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REPRODUCTIVE PERFORMANCE OF *Trichogramma pretiosum* RILEY ON *Trichoplusia ni* HÜBNER UNDER DIFFERENT THERMAL CONDITIONS

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Abstract:This study aimed to evaluate the reproductive performance of *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae) on eggs of *Trichoplusia ni* Hübner (Lepidoptera: Noctuidae) when submitted to different thermal conditions. Cartons containing eggs of *T. ni* were daily exposed to parasitism by females of *T. pretiosum* for 24 h at temperatures of 18; 21; 24; 27; 30 and 33°C until the females death. Based on the data collected, fertility life tables were constructed. The greatest daily fertility was obtained in the first day of parasitism for the temperature of 30°C (8.2 eggs/female), while the greatest total fertility was obtained at the temperature of 21°C (23.1 eggs/female). Survival of *T. pretiosum* was lowest at the highest temperatures. The *Ro* was similar for the temperature range of 24 to 30°C. The r_m and λ directly proportional to temperature increase between 18 and 33°C. On the other hand, *T* and *Td* were inversely proportional to the increase in temperature. Therefore, it was concluded that temperature affects the reproductive performance of *T. pretiosum* and that the most favorable temperature range for this parasitoid is between 24 and 27°C.

Keywords: fertility; life table; parasitoid.

DESEMPENHO REPRODUTIVO DE *Trichogramma pretiosum RILEY EM Trichoplusia* ni HÜBNER SOB DIFERENTES CONDICIONAMENTOS TÉRMICOS

Resumo: O presente estudo teve como objetivo avaliar o desempenho reprodutivo de *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae) em ovos de *Trichoplusia ni* Hübner (Lepidoptera: Noctuidae) quando submetido a diferentes condicionamentos térmicos. Cartelas contendo ovos de *T. ni* foram diariamente expostas ao parasitismo de fêmeas de *T. pretiosum* por 24 h nas temperaturas de 18;

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21; 24; 27; 30 e 33°C até morte das fêmeas. Com base nos dados coletados foram confeccionadas as tabelas de vida de fertilidade. A maior fertilidade específica diária foi obtida no primeiro dia de parasitismo para a temperatura de 30°C (8,2 ovos/fêmea), enquanto que a maior fertilidade total foi obtida para a temperatura de 21°C (23,1 ovos/fêmea). A sobrevivência de *T. pretiosum* foi menor nas temperaturas mais elevadas. A *Ro* foi semelhante para a taxa térmica de 24 a 27°C. A r_m e a λ foram diretamente proporcionais ao aumento da temperatura na faixa térmica estudada (18 a 33°C). Por outro lado, o *T* e o *Td* foram inversamente proporcionais ao aumento da temperatura. Diante a isso, conclui-se que a temperatura afeta o desempenho reprodutivo de *T. pretiosum* e que a faixa térmica mais favorável ao parasitoide situa-se entre 24 e 27°C.

Palavras-chave: fertilidade; tabela de vida; parasitoide.

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1 INTRODUCTION

Trichoplusia ni Hübner (Lepidoptera: Noctuidae), commonly known as the cabbage looper, is a cosmopolitan pest whose range of hosts includes several economically important crops such as brassica plants, solanaceous plants, cucurbits, cotton, soybeans and others (JOST; PITRE, 2002; JANMAAT; MYERS, 2003; MILANEZ et al., 2009; CARVALHO et al., 2012). In Canada and Minnesota (USA) this insect is the main pest of brassica plants, causing serious problems to crops in both fields and greenhouses. The ability of *T. ni* to feed on a wide variety of hosts, both simultaneously and in succession, is the primary factor for its presence in agricultural areas. Thus, it is highlighted among pest of great importance including *Plutella xylostella* L. (Lepidoptera: Plutellidae) and *Pieris rapae* L. (Lepidoptera: Pyralidae) (ERLANDSON et al., 2007; BURKNESS; HUTCHISON, 2009). In Brazil this insect has provoked enormous losses especially among leafy vegetables, making them unmarketable due to depreciation incurred from holes made by feeding caterpillars (CARVALHO et al., 2012).

This pest control is achieved by applying synthetic broad-spectrum insecticides (GRECCO et al., 2010). Due to high socioeconomic cost and risks offered by these products, it is necessary to seek alternatives to pest control that combine efficiency and ecological compatibility. Among alternatives, biological agents represent an important tool to reduce the indiscriminate use of insecticides for pest control (PRATISSOLI et al., 2008). The use of parasitoids in brassica crops and commercial cotton plantations may promote regulation of the insect pest population below the economic injury level (GODIN; BOIVIN, 1998; BASTOS et al., 2010).

