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*Research paper*

# Response of *Scirpophaga incertulas* Walker to different temperature regimes

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**The yellow stem borer (YSB) *Scirpophaga incertulas* (Walker) (Pyralidae: Lepidoptera) is one of the major pests in rice producing areas and accounts for 27 to 34 per cent loss in the crop yield. Climate change especially temperature increase will affect the insect physiology, behavior and development. An investigation was undertaken to study the effect of temperature on *Scirpophaga incertulas* (Walker) by constructing the stage specific life table to understand its behaviour in the future climate. Experiments were carried out at four different temperature regimes *viz.,* 28.0°C, 30.0°C, 32.0°C and 34.0°C. The results revealed that the survival fraction of a particular stage reduced with increasing temperatures. The calculated apparent mortality indicated that the percentage of insect died, increased with increasing temperatures. The results showed that the Mortality Survival Ratio (MSR) was observed to be increasing with increasing temperatures for all the stages. The value of IM was observed to be decreasing with increasing temperatures. The generation mortality of YSB was increasing with increase in temperatures for all the stages. The experiments revealed that the insects which happened to live under higher temperature would die faster and most of their energy is spent for reproduction rather than for living long time.**

*Key words: climate change, global warming, life table, plant protection, temperature, yellow stem borer*

## INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most significant staple food crops for more than 50 per cent of the global population. Several insects feed on rice, but stem borer, *Scirpophaga incertulas* (Walker) is weighed as one of the most important rice pests (Sarwar, 2012). The yield losses by YSB are to the tune of 27 to 34% every year (Sarwar et al., 2007; Sarwar, 2011). Globally, YSB solely causes 10 million tons of yield loss and accounts for 50 per cent of all chemicals applied in paddy field (Huesing and English, 2004). Weather and climate influence often vary significantly, the development rate, survival, fitness and level of activity of individual insects. Among all the climatic factors, temperature is probably the single most important environmental factor as insects are poikilothermic animals whose metabolism, rate and magnitude of growth, development and overall behavioral activities respond significantly to temperature change (Bale et al., 2002). IPCC (2019) has reported that the mean land surface air temperature and global mean surface (land and ocean) temperature (GMST) has increased by 1.53°C and 0.87°C, respectively. Insects has short life span and high reproductive rates, so they are more like to respond quicker to climate change than long living organisms, such as plants and vertebrates. Warming can potentially affect several aspects of insect and influences the life cycle, development time and rate, survival and mortality characters (Menendez, 2007). Hence, understanding the effect of temperature on insects behaviour is most important. Life table details are useful in understanding interactions of insects with temperature and other weather parameters (Carey, 1993, 2001). The collection of data on life-table at various temperature regimes yields an important task for pest management in different environmental conditions (Ali and Rizvi, 2009). With this background, an investigation was undertaken to study the effect temperature on *Scirpophaga incertulas* (Walker) under different temperature regimes by constructing the life table.

## MATERIALS AND METHODS

### *Experimental sites*

The experiments were carried out at temperature control chamber (Manikandan et al., 2014) under different temperature regimes viz., 28, 30, 32 and 34 °C. The experiments were carried out following the method proposed by Iranipour et al. (2010). For getting uniform co-hort of population, *S. incertulas* was mass cultured following the method described by Saxena et al. (1990). Life cycle of the insect was divided into different stages (Egg, larvae, pupa and adult) for the purpose of constructing life table based on the temperature. Data on mortality and survival were collected from the experiments conducted at different temperature regimes and stage specific life table was constructed.

*Survival fraction (Sx)*

Survival fraction ($S_x$) was calculated from the following formula using mortality and survival data at each stage.

$$s_x = \frac{l_x of subsequent stage}{l_x of particular stage}$$

*Apparent mortality*

Apparent mortality expressed in percentage is calculated by using the formula

$$Apparent mortality = \frac{d_x}{l_x} \times 100$$

*Mortality survivor ratio (MSR)*

Mortality Survivor Ratio answers the question of 'what would be population increase, if there is no mortality at the particular stage?' It is expressed as

$$MSR = \frac{Mortality \in particular stage}{l_x of subsequent stage}$$

*Indispensable mortality (IM)*

This is used to quantify the effect of main factor which is causing the mortality. For example, in our experiment temperature is the main factor which causes mortality. This gives answers to the assumption that, what would be the percentage of mortality that can be avoided, If the mortality causing factor i.e. temperature is not allowed to operate?

$$\Im = Number of adults emerged \times MSR of particular stage$$

*K-values*

K values indicate the increase or decrease in the number of generation from one to another and are calculated using logarithmic value of survivorship. The total generation mortality (K) was arrived by summing up k values of different stages (Southwood, 2000).

