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PARASITISM EFFICIENCY OF *Diatraeophaga striatalis* (DIPTERA: TACHINIDAE) TOWARD THE LARVAE OF THE SUGARCANE STALK BORER *Chilo auricilius* (LEPIDOPTERA: PYRALIDAE)

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ABSTRACT

The efficiency and performance of natural enemies play an important role in biological control. This study investigated the parasitic efficiency and performance of *Diatraeophaga striatalis* Townsend 1916 (Diptera: Tachinidae), a parasitoid of the sugarcane stalk borer *Chilo auricilius* Dudgeon 1905 (Lepidoptera: Pyralidae) under laboratory conditions. A factorial randomized block design was used with two factors: larval instar stage (second and third instars) and host population density (20, 38, and 56 individuals), resulting in six treatment combinations, each replicated four times. The results showed that *D. striatalis* females deposited their larvae on the feces of *C. auricilius* at the entrance of the larval tunnels. From the fecal medium, the parasitoid larvae moved toward the host inside the sugarcane stem. *Diatraeophaga striatalis* exhibited a preference for third instar larvae over second instars, with parasitism rates of 73% and 65%, respectively. Parasitism was affected by host population size, with higher densities resulting in lower parasitism rates. At host densities of 20, 38, and 56 individuals, the parasitism rates were 81%, 75%, and 60%, respectively. Not all available hosts were parasitized. The highest pupal formation occurred at the lowest host density, and third instar hosts produced larger and heavier pupae. Pupae from low-density host populations were generally heavier than those from higher-density populations. The emergence of *D. striatalis* adults was also influenced by host density: higher host densities resulted in lower adult emergence rates and a reduced number of female adults. Overall, *D. striatalis* prefers third instar larvae and performs best at low host densities, suggesting that these conditions are optimal for maximizing its parasitic efficiency. These findings provide valuable insights for potential field applications and mass-rearing programs.

Keywords: *Chilo auricilius*; parasitism efficiency; *Diatraeophaga striatalis;* sugarcane borer

ABSTRAK

Kecekapan dan prestasi musuh semulajadi memainkan peranan penting dalam kawalan biologi. Kajian ini mengkaji kecekapan dan prestasi parasitisme bagi *Diatraeophaga striatalis* Townsend 1916 (Diptera: Tachinidae), parasitoid pengorek batang tebu *Chilo auricilius* Dudgeon 1905 (Lepidoptera: Pyralidae) di bawah keadaan makmal. Reka bentuk blok rawak berfaktor telah digunakan dengan dua faktor: peringkat instar larva (instar kedua dan ketiga) dan ketumpatan populasi perumah (20, 38, dan 56 individu), menghasilkan enam kombinasi rawatan dengan empat ulangan. Hasil kajian menunjukkan bahawa induk betina *D. striatalis* meletakkan larva mereka pada najis *C. auricilius* di pintu masuk terowong larva. Dari medium najis tersebut, larva parasitoid bergerak ke arah perumah di dalam batang tebu. *Diatraeophaga striatalis* menunjukkan keutamaan terhadap larva instar ketiga berbanding instar kedua, dengan kadar parasitisme masing-masing sebanyak 73% dan 65%. Parasitisme dipengaruhi oleh saiz populasi perumah, di mana ketumpatan yang lebih tinggi mengakibatkan kadar parasitisme yang lebih rendah. Pada ketumpatan perumah 20, 38 dan 56 individu, kadar parasitisme masing-masing adalah 81%, 75% dan 60%. Tidak semua perumah yang tersedia diparasitkan. Pembentukan pupa tertinggi berlaku pada ketumpatan perumah yang paling rendah dan larva instar ketiga menghasilkan pupa yang lebih besar dan lebih berat. Pupa dari populasi perumah berketumpatan rendah secara amnya lebih berat berbanding yang berasal daripada populasi berketumpatan tinggi. Kadar kemunculan dewasa *D. striatalis* juga dipengaruhi oleh ketumpatan perumah: ketumpatan yang lebih tinggi mengakibatkan kadar kemunculan dewasa yang lebih rendah dan bilangan imago betina yang lebih sedikit. Secara keseluruhan, *D. striatalis* lebih suka larva instar ketiga dan berprestasi terbaik pada ketumpatan perumah yang rendah, menunjukkan bahawa keadaan ini adalah optimum untuk memaksimumkan kecekapan parasitnya. Penemuan ini memberikan pandangan yang berharga untuk aplikasi lapangan yang berpotensi dan program pembesaran besar-besaran.

Kata kunci: *Chilo auricilius*; kecekapan parasitism; *Diatraeophaga striatalis*; pengorek tebu

INTRODUCTION

Sugarcane is the primary crop for sugar production in Indonesia. During the 1930s, Indonesia was the world’s second-largest sugar exporter after Cuba. However, its status as a sugar exporter steadily declined until the 1950s (Tegegn & Dhont 2023). Since 1967, Indonesia has become a net importer of sugar, as domestic sugar production has not been able to meet national demand (Goebel et al. 2014). One of the main causes of low sugar production in Indonesia is the infestation by the sugarcane stalk borer *Chilo auricilius* (Lepidoptera: Pyralidae), a major pest in sugarcane plantations (Goebel et al. 2011; Sallam et al. 2021). There are six species of lepidopterous larvae known to infest sugarcane crops, including *Chilo infuscatellus*, *C. auricilius*, *C. partellus*, *C. tumidicostalis*, *Scirpophaga excerptalis*, and *Sesamia inferens* (Kumar et al. 2023). According to Subiyakto et al. (2023), *C. auricilius* is commonly found during the second growing season. Infestations by *C. auricilius* can reduce sugarcane yields by 6 to15%, while stalk borers in general can cause yield losses of 10 to 30% in sugarcane plantations (Li et al. 2024). The damage caused by *C. auricilius* includes the death of young sugarcane plants and the destruction of internodes in mature plants. The larval stage of *C. auricilius* can be identified by five dark longitudinal stripes along its body (Godoi et al. 2021).