Parasitoids of the genus *Trichogramma* are distinguished by their broad geographic distribution and activity on eggs of various hosts, especially of the Lepidoptera order (DELPUECH et al., 2010; DAVIES et al., 2011). However successful utilization of *Trichogramma* in biological control programs depends on several steps including collection, identification, maintenance in the laboratory and

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selection of species and/or lineages of the parasitoid, as well as biological and environmental studies, as indicated by Hassan (1997) and Parra et al. (2002).

The parasitoid *Trichogramma pretiosum* Riley strain Tspd (Hymenoptera: Trichogrammatidae) was highlighted by Milanez et al. (2009) in their study, as the most promising for control of *T. ni* among all species/strains studied. Continuing the work Milanez et al. (2009), Altoé et al. (2012) studied the thermal requirements for this parasitoid when created in *T. ni*. However, their work did not evaluate the Trichogramma reproductive performance of on *T. ni*. Among abiotic factors, temperature has been reported as that which most affects the development and performance of this parasitoid (MOLINA et al., 2005; SAMARA et al., 2011). Therefore, utilization of life tables allows for understanding the population dynamics of the species, showing to be an excellent method for inter and intraspecific biological studies (OLIVEIRA et al., 2007; IRANIPOUR et al., 2010). This work aimed to obtain *T. pretiosum* fertility life tables on *T. ni* at different temperatures for the diverse brassica crop producing regions, seeking its implementation in management of this pest.

2 MATERIAL AND METHODS

The experiment was conducted in the Department of Entomology at the Center for Scientific and Technological Development in Plant Health Management of Pests and Diseases (Núcleo de Desenvolvimento Científico e Tecnológico em Manejo Fitossanitário de Pragas e Doenças – NUDEMAFI) of the Center of Agrarian Sciences, Federal University of Espírito Santo, Alegre, ES, Brazil.

Rearing and maintenance of *Trichoplusia ni*. Pupae of *T. ni* from the rearing stock of the Entomology sector in the NUDEMAFI were sexed and placed in plastic pots containing moistened filter paper at the bottom. Upon emergence of adults, they were transferred to a wood cage structure (60 x 50 x 50 cm) which contained a collard green leaf whose petiole was maintained in a 300 mL glass flask containing water, as a location for oviposition by the females. It was offered a solution of 10% honey (m v^{-1})

in 20 mL vials containing a cotton swab in contact with the solution, and this food was exchanged every 48 hours.

Collard green leaf was replaced by a new one every day in the morning and those containing eggs were placed in a plastic container. After hatching three larvae were transferred and maintained in glass tubes (8.5 x 2.5 cm) containing the artificial diet proposed by Greene et al. (1976) until pupation. The rearing procedure was performed within an acclimatized environment regulated at 25 ± 1 ºC, 70 ± 10% RH and 14 h photophase.

Rearing and maintenance of *Trichogramma*. Rearing and multiplication were carried out on eggs of the alternative host *Anagasta kuehniella* (Zeller) (Lepidoptera: Pyralidae) according to the methodology described by Parra et al. (2002). Using gum arabic (30% m v^{-1}), eggs from *A. kuehniella* were placed in sky blue cardboard cartons (8.0 x 2.0 cm) which were then exposed to a germicidal lamp to make the eggs unviable for a period of 45 min. This is necessary to prevent cannibalism of eggs parasitized by the larvae of *A. kuehniella* (PRATISSOLI et al., 2010).

Then cartons were placed in glass tubes (8.5 x 2.5 cm) and parasitoid females were introduced. Honey droplets were deposited in the tubes to serve as a dietary supplement for parasitoids. This step was carried out in acclimatized chambers at 25 ± 1ºC, 70 ± 10% RH and 14 h photophase (PRATISSOLI et al., 2010).

Fertility life tables. Twenty sky blue cardboard cartons (2.5 x 0.3 cm) containing 25 eggs were separated in Eppendorf tubes (3.0 mL). In each tube, one female was introduced (age 0-6 h) of *T. pretiosum* strain Tspd from the alternative host (*A. kuehniella*), allowing parasitism in the acclimatized chambers regulated to 70 ± 10% RH, 14 h photoperiod and temperatures of 18; 21; 24; 27; 30 and 33±1°C to provide minimum, average and maximum annual estimates for the production regions. After 5 hours of parasitism, females were removed with the aid of a brush and the tubes were maintained under the same conditions, in accordance with the methodology used by Pratissoli and Parra (2000).

