka (1925).

$$T = \Sigma\,[I_x.m_x x]\,/\,\Sigma\,[l_x.m_x]$$

- **Intrinsic Rate of Increase (r):** It is also denoted by r or r_m or r_{max} and called as biotic potential. It is defined as the instantaneous rate of increase of a population in a unit time under a set of ecological conditions (Birch, 1948). An estimate of the intrinsic rate of increase (r) can be calculated by using the following equation:

$$r = [\text{Log}_e R_o]\,/\,T \text{ (for rough estimation)} \quad (1)$$

$$e^{-rx}.l_x.m_x = 1 \text{ (for accurate estimation of r)} \quad (2)$$

Where:
R_o = Net reproductive rate
T = Mean length of the generation

- **Finite Rate of Increase (λ):** It provides the information about the frequency of the population multiplication in a unit of time (Birch, 1948). It is denoted as

$$\lambda = e^r\text{. Taking log on both sides we get } \log_e \lambda = \log_e e^r$$

Where, λ = Antilog e^r

- **Potential Fecundity (P_f):** It expresses the total number of eggs laid by an average female in her life span. It is obtained or calculated by adding up the age specific fecundity column,

$$P_f = \Sigma\, m_x$$

- **Doubling Time (DT):** It is defined as the time required for the population to double and is calculated as follows:

$$DT = Log_e 2/r$$

- **Annual Rate of Increase (ARI):** This can be calculated from the intrinsic rate of increase (r) or finite rate of increase (λ) or doubling time (DT) or the net reproductive rate (R_o) assuming that the rate of increase was constant throughout the year.

$$ARI = 365 = e^{365r} = 2^{365/DT} = R_o^{365/T}$$

RESULTS

Development

It was inferred from the Table 1 that the *P. xylostella* exhibited longest incubation period at 20±1°C (3.89±0.046 days) and shortest at 25±1°C (3.27±0.121 days). Similarly, all the larval instars (1st to 4th) also registered their maximum span (3.98±0.017, 2.79±0.104, 2.76±0.102 and 2.96±0.023 days, respectively) at 20±1°C and the minimum (3.64±0.170, 2.59±0.140, 2.57±0.120 and 2.49±0.142, respectively) at 25±1°C. Likewise, prepupal and pupal stages also tuned their highest developmental period (1.35±0.124 and 5.13±0.219 days, respectively) at 20±1°C in contrast to lowest (1.00±0.033 and 4.82±0.243 days, respectively) at 25±1°C. Nevertheless, adult stage exhibited a considerable variation in longevity of *P. xylostella* at all the temperatures. The maximum adult longevity (10.27±0.859 days) was recorded at 20±1°C followed by 20/25±1°C (9.21±0.878 days) and 25±1°C (9.21±0.696 days). However, the overall developmental period of *P. xylostella* was recorded highest (33.13±0.859 days) at 20±1°C against the lowest (28.84±1.847 days) at 25±1°C.

Female Survival and Fertility

It is evident from data that females *P. xylostella* commenced egg laying during definite period of pivotal age. The longest duration of natality of 11 days was recorded at 20±1°C. However, a marked variation in egg laying capacity of female was documented at different temperatures. It was observed that the peak egg laying (18.01 eggs day^{-1}), was recorded at 20±1°C on 28th day, whereas, dip (1.95 eggs day^{-1}) at 20/25±1°C, on 23rd day (Table 2).

When a comparison was made in various life parameters at different temperatures, it was discerned that superior potential fecundity (104.42 eggs/female), was recorded at 20±1°C, as compared to inferior (78.26 eggs/female), at 25±1°C (Table 3). A high carrying capacity (26.57 female/female/day) was observed at a fluctuating temperature of 20/25±1°C, against the low (18.52 female/female/day) at 25±1°C. Whereas, the maximum mean length of generation of *Plutella xylostella* was recorded at 20±1°C (27.92 days) and the minimum at 25±1°C (24.70 days). However, the intrinsic rate of increase was of higher order (0.1228 female/female/day) at 20/25±1°C, against the low (0.1165 female/female/day) at 20±1°C. Though, the finite rate of increase did show a considerable variation, it was higher at 20/25±1°C (1.1307), followed by 20±1°C (0.1165) and 25±1°C (0.1189 females/female/day) (Table 3). When Diamond Back Moth reared at 20±1°C took longest