Losses and damage caused by *C. auricilius* larvae in sugarcane can be suppressed by natural enemies such as predators and parasitoids. Parasitoids have been proven to effectively control pest populations in sugarcane crops (Faris et al. 2022). The population pressure exerted by parasitoids on *C. auricilius* occurs at both the egg and larval stages. The eggs of *C. auricilius* are parasitized by *Trichogramma* spp. and *Telenomus* spp., while the larvae are parasitized by *Diatraeophaga striatalis* (Diptera: Tachinidae) (Wibowo et al. 2023). *Diatraeophaga striatalis* belongs to the Tachinidae family, which is well known for parasitizing stalk borers (Nurlinda et al. 2022). The parasitism rate of *D. striatalis* can reach 32.23% in sugarcane fields (Meidalima 2014). Naturally, *D. striatalis* is found as a parasitoid in sugarcane plantations (Prabowo et al. 2021). Other Tachinidae species known as parasitoids include *Trichodischia soror* parasitoid of *Spodoptera frugiperda* (Alvarez-Garcia & de Santis 2021), *Pentatomophaga latifascia* parasitoid of *Halyomorpha halys* (Chen et al. 2020), *Compsilura concinnata*, *Exorista fasciata*, and *Phryxe vulgaris* parasitoids of *Thaumetopoea pityocampa* (Georgiev et al. 2022) *Ceromasia auricaudata* parasitoid of *Neodiprion omosus* (Castañeda-Vildózola et al. 2021), and *Xanthomelanodes brasilensis* parasitoid of *Heniartes jaakkoi* (Gil-Santana & Perez Dios 2023). Insect parasitoids are among the most effective natural enemies, as they complete their life cycle at the expense of their hosts. They are key components in biological control and integrated pest management programs (Cingolani et al. 2025; Wibowo et al. 2025).

Dipteran parasitoids have been effectively used as biological control agents since the beginning of this century through inoculative, inundative, and augmentative releases in the field (Banerjee et al. 2023). These include eight families of Dipteran parasitoids, namely Cecidomyiidae, Nemestrinidae, Bombyliidae, Asilidae, Phoridae, Pipunculidae, Tachinidae, and Sarcophagidae (Chellappan & Ranjith 2023). Among these, Tachinidae is the largest and most significant family of non-Hymenopteran parasitoids, known for their diverse oviposition strategies that allow them to parasitize hosts in various environments (Dindo et al. 2019). Tachinids have been successfully used as biological control agents (Dindo 2011). It is estimated that larvae from over 30 insect families and adults from 15 Dipteran families serve as effective natural enemies, with about 20% of the total, approximately 16,000 species, considered beneficial (Banerjee et al. 2023; Feener & Brown 1997). The ecological services provided by Dipteran natural enemies have been traditionally valued at approximately USD 4.49 billion in the United States (Losey & Vaughan 2006), highlighting the crucial role of Diptera as parasitoids and biological control agents. This remarkable diversity and adaptability highlight the ecological importance of tachinid flies and underscore their potential as reliable agents in sustainable pest management programs.

The efficiency and performance of natural enemies play a critical role in determining the survival of natural enemies. Members of the family Tachinidae often exhibit host-stage preferences, typically selecting larval instars that provide sufficient nutritional resources for parasitoid development while minimizing host immune defenses (Stireman et al. 2006). Parasitism success is influenced not only by host age but also by host population density, as overcrowding may reduce host quality and increase competition among parasitoid larvae (Dindo & Nakamura 2018). Tachinid parasitoids often favour host larvae at specific instar stages because intermediate-sized larvae offer a balance between nutritional suitability and vulnerability to immune responses: hosts that are too young may not provide sufficient resources, while hosts that are older may possess stronger immune defences or be less exploitable (Caron et al. 2009; Dindo & Nakamura 2018; Dai et al. 2022; Guzzo et al. 2023). Moreover, tachinids' success can be modulated by host population density, since high densities may reduce individual host quality (through competition or resource depletion) and increase intra-parasitoid competition or superparasitism, thereby lowering parasitoid fitness (Dai et al. 2022). These behavioral adaptations, selecting not just a host species but the right instar and density context, enhance offspring survival, reduce wasted oviposition effort, and support stable parasitoid populations in variable environments.

Although host selection strategies among tachinid parasitoids are well documented, the parasitic efficiency and performance of *D. striatalis* in relation to host instar and population density remain poorly understood. Therefore, this study evaluated the parasitic performance of *D. striatalis* against the sugarcane stalk borer *C. auricilius* under laboratory conditions. Understanding these aspects is essential for developing effective mass-rearing techniques and improving the practical application of *D. striatalis* in the biological control of sugarcane pests.

