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# Impact of Elevated Temperature on the Survivorship of *Plutella xylostella* (L.) in Cauliflower †

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**Abstract:** Diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) is an important pest of crucifers distributed along different climatic regions across the world. To understand the effect of elevated temperatures on the survival rate and development of diamondback moth on cauliflower, an experiment was conducted evaluating six different temperatures (31, 32, 33, 34, 35 and 36°C) in Open Top Chambers during 2019- 2020. Survival and longevity were recorded at daily intervals. Results revealed that the total life cycle of *P. xylostella* was longest at 31°C and it declined with increasing temperatures. However, *P. xylostella* did not complete its development at 35 and 36°C. Fifty percent mortality was observed after 24.4 days at 31°C, after 22.6 days at 32°C, and after 14 days at 34°C. Increasing temperatures significantly reduce the survival rate of *P. xylostella*, but temperatures above 34°C were found to be lethal affecting the growth and development of *P. xylostella*. The most probable reason for the incomplete development of the insects at higher temperature was the inability of the larvae to consume adequate nitrogen to support the temperature dependent development rate.

**Keywords:** *Plutella xylostella*; elevated temperature; survivorship; Kaplan-Meier; 50% mortality

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## 1. Introduction

Diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) is a crucial pest of crucifers distributed along different climatic regions across the world [1-3]. The yield loss estimated due to this destructive insect pest was around 90% [4, 5]. Globally, 4-5 billion US dollars were spent on the management of *P. xylostella* [6]. The ability to complete several generations per year, higher reproductive rate and insecticide resistance made *P. xylostella* management difficult [7-9].

Temperature is considered a critical abiotic factor influencing the survival, development and reproduction of insects [10]. It also affects the population dynamics and confines insects' biological activities [11, 12]. Temperature and generation time of insects are highly inter-related to each other [13], and elevated temperature reduces the generation time of most of the insects with more number of generations per season and finally leads to exacerbation of crop losses [14].

Weather and climate influence often vary significantly, the development rate, survival, fitness and level of activity of individual insects; the phenology, distribution, size, continuity of insect populations, migration and the re-establishment of populations following local extinction, the initiation of outbreaks, the susceptibility of crops and stock to insect attack and the capacity of producers to manage insect populations. Keeping these views in mind, the present study was conducted to understand the population dynamics of *P. xylostella* on cauliflower in relation to temperature changes.

## 2. Materials and Methods

### *2.1. Insect culture*

The cauliflower (*Brassica oleracea* var. *botrytis*) seeds of variety Arka Kanti was grown in pots in a greenhouse and used for the experiments. The mother culture of *P. xylostella* larvae and pupae were collected from the cauliflower fields of Thondamuthur and Narasipuram, Coimbatore during February 2019. The collected larvae were reared on the leaves of cauliflower at 28 ± 2°C, 70 ± 5% RH in plastic containers (13 × 15 × 11 cm) covered with a fine muslin cloth. The pupae formed were placed in adult emergence cage (60 × 60 × 60 cm) which consists of a clear, plexiglass on one side and remaining sides made of fine nylon mesh gauze. An opening was made on one side for providing fresh leaves and food. Honey solution (10%) was soaked in a cotton wick (10 cm) and given to adult as feed along with fresh cauliflower leaves [15]. The cage was covered with black muslin cloth for egg laying. Every 24h, the leaves with freshly laid eggs were collected from the cage and used for experiments.

### *2.2. Experimental procedure*

Developmental parameters of *P. xylostella* were studied at six constant temperatures (31, 32, 33, 34, 35 and 36°C) in separate Open Top Chambers (OTC). A total of 100 eggs were examined at each temperature. The eggs were carefully examined until hatching. Each egg was noted as a replication. The newly emerged I instar larvae from each temperature treatment were placed individually on cauliflower leaf disc placed on water - soaked cotton in Petri dishes (4.5 cm dia, 4 cm ht). Fresh cauliflower leaves were given every day during the experimental period. The mortality, developmental time of each instar and life cycle of *P. xylostella* were recorded at each temperature treatment.

### *2.3. Survivorship curves*

The survivorship curves were prepared by plotting the survival rate of *P. xylostella* ($l_x$) against the age of an insect. It helps in assessing variations among different groups of populations and gives visual presentation. The probability of survival concerning an insects' age follows a logistic curve of type III. Hence the curves are fixed by Doesn't Use Derivative (DUD) using the following formula [16].

$$\text{Probability of survival} = \frac{1}{1 + \exp(\frac{x - a}{b})} \quad (1)$$

Where, a is the Day in which 50 per cent mortality was observed (Point of inflexion), b is the Intercept (Shape of the curve) and x is the age in days.

### *2.4. Kaplan-Meier estimate on survival*

Kaplan-Meier is helpful in the estimation of survival fraction from life history data. The population survival curve estimated over different periods gives the Kaplan-Meier analysis [17]. It is considered one of the best tools to identify the rate of individuals surviving over a definite time after each treatment. A Kaplan-Meier was utilized for comparing mean survival times of different treatments. The possible impact of elevated temperature on insect survival over a particular period was assessed through a multivariate cox proportional hazard model.