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Upon emergence of the adults, 20 females (age 0-6 h) from each temperature (18; 21; 24; 27; 30 and 33±1ºC), were isolated in Eppendorf tubes (3.0 mL) and returned to their respective temperatures. Sky blue cardboard cartons (2.5 x 0.3 cm) containing 25 eggs of *T. ni* (age 0-24 h) were offered daily until confirmation of death of the *Trichogramma* female. Cartons with parasitized eggs from each treatment were placed in plastic bags (23.0 x 4.0 cm) and maintained under the same conditions. The parameters measured were: daily and total fecundity, survival and longevity of the females.

Life tables were calculated based on the studies of Silveira-Neto et al. (1976). From the values of age intervals (x), specific fecundity (m_x) and probability of survival (l_x) obtained from the fertility life tables, a fertility life table was generated based on estimates of bootstrap, where the following parameters were determined: net reproductive rate (*Ro*), time interval between each generation (*T*), intrinsic rate of natural increase (r_m), finite rate of increase (λ) and the time required for the population to double in number of individuals (*Td*), where:

$$Ro = \sum(m_x \cdot l_x) \quad (01)$$

$$T = \sum(m_x \cdot l_x \cdot x) / \sum(m_x \cdot l_x) \quad (02)$$

$$r_m = \frac{log_e Ro}{T} = \frac{lnRo}{T} \quad (03)$$

$$\lambda = e^{r_m} \quad (04)$$

$$Td = \frac{\ln(2)}{r_m} \quad (05)$$

Statistical Analysis. The design utilized was completely randomized with six treatments (temperatures) where the quantitative data was submitted to regression analysis. Selection of the equation that best fit to the data was based on the phenomenon under study and the significance of the regression coefficients (β_i), regression by the F-test at 5% probability of error and the coefficient of determination (R^2).

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3 RESULTS AND DISCUSSION

At all temperatures studied, adults of *T. pretiosum* strain Tspd presented no pre-reproductive period, initiating their oviposition period upon the emergence of adults (Figure 1). This period varied between 13 and 6 days for the range of 18 to 33°C. However, at 18 and 33°C the reproductive period was less than the mean longevity of the adults, indicating that the extreme temperatures (18 and 33°C) influenced the reproductive period (Figure 1).