$K = K_E + K_{L1} + K_{L2} + K_{L3} + K_{L4} + K_{L5} + K_P$

## RESULTS AND DISCUSSION

*Survival fraction ($S_x$)*

Survival fraction ($S_x$) was found maximum (0.91) at 30.0°C for egg stage and minimum (0.71) at 34.0°C. This meant that, if 100 eggs were incubated, 91 eggs will be successfully emerging into larvae at 30.0°C, whereas only 71 eggs emerged into larvae at 34.0°C. Among the larval stages, fourth instar seemed to be more successful at 30.0°C as the $S_x$ remained higher (0.85) and the rate of success was lower for second instar stage at 34.0°C as the $S_x$ was found lower (0.72) (Table 1). At pupal stage, the maximum $S_x$ (0.93) was noticed at 30.0°C in contrast to minimum (0.64) at 34.0°C. The above results indicated that the successful completion of a particular stage reduced with increasing temperatures (Katsarou et al., 2005; Ali and Rizvi, 2010; Aziz et al., 2013).

**Table 1. Survival fraction of YSB at different temperature regimes**

| Stages | Temperature regimes (°C) | | | |
|---|---|---|---|---|
| | 28 | 30 | 32 | 34 |
| Egg | 0.90 | 0.91 | 0.86 | 0.71 |
| 1st Instar | 0.77 | 0.82 | 0.78 | 0.73 |
| 2nd Instar | 0.80 | 0.83 | 0.84 | 0.72 |
| 3rd Instar | 0.82 | 0.79 | 0.83 | 0.75 |
| 4th Instar | 0.83 | 0.85 | 0.80 | 0.77 |
| Pupa | 0.91 | 0.93 | 0.84 | 0.64 |

*Apparent mortality*

At egg stage the apparent mortality was more (29.17 %) at 34.0°C and minimum (9.4%) at 30.0°C. When the comparison was made between the larval instars, highest mortality (27.59 %) was observed at 34.0°C for second instar, whereas minimum mortality (13.8 %) was observed at 28.0°C for fourth instar. Similarly, mortality at pupal stage remained higher (36.11 %) at 34.0°C and lower (6.9 %) at 30.6°C (Table 2). Generally, apparent mortality increased towards the higher temperature regimes, indicating the less tolerance of insects to higher temperature regimes (Katsarou et al., 2005; Ali and Rizvi, 2010; Aziz et al., 2013).

**Table 2. Apparent mortality of YSB at different temperature regimes**

| Stages | Temperature regimes (°C) | | | |
|---|---|---|---|---|
| | 28 | 30 | 32 | 34 |
| Egg | 10.5 | 9.4 | 14.1 | 29.17 |
| 1st Instar | 22.7 | 18.3 | 21.9 | 26.89 |
| 2nd Instar | 20.2 | 16.5 | 16.0 | 27.59 |
| 3rd Instar | 17.7 | 20.9 | 16.7 | 25.40 |
| 4th Instar | 13.8 | 14.7 | 20.0 | 23.40 |
| Pupa | 9.3 | 6.9 | 16.1 | 36.11 |
| Adult | 100.0 | 100.0 | 100.0 | 100.00 |

*Mortality survivor ratio*

Mortality survivor ratio (MSR) was calculated to understand the amount of population increase in particular stage, if, the mortality in the particular stage had not occurred. MSR was found maximum (0.41) at 34.0°C and minimum (0.10) at 30.0°C for egg stage. Among larval instars, maximum MSR (0.38) was observed at 34.0°C for second instar. On the other hand, the minimum (0.17) MSR was obtained at 28.0°C and 30.0°C for fourth instar larvae. Furthermore, when the pupal stage was examined, the highest MSR (0.57) was observed at 34.0°C and lowest was (0.07) at 30.0°C (Table 3). The results revealed that the population increase would be more at higher temperature regimes, if the mortality doesn't occur. The increase in the MSR with increasing temperatures was attributed to the decrease in the survival ($l_x$) with increasing temperature, as the MSR

**Table 3. Mortality survivor ratio of YSB at different temperature regimes**

| Stages | Temperature regimes (°C) | | | |
|---|---|---|---|---|
| | 28 | 30 | 32 | 34 |
| Egg | 0.12 | 0.10 | 0.16 | 0.41 |
| 1st Instar | 0.29 | 0.22 | 0.28 | 0.37 |
| 2nd Instar | 0.25 | 0.20 | 0.19 | 0.38 |
| 3rd Instar | 0.22 | 0.26 | 0.20 | 0.34 |
| 4th Instar | 0.17 | 0.17 | 0.25 | 0.31 |
| Pupa | 0.10 | 0.07 | 0.19 | 0.57 |

was the function of the $l_x$. Similar results were reported by Butler (1982); Rai *et al.* (2002); Aziz *et al.* (2013).

