Crop Protection 89 (2016) 248–254

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

# Temperature-dependent development of pale damsel bug, *Nabis capsiformis* Geramer (hemiptera: nabidae) using linear and non-linear models

Abbas Arbab*, Nasim Heydari, Hajar Pakyari

*Department of Entomology, Takestan Branch, Islamic Azad University, Takestan, Iran*

A R T I C L E  I N F O

*Article history:*
Received 18 May 2016
Received in revised form
25 July 2016
Accepted 26 July 2016
Available online 4 August 2016

*Keywords:*
*Nabis capsiformis*
Temperature
Developmental rate
Modeling

A B S T R A C T

Temperature can affect the predation potential of predators. The temperature-dependent development of *Nabis capsiformis* (Geram) was studied in the laboratory in six constant temperatures (18, 22, 24, 28, 31 and 33 °C) on green pods of bean (*Phaseolus vulgaris*, L.) infested with pea aphid, *Acyrthosiphon pisum* (Harris). Developmental times in days for separate immature and total development (egg to adult) were inversely proportional to temperature between 18 and 28 °C but increased at 31 °C. Bugs did not manage to complete development at 33 °C. Thermal parameters were estimated by fitting two linear (common and Ikemoto- Takai) models and four non-linear (Taylor, Hilbert – Logan, Briere and Lactin) models to the data. The lower developmental thresholds, calculated using the common linear model and Ikemoto-Takai model for egg, total nymph, and total development were 15.91, 10.01, and 11.76 °C and 14.74, 10.55, and 12.07 °C respectively. The thermal constants for total development were estimated 341.29° – days with common linear model and 313.40° – days with Ikemoto – Takai model. Four non linear models, Taylor, Hilbert and Logan, Briere and Lactin fitted the data well as measured by the "z weight" indicator. Temperature threshold parameters for these non linear models ($T_{(min)}$, $T_{(opt)}$, and $T_{(max)}$) were estimated for eggs, total nymphal stages, and total development time (egg to adult). The Taylor model is recommended for the description of temperature-dependent development of *N. capsiformis*. The optimal temperature for the development of eggs, the five nymphal instars and the egg-adult period predicted by this model ranged between 29 and 30 °C. Results from this study will provide basic information for the development of predictive models of the seasonal progress of this natural enemy.

## 1. Introduction

Damsel bugs (*Nabis* spp.) are considered generalized predators, attacking a great number of insect species. Twelve species of this group have been reported from Iran (Ghahari et al., 2010; Razmjoo, 2012). They are the most prevalent group of hemipterans predators in alfalfa fields (Elliott and Kieckhefer, 1990; Pons et al., 2005; Rakhshani et al., 2009). The most abundant species in Iran are *Nabis pseudoferus* (Remane) and *N. capsiformis* (Khalilzadeh et al., 2007). An evaluation of the potential of *N. capsiformis* to reduce alfalfa pest populations (such as aphids) is needed in order to assess the importance of this predator. The efficacy of biological control by natural enemies depends on a complex but delicate relationship between natural enemies and their hosts. This balance can be offset by a changing climate. Environmental factors (especially temperature) directly affect the survival, development, reproduction and dispersal of pest insects and thus their potential biogeography and biotic potential (Chidawanyika et al., 2012). Also it is well known that temperature is a major factor affecting insect biology, activity and distribution of natural enemies in agro-ecosystems (Chidawanyika et al., 2012; Prado et al., 2015). Many studies have demonstrated that temperature affects some life history parameters e.g., fecundity, sex ratios, generation time and lifespan of hemipteran predators (Hofsvang, 1976; Medeiros et al., 2004; Pourali et al., 2010; Calixto et al., 2014). Similarly, temperature extremes may reduce insect survival, reduce fecundity and retard natural enemy development (Hance et al., 2007). In biological control, information concerning such responses are useful to select natural enemies that are best adapted to conditions favoring target pests (Roy et al., 2002). Biological control is facilitated when the climatic

---

* Corresponding author.
*E-mail address:* abbasarbab@hotmail.com (A. Arbab).

http://dx.doi.org/10.1016/j.cropro.2016.07.031

responses of biocontrol agents are known, especially temperature (Roy et al., 2002). On the other hand, knowledge of the optimal temperatures for development and survival of biological control agents is essential for efficient mass-rearing and introduction of natural enemies in augmentative biological control programs (Calixto et al., 2014). Natural enemies and their host/prey may have different thermal limits and effective temperature ranges for survival, development, reproduction and mobility (Roy et al., 2002; Medeiros et al., 2003).

The use of temperature-dependent developmental data and its application in insect population models has long been recognized as a key tool to help solve pest problems. Insect phenological models have historically been used to help insect pest management programs to predict seasonal emergence, density, and survival of insect pests under field conditions and to further help farm managers and entomologists optimize pesticide use (Herrera et al., 2005). Population models to simulate predator-prey interactions also have been constructed to control insect pests in crop systems to explore and/or improve integrated pest management (IPM) programs (Herrera et al., 2005).