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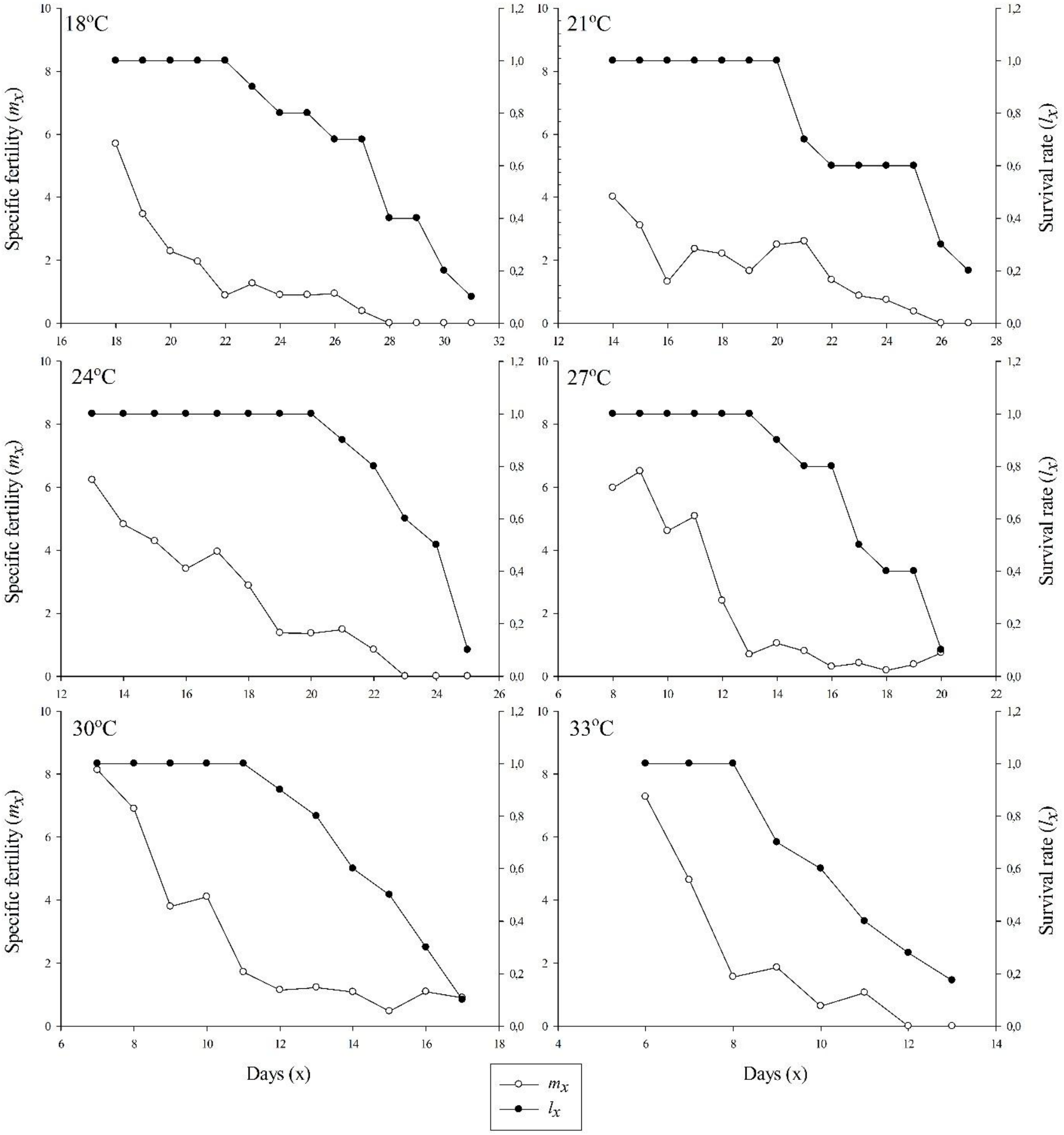
Figure 1 - Fecundity (m_x) and survival rate (l_x) of adults of *T. pretiosum* on eggs of *T. ni* at different temperatures.



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The greatest average daily fecundities were observed on the first day of life at all temperatures, except at 27°C where it was observed on the second day (Figure 1). After the second day fecundity showed a decrease, followed by a slight recovery and another decrease until death of the adults at temperatures of 18; 24; 27; 30 and 33°C. However, at 18°C the adult parasitoids ceased oviposition before their deaths. At the temperature of 21°C there was a higher oscillation in fecundity of *T. pretiosum* strain Tspd at the point of decrease initiated among three day old adults (Figure 1). The highest daily fertility rate was observed at 30°C (8.2 eggs/female), whereas the lowest was at 21°C (4.0 eggs/female) (Figure 1).

Moezipour and Shojaei (2008) and Pratissoli et al. (2009) reported a similar behavior in their studies. However, when studying *Trichogramma acacioi* Brun, Moraes and Soares, Pratissoli et al. (2009) found that independent of the host and temperature of the parasitoid, higher fecundity occurred on the first day. Differences were found between temperatures, the hosts and oviposition period. Nevertheless, Zago et al. (2007) reported in their study that the performance loss of females is directly influenced by their advancing age, thus showing to be a natural behavior.

With respect to the mean total fertility/female, the lowest value was observed at 33°C (17.0 eggs/female) and highest values in the range between 24 and 30°C, where there was no significant difference in this range. At the temperatures of 18 and 21°C females showed fecundities of 18.7 and 23.1 eggs/female, respectively.

Different from the values observed in this study, Pastori et al. (2007) verified a higher average total fertility per female at 18°C when studying the *T. pretiosum* strain bonagota on eggs of *Bonagota salubricola* Meyrick (Lepidoptera: Totricidae). In contrast, Pratissoli et al. (2004) and Pereira et al. (2007) observed a higher fecundity in the range of 25 to 30°C.

The average intervals between generations (*T*) varied between temperatures (F=2042.8, df=5; 114, P<0.001), indicating an inverse relationship with the increase in temperature from 18 to 33°C (Figure 2A). This variation resulted in a difference in amplitude of 13 days between the highest and lowest range.