MATERIALS AND METHODS

Preparation of *Chilo auricilius* Larvae

This study was conducted at the Research and Development (R&D) Laboratory of PT Perkebunan Nusantara VII, Cintamanis, South Sumatra. The environmental conditions during the study were as follows: temperature ranged from 21.5 to 32.3 °C (average 27.9 °C) and relative humidity from 59 to 94% (average 81.4%). Lighting was provided by diffuse natural light from windows. Larvae of *Chilo auricilius* collected from sugarcane fields in Cintamanis were reared in plastic jars (13 cm in diameter and 25 cm in height), covered with mesh cloth and fed fresh sugarcane leaf sheaths until adult moths emerged. The jars containing *C. auricilius* larvae were arranged on laboratory shelves. The emerged adults were paired and confined to allow mating and oviposition. Eggs laid by the females were transferred into jars lined with filter paper. Darkened eggs were then transferred into test tubes containing an artificial diet composed of mung bean powder (30 g), young sugarcane shoots (30 g), sorbic acid (0.4 g), ascorbic acid (1.3 g), methyl *p*-hydroxybenzoate (0.8 g), yeast (1 g), agar (5.1 g), 10% formalin (200 mL), and water (150 mL). The larvae were reared in these tubes until pupation, and the resulting pupae were placed in mesh cages (30 × 30 × 30 cm) until adult emergence. Thirty pairs of newly emerged *C. auricilius* adults were reared on sugarcane leaves in plastic jars to obtain parasitoid-free eggs and larvae. The larvae were maintained until reaching the second and third instars, identified by increased body size, darker head capsules, and more distinct striped patterns, before being separated for experimentation.

Preparation of *Diatraeophaga striatalis* Parasitoids

Diatraeophaga striatalis used in this study were obtained from the laboratory-reared insect collection of the R&D Unit of PTPN VII, Cintamanis. Parasitoids were collected in the pupal stage and reared in plastic jars until adult emergence. Emerged male and female *D. striatalis* adults were separated and kept in different cages, where they were fed a 20% honey solution absorbed on cotton, tied with a thread, and suspended inside the cage. Mating was induced by placing males and females together in a mesh cage at a 1:1 ratio. Mating occurred between 08:00 and 10:00 a.m. The mating cage was covered with black cloth for about one hour, then uncovered to observe copulating pairs. Copulating adults were collected using a test tube and allowed to complete mating. Once the pair separated, the mated female was considered ready for oviposition (Dindo et al. 2019).

Mass Rearing of *Diatraeophaga striatalis* on *Chilo auricilius* Larvae

Mass rearing of *D. striatalis* was performed by dissecting the abdomens of mated female adults 6–8 days post-mating to extract two *D. striatalis* larvae. These larvae were then inoculated into a single *C. auricilius* larva using a fine brush (size 0). The inoculated *C. auricilius* larvae were maintained in plastic jars and fed fresh sugarcane leaf sheaths until pupation. The resulting pupae were collected and reared until adult emergence. The emerged *D. striatalis* adults were immediately mated and maintained for 2 days in mesh cages until they were ready for use in the infestation experiments.

Infestation of *Diatraeophaga striatalis* Parasitoids

The experiment was conducted using a factorial randomized complete block design (RCBD). The first factor was the larval instar stage of *C. auricilius* (second and third instars), and the second factor was the larval population size (20, 38, and 56 larvae), resulting in six treatment combinations. The population size of 38 larvae was chosen because it represents the average number routinely used in *D. striatalis* rearing at the R&D Unit of PTPN VII, Cintamanis, while the lower (20) and higher (56) densities were included to evaluate the effects of decreasing or increasing host population on parasitism performance. Each treatment was exposed to a single mated female adult of *D. striatalis*, which was allowed to remain in the jar until complete oviposition, and all treatments were replicated four times. Infestations were conducted in plastic jars containing pieces of sugarcane stalks that harbored *C. auricilius* larvae, with each stalk piece containing two larvae. To achieve the desired larval population sizes, 20, 38, or 56 stalk pieces were placed in the jars accordingly. Each treatment jar received one mated female *D. striatalis* and a 20% honey solution as a food source. Behavioral observations and parasitism assessments were conducted two weeks after infestation.

Observation Variables and Data Analysis

Parasitism Rate of Diatraeophaga striatalis on Chilo auricilius Larvae

Parasitism was assessed two weeks after infestation to determine the percentage of *C. auricilius* larvae parasitized by *D. striatalis*. Parasitized larvae were identified by a dull body color, sluggish movement, and shrunken appearance (Dindo & Nakamura 2018). The parasitism rate was calculated as the percentage of the number of parasitized *C. auricilius* larvae out of the total number of *C. auricilius* larvae.

Pupation Percentage of Diatraeophaga striatalis

Pupation observations were conducted on parasitized *C. auricilius* larvae to determine how many *D. striatalis* larvae successfully reached the pupal stage. The pupation percentage was calculated as the proportion of parasitized *C. auricilius* larvae that produced *D. striatalis* pupae relative to the total number of parasitized larvae. Each *D. striatalis* pupa was weighed using an analytical balance. Pupal morphology, including shape, size, color, and surface texture, was recorded and compared between treatments involving second- and third-instar host larvae.

Emergence Rate of Diatraeophaga striatalis Adults

Adult emergence was calculated based on the number of *D. striatalis* pupae that successfully developed into adults. The emergence rate (R) was calculated as:

$$R = \frac{Number\ of\ pupae\ that\ produced\ adults}{Total\ number\ of\ pupae} \times 100\%$$

Adult Morphology and Sex

The morphological traits of male and female adults were examined to identify sex-specific characteristics, focusing on differences in body size, as well as the shape of the antennae and the tip of the abdomen. Further observations included counts of male and female *D. striatalis* adults emerging from second and third instar *C. auricilius* larvae.