Table 1: Development of diamond back moth, *Plutella xylostella* at varying temperatures on cabbage

Stages	Temperatures 20±1°C	25±1°C	20/25±1°C
Egg	3.89±0.046 (3-4)	3.27±0.121 (3-4)	3.58±0.109 (3-4)
Ist instar	3.98±0.017 (3-4)	3.64±0.170 (2-4)	3.89±0.050 (3-4)
2nd instar	2.79±0.104 (2-3)	2.59±0.140 (2-3)	2.76±0.077 (2-3)
3rd instar	2.76±0.102 (2-3)	2.57±0.120 (2-3)	2.72±0.098 (2-3)
4th instar	2.96±0.023 (2-3)	2.49±0.142 (2-3)	2.49±0.145 (2-3)
Prepupal	1.35±0.124 (1-1.5)	1.00±0.033 (0-1)	1.20±0.061 (1-1.5)
Pupal	5.13±0.219 (4-6)	4.82±0.243 (3-5)	4.90±0.277 (4-6)
Adult	10.27±0.859 (6-15)	8.46±0.878 (5-14)	9.21±0.696 (6-13)
Overall	33.13±1.494 (23-40)	28.84±1.847 (19-37)	30.75±1.513 (23-38)

The values in the parenthesis showing the range of development in days at respective stage

Table 2: Life and fertility table of *P. xylostella* on cabbage at varying temperatures

Pivotal age (Days) x	Age specific female survivourship (l_x)	Natality rate (m_x)	Net reproductive rate ($l_x.m_x$)	$l_x.m_x.x$	Value of $e^{-rx}.l_x.m_x$	(%) contribution of each age group towards (r)
0.50-23.50 immature stage and pre-oviposition period					r = 0.116589	
20±1°C						
24.50	0.39	7.05	2.75	67.36	0.1580	15.8025
25.50	0.35	9.04	3.16	80.68	0.1618	16.1836
26.50	0.31	11.00	3.41	90.37	0.1552	15.5224
27.50	0.27	14.08	3.80	104.54	0.1540	15.4006
28.50	0.23	18.01	4.14	118.06	0.1493	14.9341
29.50	0.21	15.06	3.16	93.30	0.1015	10.1472
30.50	0.19	11.04	2.10	63.98	0.0599	5.9895
31.50	0.17	8.07	1.37	43.21	0.0349	3.4862
32.50	0.13	6.04	0.79	25.52	0.0178	1.7758
33.50	0.09	3.00	0.27	9.05	0.0054	0.5434
34.50	0.06	2.03	0.12	4.20	0.0022	0.2182
Sum		104.42	25.08	700.26	1.0000	100.0000
0.50-21.50 immature stage and pre-oviposition period					r = 0.118901	
25±1°C						
22.50	0.36	10.07	3.63	81.57	0.2497	24.9733
23.50	0.31	11.04	3.42	80.43	0.2093	20.9332
24.50	0.26	14.03	3.65	89.37	0.1981	19.8106
25.50	0.22	16.04	3.53	89.98	0.1702	17.0160
26.50	0.19	13.03	2.48	65.61	0.1060	10.5996
27.50	0.14	9.02	1.26	34.73	0.0480	4.8005
28.50	0.11	5.03	0.55	15.77	0.0187	1.8676
Sum		78.26	18.52	457.45	1.0000	100.0000
0.50-22.50 immature stage and pre-oviposition period					r = 0.122840	
20/25±1°C						
23.50	0.41	6.04	2.48	58.20	0.1381	13.8080
24.50	0.38	9.02	3.43	83.98	0.1690	16.9025
25.50	0.33	11.04	3.64	92.90	0.1589	15.8890
26.50	0.30	12.99	3.90	103.27	0.1503	15.0312
27.50	0.29	16.00	4.64	127.60	0.1583	15.8283
28.50	0.26	14.05	3.65	104.11	0.1102	11.0209
29.50	0.21	10.01	2.10	62.01	0.0561	5.6088
30.50	0.17	8.00	1.36	41.48	0.0321	3.2093
31.50	0.14	5.97	0.84	26.33	0.0174	1.7443
32.50	0.10	3.96	0.40	12.87	0.0073	0.7309
33.50	0.07	1.95	0.14	4.57	0.0022	0.2228
Sum		99.03	26.57	717.32	1.0000	100.0000