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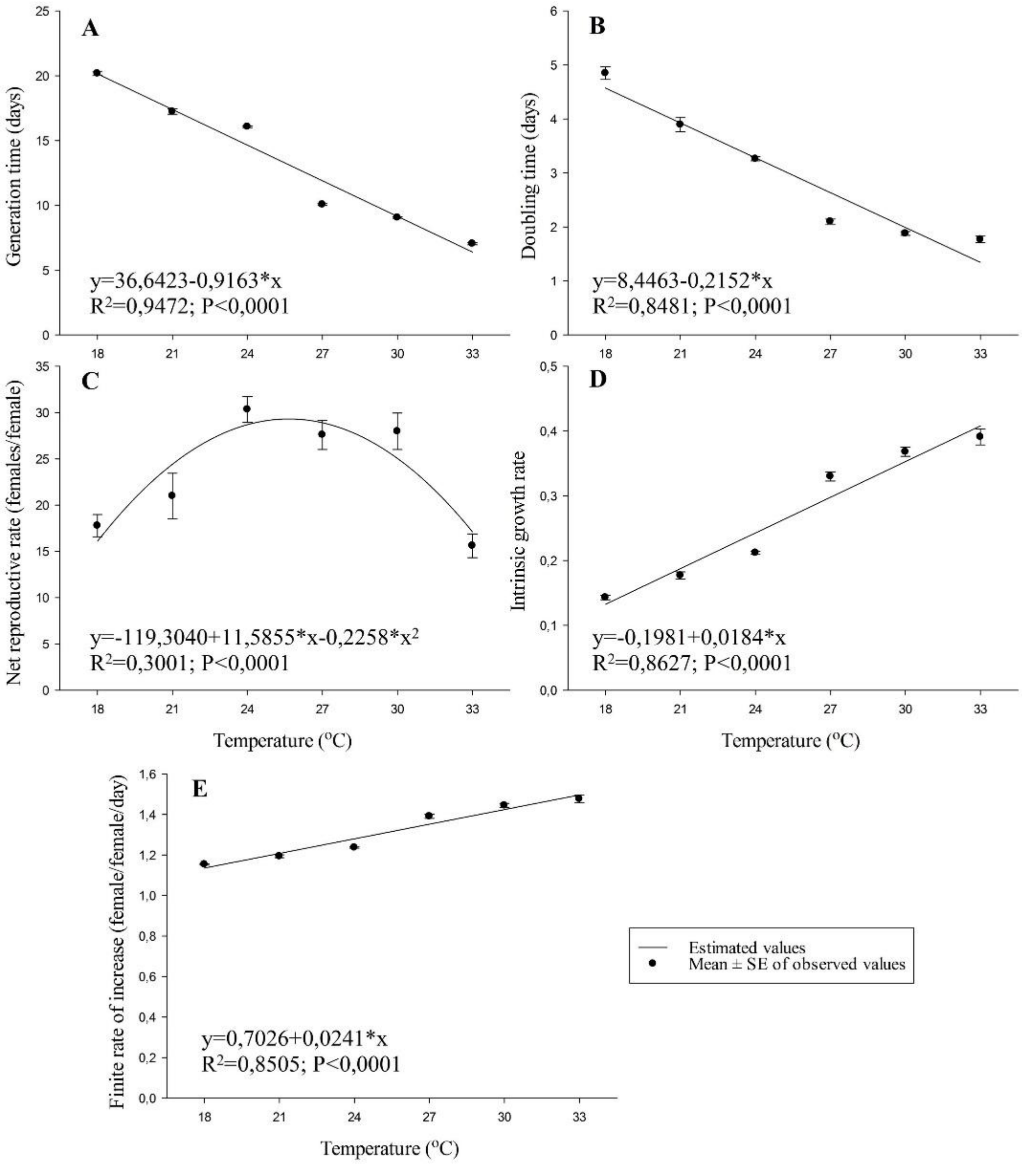
Figure 2 - Life parameters of *T. pretiosum* on eggs of *T. ni* at different temperatures: time intervals between each generation (*T*) (A), time interval for doubling the population (*Td*) (B), net reproductive rate (*Ro*) (C), innate ability to increase in number (r_m) (D) and finite rate of increase (λ) (E).



For *Trichogramma brassicae* Bezdenko, Moezipour and Shojaei (2008) observed an interval between generations of approximately 20.7 days at 20°C, while in the present study at 21°C this value was lower (17.2 days). However, the results of this

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study at 24°C (16.1 days) are higher than those found by Dias et al. (2010). These authors studied three species of *Trichogramma* on different hosts at 25°C, reporting values that differed among hosts and thus demonstrating that the characteristics of the host result in changes in the development of these parasitoids.