Data Analysis

All data were analyzed statistically using a factorial randomized complete block design (RCBD). Statistical analyses were performed using R version 4.2.2 (The R Foundation for Statistical Computing). The normality of the data was tested using the Shapiro–Wilk test, and the homogeneity of variances was assessed using Levene’s test. The variables including number of parasitized larvae, percentage of parasitism, pupal formation percentage, pupal weight, and percentage of adult emergence met the assumptions of ANOVA, as they followed a normal distribution and showed homogeneous variances. Differences among treatment means were statistically compared using Tukey's Honest Significant Difference (HSD) test.

RESULTS

Parasitism Rate

The parasitic efficiency of *Diatraeophaga striatalis* on *Chilo auricilius* larvae was significantly influenced by both host population density and larval instar stage. Higher parasitism percentages were consistently recorded at lower host population densities. The parasitism rate in third-instar larvae was significantly higher than that observed in second-instar larvae (Figure 1A). Host population density exerted a significant effect ($p < 0.0001$) on parasitism efficiency, where larger populations led to a marked decrease in parasitism rates (Figure 1B). At a population density of 20 larvae, third-instar hosts yielded a parasitism rate of 87.5%, which was notably higher than the 72.37% recorded for second-instar larvae at the same density. Both larval instar and host density played a significant role in determining the success of the parasitoid, with the lowest efficiency recorded in second-instar larvae at the highest population density of 56 individuals (Figure 1C). An inverse correlation was observed between host population size and parasitism percentage, indicating that an increase in host availability led to a reduction in the overall efficiency of *D. striatalis* (Figure 1D).

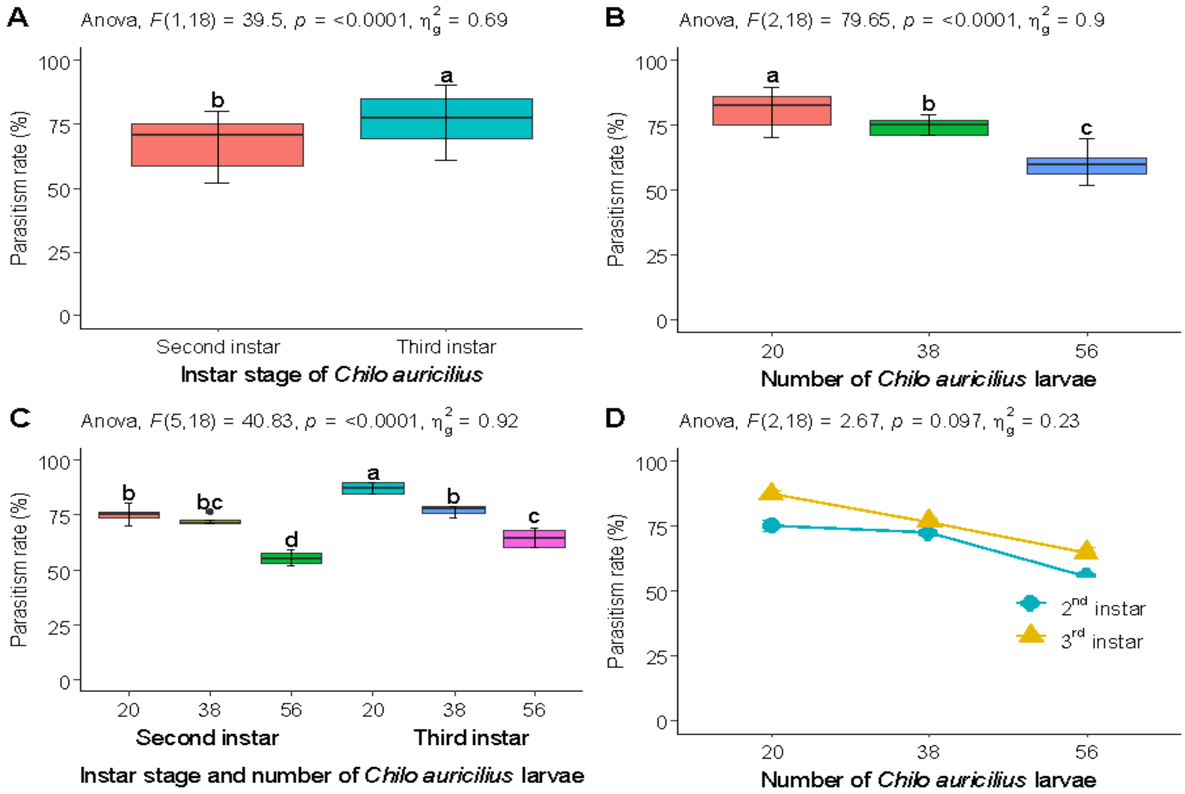

Figure 1. Parasitism efficiency of *Diatraeophaga striatalis* on *Chilo auricilius* larvae. (A) Parasitism percentage was significantly lower in second-instar larvae compared to third-instar larvae. (B) Host population density significantly affected parasitism, with higher densities associated with lower efficiency. (C) Parasitism rates in both instars consistently decreased as host density increased

from 20 to 56 individuals. (D) The parasitism percentage declined with increasing host population and was independent of larval instar in this specific correlation

Developmental Performance

Pupal Formation of Diatraeophaga striatalis

The results indicated that the percentage of pupal formation from third-instar *C. auricilius* larvae did not differ significantly ($p = 0.24$) from that of second-instar larvae (Figure 2A). However, pupal formation performance was significantly ($p < 0.0001$) influenced by host density, as a higher host population resulted in a lower percentage of successful pupation. At a population density of 20 larvae, the pupal formation rate for third-instar hosts reached 95.75%, which was higher than the 83.41% recorded for second-instar larvae. Overall, pupal formation at a density of 20 larvae was significantly ($p < 0.0001$) higher than at densities of 38 and 56 larvae (Figure 2B). Specifically, the formation rate for both second and third instars at a population of 20 individuals was superior to higher density treatments (Figure 2C). A significant ($p < 0.0001$) interaction was found between host larval instar and initial population density regarding pupal formation. While pupal formation in second-instar hosts was lower at a density of 20 individuals, it appeared higher when exposed to 56 individuals of the same instar (Figure 2D).