Table 3: Summary of life parameters of *P. xylostella* at varying temperatures

Life parameters	20±1°C	25±1°C	20/25±1°C
Potential fecundity	104.420000	78.260000	99.030000
Net reproductive rate	25.076500	18.516000	26.567600
Mean length of generation	27.925100	24.705710	26.999680
Intrinsic rate of increase (approx)	0.115378	0.118136	0.121472
Intrinsic rate of increase (accurate)	0.116589	0.118901	0.122840
Finite rate of increase	1.123657	1.126258	1.130703
Doubling time	5.950000	5.830000	5.640000
Annual rate of increase	3.03E+18	7.05E+18	2.97E+19

period of 5.95 days for the population to double as compared to shortest of 5.64 days at fluctuating temperature, 20/25±1°C. There was a considerable effect of varying temperature on Annual Rate of Increase (ARI) of *P. xylostella*. The maximum annual rate of increase (2.97E+19) was computed at 20/25±1°C followed by 25±1°C (7.05E+18) and 20±1°C (3.03E+18) (Table 3).

DISCUSSION

Development

A comparative study of *P. xylostella* on different developmental stages revealed that the value of its development ranged 3-4, 8-13, 1.0-1.5, 4-6 and 5-15 days at egg, larval, prepupal, pupal and adult stage, respectively at different temperatures. Similar judgment also made by Hemchandra and Singh (2003). They reported the incubation, larval, pre pupal, pupal and adult period of *P. xylostella* ranged 3-4, 5-11, 1-2, 4-5 and 8-10 days, respectively at various temperatures. However, Devjani and Singh (1999) was recorded the incubation, larval, prepupal, pupal and adult duration of diamondback moth as 2.10, 10.5, 1.6, 6.06 and 16.7 days, respectively at 23±1°C and 45±2% relative humidity.

It was also evident from the present findings that *Plutella xylostella* registered maximum range of its life span of 23-40 days at 20±1°C, followed by 23-38 days at 20/25±1°C and 19-37 days at 25±1°C. Similar study also made by Hemchandra and Singh (2003), who reported that the total life span of *Plutella xylostella* ranged from 28-34 days at 22±1°C.

Female Survival and Fertility

It was inferred from the result that the longest duration of natality was recorded at 20±1°C against the shortest at 25±1°C and the peak egg laying was also recorded highest at 20±1°C, whereas, the minimum at 25±1°C. These findings are the corroborative study of Shirai (2000) and Liu *et al.* (2002), who concluded that the female did not exhibited good tolerance with high-temperature as compare to low and the fecundity also decreased with increase in temperature.

In the present findings the maximum mean length of generation was recorded at 20±1°C against the minimum at 25±1°C. Similar observations also made by Liu *et al.* (1985), who reported maximum generation length of 22.69 days at 20±1°C. However, the judgment of Hemchandra and Singh (2005) also complete agreement of present findings, who reported longest mean length of generation of 29.48 days at 22.2±1°C. The highest carrying capacity was observed at fluctuating temperature (20/25°C) as compare to lowest at constant temperatures (20±1 and 25±1°C). The results obtained by Shirai (2000) and Chen and Liu (2004) also support these findings.

In present experiment, different rates of increase viz., intrinsic, finite and annual rate of increase were maximum at 20/25±1°C in contrast to minimum at 20±1°C. These findings has been well supported by the findings of Liu *et al.* (1985), Reddy and Singh (1998), Hemchandra and Singh (2003, 2005) and Navatha and Murthy (2006). The population of *P. xylostella* required maximum time to become double at 20±1°C and minimum at fluctuating temperature of 20/25±1°C. The corroborative study also made by Devjani and Singh (1999), Shirai (2000), Liu *et al.* (2002), Chen and Liu (2004), Hemchandra and Singh (2003, 2005) and Kumar *et al.* (2007).

It is accomplished from present findings that the development of the subsequent stages of *P. xylostella* and the fecundity of female decreased with increase in temperature, whereas, population took the shorter period to become double at fluctuating temperature (20/25±1°C). Therefore, both minimum and fluctuating temperatures favor the development and survival of *Plutella xylostella* on cabbage under controlled condition. This study also gave the detail information of survival and fecundity of *P. xylostella* at different temperatures that is necessary for management of this pest in cabbage ecosystem.

ACKNOWLEDGMENT

Authors are grateful to the authority of the Department of Plant Protection, Faculty of Agricultural Sciences for providing necessary facilities during the experimental work.

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