### *Indispensable mortality*

Indispensable mortality (IM) was recorded to understand the amount of mortality which can be avoided if the factor causing mortality is not allowed to operate. It was found that the IM was maximum (9.47) at 34.0°C and minimum (5.6) at 30.0°C for egg stage. The examination of larval instars revealed that the IM remained maximum (14.4) at 28.0°C for first instar, whereas the minimum value (7.03) was encountered at 34.0°C for fourth instar larva. Likewise, the IM for pupa was observed to be minimum (4.00) at 30.0°C, and maximum (13.00) at 34.0°C (Table 4). The results were in line with the studies conducted by Katsarou et al. (2005); Ali and Rizvi, (2010); Aziz et al. (2013) who reported that the IM was lower for the insects which were happened to live under the higher temperature regimes.

**Table 4. Indispensable mortality of YSB at different temperature regimes**

| Stages | Temperature regimes (°C) | | | |
|---|---|---|---|---|
| | **28** | **30** | **32** | **34** |
| Egg | 5.7 | 5.6 | 7.71 | 9.47 |
| 1st Instar | 14.4 | 12.1 | 13.16 | 8.46 |
| 2nd Instar | 12.4 | 10.7 | 8.95 | 8.76 |
| 3rd Instar | 10.6 | 14.3 | 9.40 | 7.83 |
| 4th Instar | 8.2 | 9.3 | 11.75 | 7.03 |
| Pupa | 5.0 | 4.0 | 9.00 | 13.00 |

### *K - Values*

At egg stage, the k-value was found maximum (0.1498) at 34.0°C and minimum (0.0426) at 30.0°C. Comparision of larval instars revealed that the highest 'K' value (0.1402) was recorded at 34.0°C for second instar and lowest (0.0691) was recorded at 30.0°C for fourth instar larva. At pupal stage, K-value remained at its maximum (0.1946) at 34.0°C and minimum (0.0310) at 30.0°C. The total generation mortality was observed to be increasing with increasing temperatures. K - value was observed to be maximum (0.1439) at 36.0°C and minimum (0.0684) at 30.0°C (Table 5). It revealed that the insects which happened to live under higher temperature regimes were reproduction oriented as the most of the energy was spent in reproduction rather than spending the energy for living for longer time. Similar results were obtained by Omkar and Pervez, (2004); Ali and Rizvi, (2009); (2010); Aziz et al. (2013). Generally YSB tend to be K favoring at higher temperature from being r favoring at lower temperature. The tradeoff between survival and reproduction is yet to be explored full.

**Table 5. K values of YSB at different temperature regimes**

| Stages | Temperature regimes (°C) | | | |
|---|---|---|---|---|
| | **28** | **30** | **32** | **34** |
| Egg | 0.0481 | 0.0426 | 0.0660 | 0.1498 |
| 1st Instar | 0.1116 | 0.0875 | 0.1072 | 0.1360 |
| 2nd Instar | 0.0980 | 0.0783 | 0.0757 | 0.1402 |
| 3rd Instar | 0.0847 | 0.1020 | 0.0792 | 0.1272 |
| 4th Instar | 0.0805 | 0.0691 | 0.0969 | 0.1158 |
| Pupa | 0.0422 | 0.0310 | 0.0761 | 0.1946 |
| Average | 0.0775 | 0.0684 | 0.0835 | 0.1439 |

## CONCLUSION

The temperature of the earth is increasing and IPCC has projected that the increase to be continuous with a magnitude of 1-4°C by 2100. The experiments revealed that the mortality of the insects would increase with increase in temperature. It is also understood that the insects would live for shorter period with most of its energy spent towards reproduction.

## AUTHOR CONTRIBUTIONS

Manikandan – executed work, collected observation and prepared the manuscript. Kennedy – fixed the hypothesis and designed the study. Geethalakshmi –contributed in planning and execution of temperature controlled experiments.

## COMPETING INTERESTS

The authors declare that they have no competing interests.

## ETHICS APPROVAL

Not applicable.

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