This study was conducted to (1) determine the stage-specific development of *N. capsiformis* at six constant temperatures ranging from 18 to 33 °C, (2) develop linear and non linear models to realistically describe thermal development, and (3) estimate developmental parameters of biological significance for mass rearing, prediction of seasonal phenology, and estimation of prospective establishment range if introduced.

## 2. Material and methods

### 2.1. Experimental insects

The laboratory colony of *N. capsiformis* used in this study was started from the adults collected by sweep netting in early June 2015 in several commercial alfalfa fields. The insects were reared by feeding them with the pea aphid, *Acyrthosiphon pisum* (Harris) on green pods of bean, *Phaseolus vulgaris* (L.). The colony was maintained inside temperature-controlled environmental chambers (model GL-700W; Dena, Iran) under the constant temperature, (26 ± 1 °C), a photoperiod of 16:8 (L:D) h, and 65 ± 5% RH.

### 2.2. Experimental design

Effects of temperature on the development of *N. capsiformis* were examined at six different temperatures (18, 22, 24, 28, 31 and 33 °C) under a photoperiod of 16:8 (L:D) h and 65 ± 5% RH by using environmental chambers (model GL-700W; Dena, Iran). The temperature range was chosen to include the both ends of extreme temperatures, which were not tested in the previous studies. A total of 25 pairs of newly-emerged adults were randomly collected from the rearing colony and transferred into rearing cups (30 × 20 × 15 cm) to obtain newly-laid eggs (<1 day old). Adults and nymphs of *A. pisum* were provided in the cups as food and green pods of bean were provided as water sources and oviposition sites (Alvarado-Rodriquez et al., 1986). The rearing cups were checked of 12-h intervals and the green bean pods containing newly deposited eggs were placed in new rearing cups in the growth chambers. Ten bean pods containing an average of 150 eggs were collected and placed into rearing cups provisioned with moistened dental wicks. Each set of eggs was randomly allocated and placed into one of the six environmental chambers. The eggs were checked twice daily (09:00 and 17:00 h) by examining pods under a binocular microscope (40×) until all eggs hatched. The first-instar nymphs were transferred to new rearing cages. The nymphal instar of a particular immature nabid was determined by assessing the amount of wing pad development (Elvin and Sloderbeck, 1984). The nymphs were examined at 12 h intervals to determine their developmental time. The nymphs were fed with fresh green bean pods (every 3 days) and 5–10 nymphs of *A. pisum* (every day) until they reached adulthood.

### 2.3. Temperature-dependent development and survival models

Mean developmental rate of eggs and the nymph instars at various temperatures was estimated using equation (1) to account for linearity in the transformation of development time to developmental rate (Arbab and McNeill, 2011).

$$r(T) = 1\Big/e^{\left[\sum \ln(dt)/n\right]} \tag{1}$$

where *r(T)* is the mean developmental rate (reciprocal of development time) at temperature *T* (°C); *dt*, individual observations of development time in days; and *n*, number of observations. These rates are used in development models where data are added daily.

The temperature effect on developmental time (day) for each stage was determined using ANOVA (PROC GLM) and Tukey's HSD test at 5% error rate was used for mean separation (SAS Institute, 1989). Regression analyses were used to model temperature-dependent development for each developmental stage of *N. capsiformis*. The estimates of model parameters were obtained by using the JMP (v.4.0.2).

### 2.4. Linear modeling

The Ikemoto-Takai linear model (2) and common linear model (3) were used to determine the relationship between temperature and *N. capsiformis* developmental rate. The parameters of interest are the lower temperature threshold ($T_{min}$) and the thermal constant (*K*).

$$DT = K + tD \tag{2}$$

where D represents developmental duration (days), T represents constant temperature (°C), k represents the sum of effective temperatures and t presents the lower developmental threshold (°C).

To estimate the thermal constant (k) in degree-days development rates (*r(T)*) were plotted against the four lower temperatures (T) occurring in the straight line portion of the curve and fitted by linear regression using the common linear model

$$r(T) = \mathrm{a} + \mathrm{b}\mathrm{T}, \tag{3}$$

where a is developmental rate when T is 0 °C, b is slope of the regression line.

The thermal requirement for development was then estimated as k = 1/b degree-days (Gadino and Walton, 2012). The SE of K was estimated as follows (Campbell et al., 1974)

$$SE_k = \frac{SE_b}{b^2} \tag{4}$$

The common linear model can also be used to estimate the lower developmental threshold by $T_0 = -a/b$ °C, for comparison purposes with the non-linear model. The standard error (SE) of $T_0$ can be calculated using the following formula (Campbell et al., 1974)

$$SE_{T_0} = \frac{r}{b}\sqrt{\frac{s^2}{N^*r^2} + \left(\frac{SE_b}{b}\right)^2} \tag{5}$$