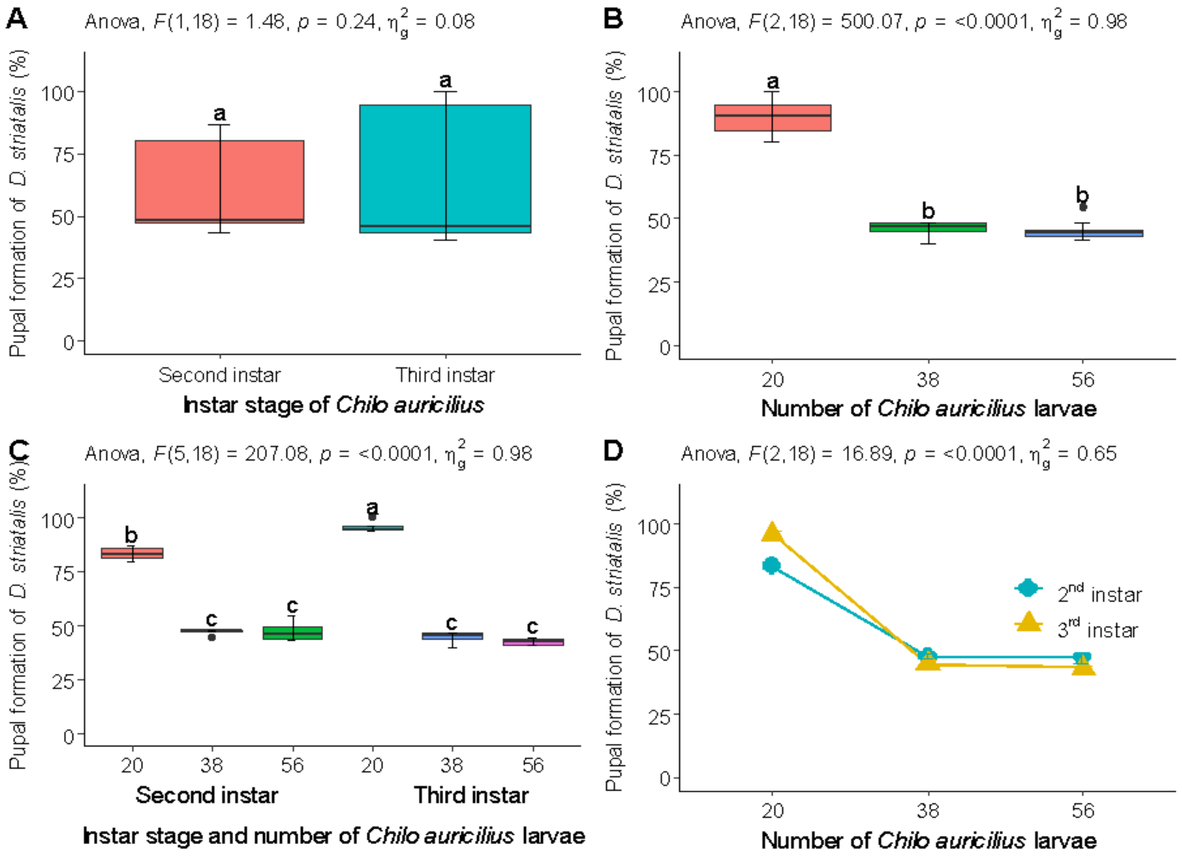

Figure 2. Pupal formation percentage of *Diatraeophaga striatalis* on parasitized *Chilo auricilius* larvae. (A) Host larval instar had no significant effect on pupal formation success. (B) Host population density significantly impacted pupal formation, with higher populations reducing success rates. (C) The highest

pupal formation was observed in third-instar larvae at a density of 20 individuals. (D) Increasing host population size generally led to a decrease in the percentage of parasitoid pupae formed

Pupal Morphology and Performance

Pupae of *D. striatalis* emerging from *C. auricilius* exhibited typical Dipteran characteristics, being oval, elongated, and showing clearly segmented bodies. Their color transitioned from an initial brown to a deeper dark brown or blackish-brown (Figure 3A). The posterior apex of the pupae provided a reliable means to differentiate sexes. Male pupae featured a prominent circular protrusion at the tip, whereas female pupae were characterized by a smooth, flat tip. Furthermore, pupal performance varied by host stage; pupae emerging from third-instar larvae were relatively larger and heavier than those emerging from second-instar larvae (Figure 3B).