## 3. Results

### *3.1. Developmental duration*

The developmental duration of egg, larvae and pupae differed significantly among different temperature treatments. The duration of the egg ranged from 2.56 days at an elevated temperature of 35°C to 2.73 days at the ambient temperature of 31°C. However, there was no hatching when the eggs were exposed to a temperature of 36°C. *P. xylostella* completed its development at temperatures between 31 and 34°C. All the fourth instar larvae attained mortality before reaching the pupal stage at 35°C.

The duration of first, second, third and fourth instar larvae was significantly longer at the minimum temperature treatment of 31°C (1.99, 1.91, 2.07 and 2.03 days, respectively) and the duration steadily declined at a higher temperature of 35°C (1.89, 1.35, 1.14 and 1.00 days, respectively). The pupal period lasted for about 3.16 days at 31°C whereas, it significantly reduced to 2.67 days at 34°C.

The pre-adult duration (egg to eclosion) also exhibited a significant difference between different temperatures. The pre-adult period was minimum at 34°C (10.93 days), while the maximum duration occurred at 31°C (13.91 days) (Table 1).

**Table 1.** Developmental duration of *Plutella xylostella* at different temperature regimes.

| Temperatures (°C) | Developmental duration (Days ± SE)* | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Egg** | **I instar** | **II instar** | **III instar** | **IV instar** | **Pupa** | **Pre-adult** |
| 31 | 2.73 ± 0.05[b] | 1.99 ± 0.01[c] | 1.91 ± 0.07[e] | 2.07 ± 0.06[d] | 2.03 ± 0.05[d] | 3.16 ± 0.05[d] | 13.91 ± 0.14[d] |
| 32 | 2.61± 0.05[b] | 1.97 ± 0.02[c] | 1.71 ± 0.07[d] | 1.91 ± 0.05[d] | 2.04 ± 0.05[d] | 3.12 ± 0.05[d] | 13.39 ± 0.18[c] |
| 33 | 2.60 ± 0.04[b] | 1.93 ± 0.03[c] | 1.50 ± 0.06[c] | 1.42 ± 0.06[c] | 1.82 ± 0.05 | 2.94 ± 0.06[c] | 12.23 ± 0.13[b] |
| 34 | 2.63 ±0.05[b] | 1.86 ± 0.04[b] | 1.27 ± 0.05[b] | 1.13 ± 0.04[b] | 1.44 ± 0.06[b] | 2.67 ± 0.07[b] | 10.93 ± 0.11[a] |
| 35 | 2.56 ± 0.05[a] | 1.89 ± 0.04[a] | 1.35 ± 0.10[a] | 1.14 ± 0.14[a] | 1.00 ± 0.01[a] | 0.00 ± 0.00[a] | - |
| | F- 11.26<br>p- <0.001 | F-3.208<br>p- <0.001 | F- 4.807<br>p- <0.001 | F- 3.829<br>p- <0.000 | F- 4.251<br>p- <0.000 | F- 4.603<br>p- <0.000 | F- 198.76<br>p- <0.001 |

### *3.2. Survivorship*

The survival of *P. xylostella* population depicted a type III survivorship curve which indicated the rate of survival decreased with increased temperatures (Figure 1). The survival of *P. xylostella* under elevated temperatures followed a logistic pattern. Therefore, the survivorship curve was smoothened using the Doesn't Use Derivative (DUD) method. The mortality rate was more pronounced during the early life stages at higher temperatures. Fifty per cent mortality was observed on 24.4 days at 31°C followed by 22.6 days at 32 °C whereas at 34 °C, it occurred as early as on 14.0 days (Table 2).