The time periods required for the population of *T. pretiosum* to double in number of individuals (*Td*) varied with temperature (F=658.9, df=1; 118, P<0.0001), presenting a reduction with increasing temperature (Figure 2B). At 24°C the time necessary to double the population was 1.5 times less than at 18°C, whereas at 33°C this value was 2.7 times smaller, indicating that increases in temperature result in an acceleration of the parasitoid reproductive process. Above all, alternating between alternative and destination hosts may influence the rate of development of the parasitoid, accelerating or slowing its development.

Reinforcing this statement, when Iranipour et al. (2010) evaluated *T. brassicae* at 25°C on continuous and altered hosts, they encountered values of *Td* which varied in function of the alteration of hosts. These authors found that the initial alternation from initial (Pyralids) to secondary hosts (Noctuids) resulted in an increase in the values of *Td*.

The highest net reproductive rates (*Ro*) were observed in the temperature range of 24 to 30°C, different from the other temperatures (F=25.1, df=2; 117, P<0.0001) (Figure 2C). These values were equal to 30.3; 27.6 and 27.9 females/female at the temperatures of 24; 27 and 30°C, respectively, indicating that in this temperature range the parasitoid has a higher growth potential. At extreme temperatures (18 and 33°C) the lowest values were found (17.8 and 15.6 females/female, respectively).

Chen et al. (2005), when evaluating *Trichogramma bactrae* Nagaraja on eggs of *C. cephalonica*, found the greatest *Ro* at 23°C (64.2 females/female), while Özder and Kara (2010) reported similar values of *Ro* at 25 and 30°C for *T. brassicae* on *E. kuehniella* and *Cadra cautella* Walker (Lepidoptera: Pyralidae). Lashgari et al. (2010) further reported values equivalent to 1.4 and 1.8 times greater than those encountered in the present study. In any event, as the parasitoid adapts and/or specializes to a particular

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host, it is expected that its biological parameters balance. However, Oliveira et al. (2007) found in their study with *Trichogramma exiguum* Pinto and Platner reared for several generations on *A. kuehniella* and *S. cerealella*, a variation between net reproduction rates between the different generations studied for the two hosts. In accordance with these authors, the results of Iranipour et al. (2010) showed a variation between the second and third generations (54.7 and 37.9 females/female, respectively), which did not occur between the first and second or between the third and fourth generations. These results demonstrate that independent of the host and temperature, the intrinsic characteristics of the parasitoid, especially the genetic character, act with greater influence on the life history of these insects.

All intrinsic growth rate values (r_m) were positive, indicating population increases in the temperatures evaluated, and thus presenting significant variation between temperatures (F=741.2, df=1; 118, P<0.0001) (Figure 2D). Thus, a higher rate was observed at 33°C (0.39) and lower at 18°C (0.14). However, between different species and/or strains there may occur distinct values, since this parameter is an individual characteristic, as well as submissive to external influences such as the host.

Superior results were obtained by Chen et al. (2005) at different temperature (29°C). These authors reported an r_m value of 0.489 for this temperature and of zero at 35°C for *T. bactrae*. Iranipour et al. (2010) reported a differentiation of r_m between different hosts and between hosts and generations when working with *T. brassicae*. The authors attributed this variation to the intrinsic characteristics of the host, including nutritional quality.

The finite rates of increase (λ) found presented a directly proportional relationship with the increase in temperature, ranging between the temperatures (F=671.1, df=1; 118, P<0.0001) (Figure 2E). This variation was from 1.48 to 1.15 females/female/day between the highest and lowest values. These results present a direct relationship with the net reproduction rate and the intrinsic rate of increase, since these are the main factors that influence the value of λ.

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Values found for *T. pretiosum* in the present study were lower than those encountered by Özder and Kara (2010) for *Trichogramma cacoeciae* Marchall and *T. brassicae* at 30°C (1.768 and 1.769 female/female/day, respectively). However, our results are within the range observed by Pratissoli et al. (2004) for *T. pretiosum* and *T. acacioi* on *S. cerealella*.

4 CONCLUSIONS

1. Temperature affected the reproductive performance of the *T. pretiosum* strain Tspd on *Trichoplusia ni*,

2. *T. ni* presented favorable characteristics for development of the *T. pretiosum* strain Tspd,

3. The temperature range between 24 and 27°C showed to be most favorable for development of the parasitoid, with maximum the 25.5°C.

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