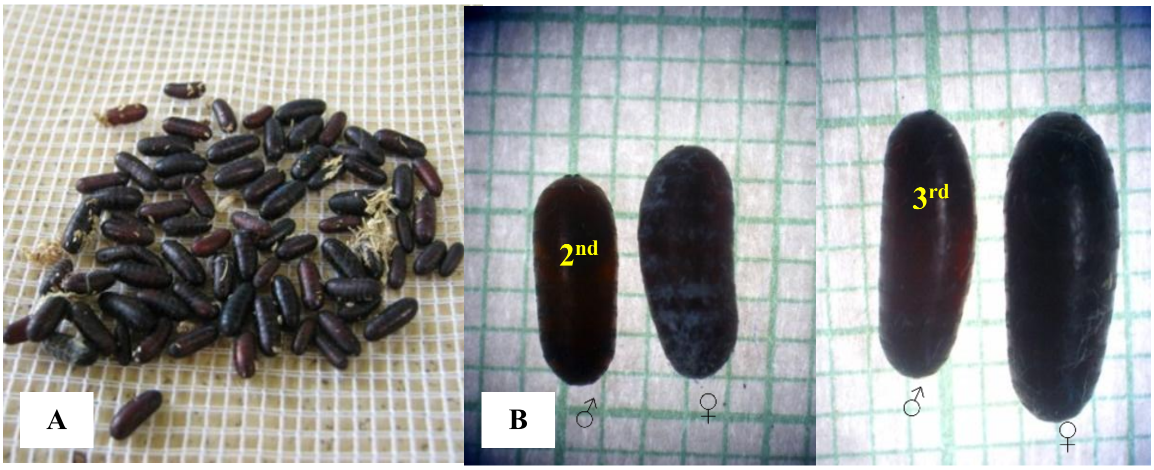

Figure 3. Morphology of *Diatraeophaga striatalis* pupae emerging from *Chilo auricilius* larvae. (A) Pupal coloration ranged from brown to dark brown. (B) Performance comparison showing that pupae from third-instar hosts were larger than those from second-instar hosts, with female pupae being larger than males

Pupal Weight of Diatraeophaga striatalis

The host larval stage significantly (p=0.026) influenced the pupal weight of *D. striatalis*, where pupae from third-instar larvae were consistently heavier than those from second-instar larvae (Figure 4A). In contrast, the host population density did not have a statistically significant (p = 0.34) effect on the average weight of individual pupae (Figure 4B). Although pupae from third-instar larvae at a density of 20 individuals tended to be heavier, this difference did not reach statistical significance (p = 0.18) (Figure 4C). No significant (p = 0.78) interaction was observed between host population size and pupal weight, although a general trend suggested that higher host densities tended to produce lighter pupae across all treatments (Figure 4D).

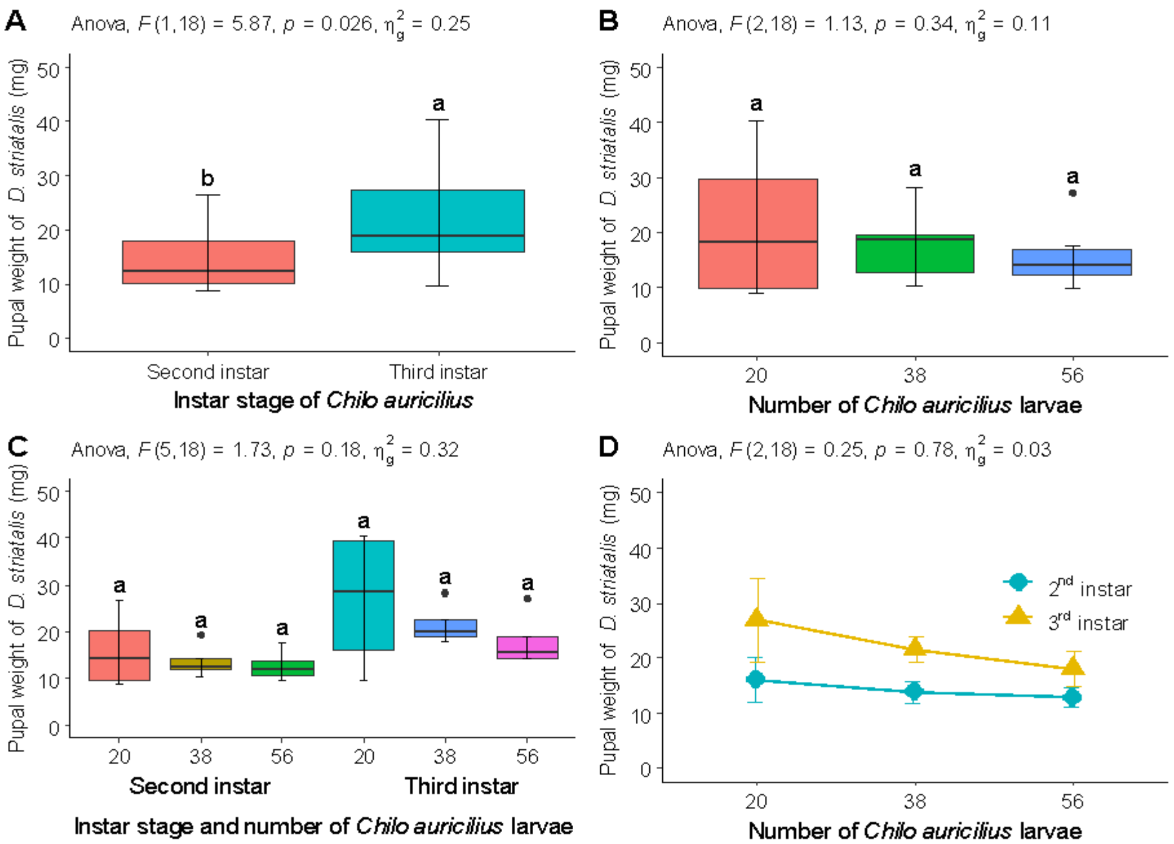

Figure 4. Pupal weight of *Diatraeophaga striatalis* emerging from *Chilo auricilius* larvae. (A) Host larval instar significantly affected pupal weight. (B) Host population density had no significant effect on weight. (C) Interaction between instar and density was not statistically significant. (D) General trend indicating that higher host densities yielded lighter parasitoid pupae

Adult Emergence and Sex Ratio

Emergence Rate of Diatraeophaga striatalis

The adult emergence rate was approximately 60%, suggesting that a portion of the pupae did not complete development. Emergence rates from pupae reared on second and third-instar hosts were not significantly different ($p = 0.65$) (Figure 5A). However, host population density significantly ($p = 0.002$) affected the emergence performance; higher host densities resulted in lower emergence rates (Figure 5B). Both factors influenced emergence, with lower host populations yielding the highest success (Figure 5C). A significant ($p = 0.011$) interaction was observed, where the highest emergence occurred at a population of 38 third-instar larvae and 20 second-instar larvae (Figure 5D).

