

Temperature influences the performance and effectiveness of field and laboratory strains of the ichneumonid parasitoid, *Campoletis chlorideae*

Mukesh K. Dhillon · Hari C. Sharma

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Abstract To understand the influence of temperature on host–parasitoid interactions as a consequence of climatic change, we studied development, survival, and fecundity of field and laboratory strains of the *Helicoverpa armigera* larval endoparasitoid, *Campoletis chlorideae* at five different temperatures under laboratory conditions. Post-embryonic development period and degree-days required for completing the life cycle by both the strains decreased by 2.5 and 1.5 folds at 27°C compared to 18°C. Post embryonic development period showed a negative ($r = -0.99$, $P < 0.001$) and the development rate a positive ($r = 0.99$, $P < 0.001$) association with an increase in temperature. However, no parasitoid larvae survived in *H. armigera* larvae reared at 12 and 35°C after parasitization, suggesting that temperatures $\geq 35^\circ\text{C}$ as a result of global warming will be lethal for development and survival of immature stages of *C. chlorideae*. Adult longevity was negatively associated ($r = -0.91$ to -0.96 , $P < 0.001$) with temperatures between 12 and 35°C. The parasitoid adults stored at

12°C survived for longer period and exhibited higher fecundity than those kept at 27°C, but the efficiency of parasitism and adult emergence were quite low. Sex ratio of the progeny at 12°C was highly male-biased than the insects kept at 27°C. Laboratory strain of the parasitoid exhibited better survival, and the adults lived longer than the field strain at 18°C than at 27°C. Therefore, *C. chlorideae* adults stored at 18°C could be used for parasitism, while the immature stages should be reared at 27°C for mass production of the parasitoid for biological control of *H. armigera*.

Keywords *Campoletis chlorideae* · *Helicoverpa armigera* · Temperature · Climatic change · Biological control

Introduction

The ichneumonid parasitoid, *Campoletis chlorideae* Uchida (Hymenoptera: Ichneumonidae) is an important biocontrol agent of the noctuid pest, *Helicoverpa armigera* (Hubner) and other lepidopteran insects in pigeonpea [*Cajanus cajan* (L.) Millsp.], chickpea (*Cicer arietinum* L.), and cotton (*Gossypium* spp.) (Bhatnagar et al. 1982; Romeis and Shanower 1996; Dhillon and Sharma 2007a). It preferentially attacks second- and third-instar larvae of *H. armigera*, and the parasitoid larvae emerge from the fourth-instars for pupation. After oviposition, the parasitoid eggs hatch in 1.0–1.5 days inside the insect larvae and

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M. K. Dhillon · H. C. Sharma (✉)
International Crops Research Institute for the Semi-Arid
Tropics (ICRISAT), Patancheru, Andhra Pradesh 502324,
India
e-mail: h.sharma@cgiar.org

M. K. Dhillon
e-mail: m.dhillon@cgiar.org