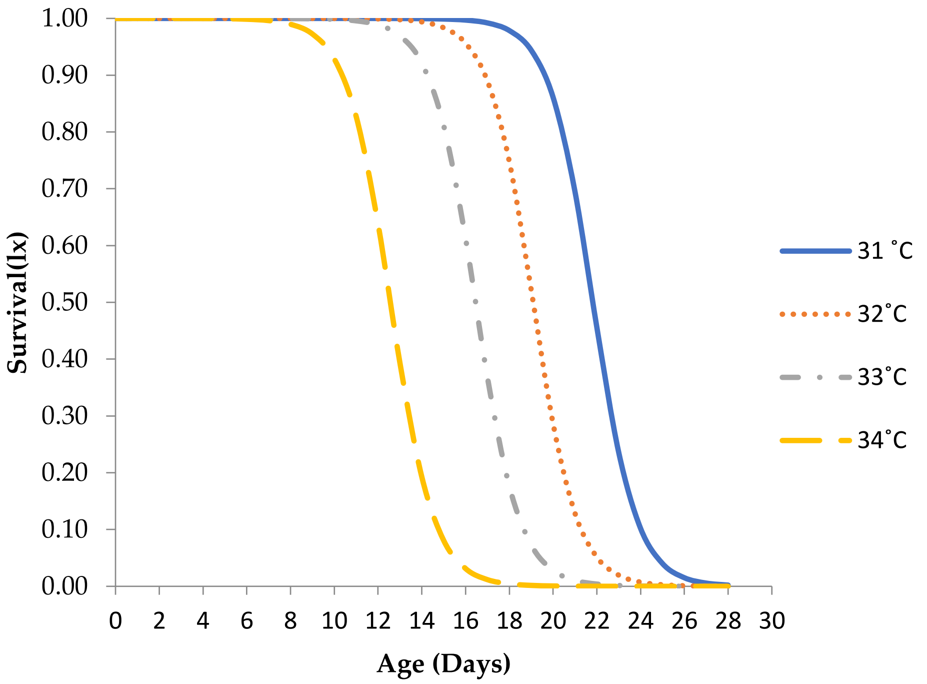


**Figure 1.** Survivorship curves of *Plutella xylostella* under different temperature regimes.

**Table 2.** Survival response of *Plutella xylostella* to different temperatures.

| Temperature (° C) | 'a' (50% mortality) | 'b' (intercept) | Regression equation | $r^2$ |
|---|---|---|---|---|
| 31 | 24.4 | 1.118 | y = - 0.020x + 1.118 | 0.471 |
| 32 | 22.6 | 1.184 | y = - 0.029x + 1.184 | 0.569 |
| 33 | 19.8 | 1.203 | y = - 0.040x + 1.203 | 0.757 |
| 34 | 14.0 | 1.114 | y = - 0.048x + 1.114 | 0.885 |

### *3.3. Kaplan- Meier estimate on survival of Plutella xylostella*

The cumulative survival probability of *P. xylostella* in cauliflower concerning the number of days was represented using Kaplan-Meier estimate in Figure 2. Each survival curve in different colours indicated different temperature treatments. Each step down denotes the death of insects on each day. The probability of survival among different treatments was compared using a log-rank test. The mean survival distributions were statistically non-significant between different treatments (Log-rank: Chi-square-5.376, p-0.800). A Cox proportional hazard model showed a significant role of both temperatures ($p<0.001$) and carbon dioxide level ($p<0.001$) on the mortality of insects.

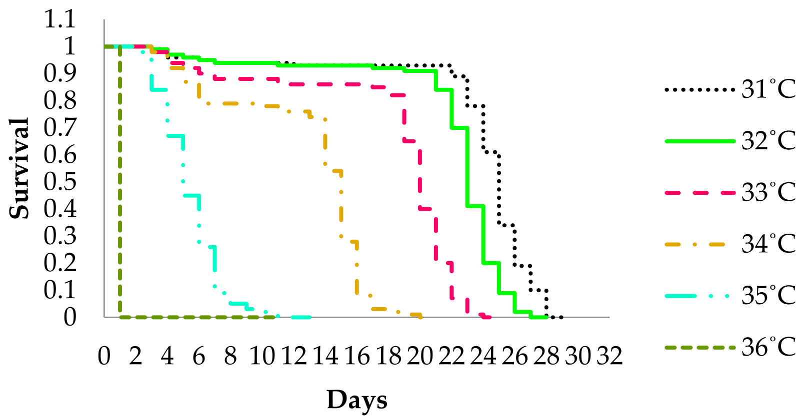


**Figure 2.** Kaplan-Meier estimate on survival of *Plutella xylostella* under increasing temperatures.

## 4. Discussion

In the present investigation, it was found that *P. xylostella* completed its development to adulthood till 34°C. At higher temperatures of 35 and 36°C, the life span was much shortened. Similarly, in cabbage and cauliflower, the survival rate of *P. xylostella* was reduced at 35°C [15]. It was found that 20-25°C was the favourable condition for the reproduction of *P. xylostella* [18], while in our study the fecundity can be observed up to 34 °C. Also, few studies concluded that *P. xylostella* developed successfully from egg to adult at temperatures between 8 and 32°C and there was only partial development at temperatures ranging from 34°C to 40°C [19]. Contrarily, the egg development of codling moth, *Cydia pomonella* decreased with elevated temperature up to 30°C and then increased at 33°C [20].

[21] opined that the impact of temperature varies among different insects. In general, the lower temperature reduces the developmental rate and increases the duration of each life stage. The most probable reason for the incomplete development of the insects at higher temperatures was the inability of the larvae to consume adequate nitrogen to support the temperature-dependent development rate [22, 23].

Results indicated that per cent survival of *P. xylostella* decreased with increasing temperatures. 50 per cent mortality was observed on 24.40 days at a lower temperature of 31°C while it occurred as early as 14.00 days when the temperature is elevated to 34°C. The survival was greatly reduced at 35°C and cent percent mortality was observed at 36°C. Our results were consistent with the results of [24] who reported 100 per cent mortality of *P. xylostella* second instar larvae at 35°C. 50 per cent mortality of corn aphid, *Rhopalosiphum maidis* on 38$^{th}$ pivotal age at 6°C and cent percent mortality on 14$^{th}$ pivotal age at 35°C [25]. Similarly, 100 per cent mortality was observed in *Brachycaudus schwartzi* at 35°C [26].

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