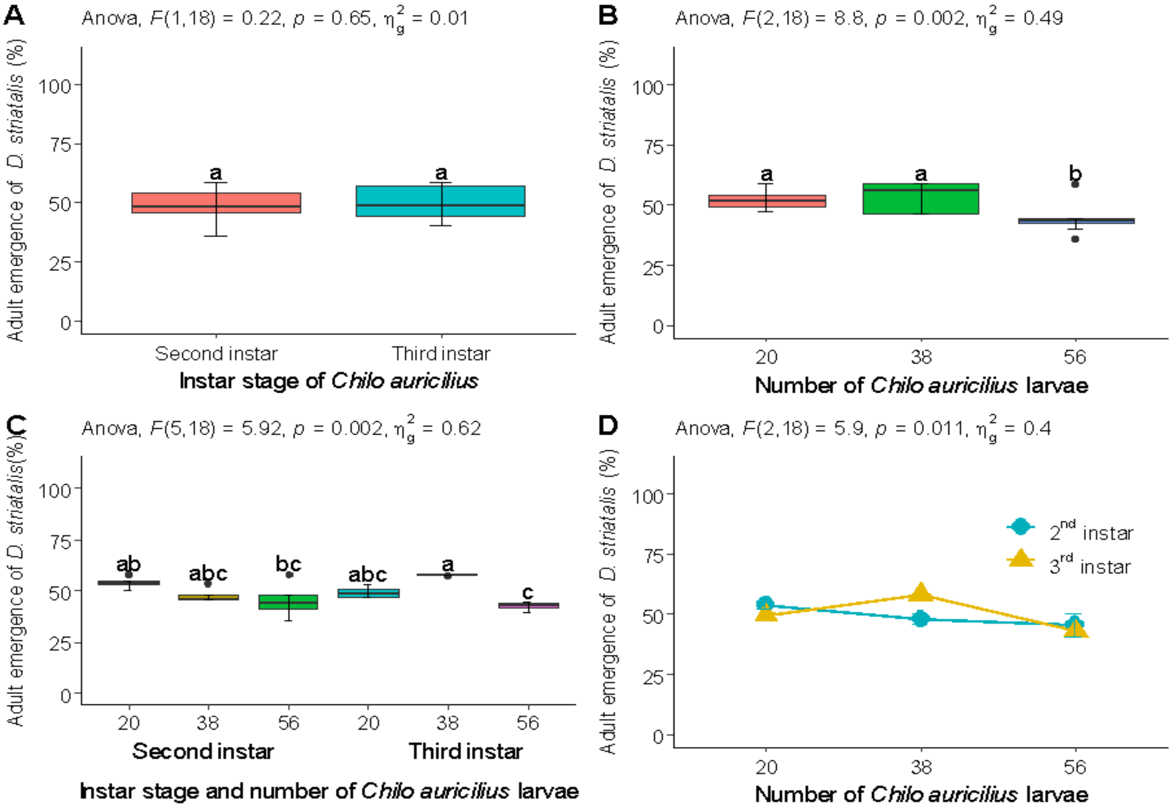

Figure 5. Adult emergence of *Diatraeophaga striatalis* from pupae. (A) Emergence rates did not differ significantly between host instars. (B) Higher host populations reduced the number of emerging adults. (C) Low host densities favored higher adult emergence. (D) Interaction showing optimal emergence at specific combinations of instar and density

Sex Ratio and Adult Morphology

The sex ratio (percentage of females) was significantly ($p = 0.004$) influenced by host density but not ($p = 0.1$) by the larval instar stage. The ratio remained consistent between second and third instars (Figure 6A). However, female emergence was negatively impacted by host density; higher densities resulted in a reduced proportion of female adults (Figure 6B). The highest number of females was produced when *D. striatalis* was reared with 20 second-instar host larvae (Figure 6C). This reduction in female-biased sex ratio at higher densities was consistent across both host instars (Figure 6D).

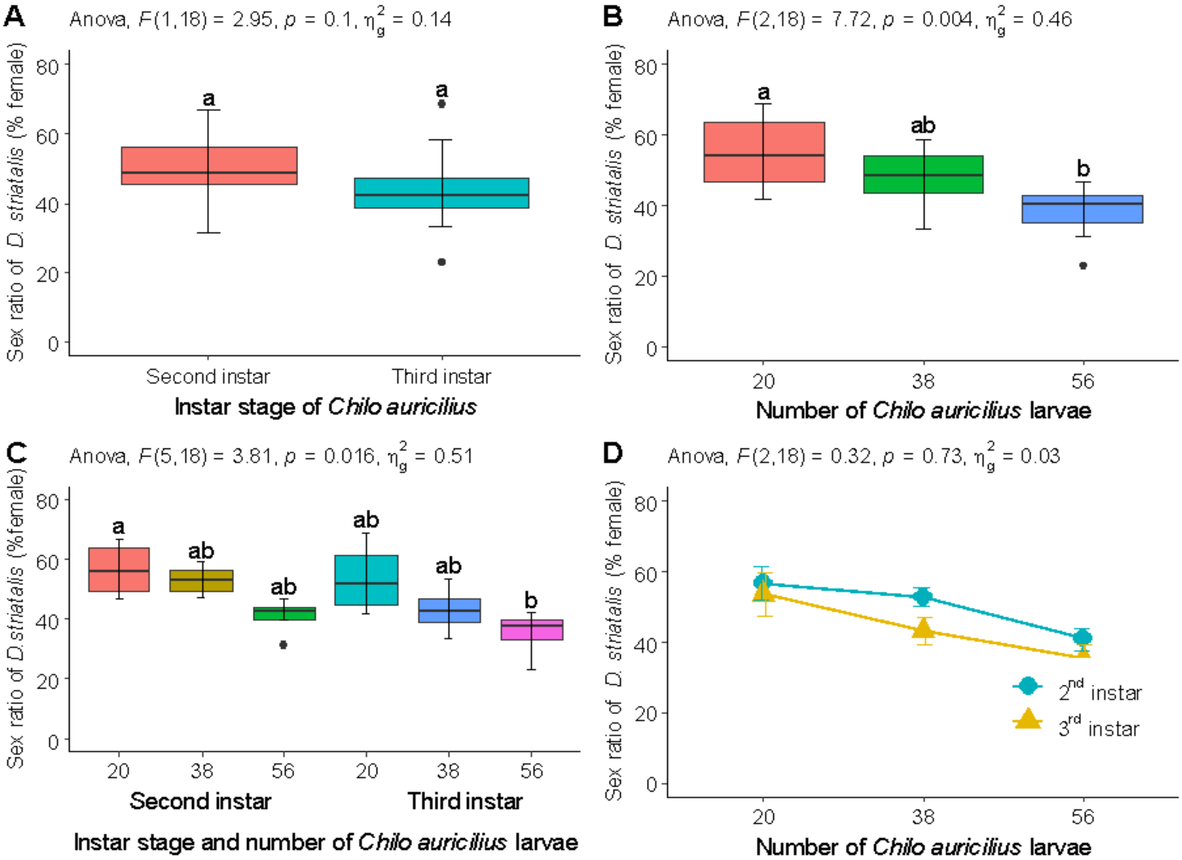

Figure 6. Sex ratio (percentage of females) of *Diatraeophaga striatalis* adults. (A) The proportion of females was not influenced by the host larval stage. (B) Higher host densities led to a lower proportion of female adults. (C) Females predominated in low-density host populations. (D) Increased host density reduced female emergence across both instar stages

` Adult of *D. striatalis* displayed distinct sexual dimorphism. Differences were evident in the aristate antennae and the abdominal tip. Female antennae featured a pointed aristate that was longer than the flagellomere (Figure 7A), whereas the male aristate was shorter and blunt (Figure 7B). Additionally, the female abdomen was tapered at the tip (Figure 7C), while the male abdomen was relatively flat (Figure 7D).

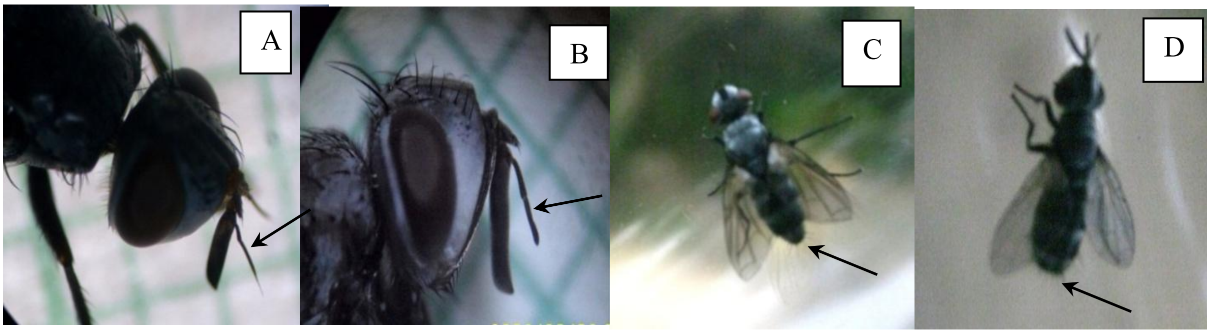

Figure 7. Adult morphology of *Diatraeophaga striatalis*. (A) Pointed aristate antenna of a female. (B) Blunt aristate antenna of a male. (C) Tapered abdomen of a female. (D) Flat abdominal tip of a male

DISCUSSION

The parasitic efficiency and performance of *Diatraeophaga striatalis* toward *Chilo auricilius* larvae were significantly influenced by the host's larval instar and population density. A greater attraction toward larger host instars, specifically the third instar, suggests that *D. striatalis* utilizes chemical cues such as feces and odor emissions to maximize its searching efficiency. Previous studies have indicated that later instar stages provide more substantial stimuli for parasitoids, which facilitates more successful host location (Stireman 2002; Steiner et al. 2007; Crespo & Castelo 2008; Stireman et al. 2017; Mizuno et al. 2019). While higher host populations increased the frequency of parasitoid-host encounters (Ebert 2005; Ichiki et al. 2011; Kruitwagen et al. 2022; Horn et al. 2023), leading to a linear increase in the total number of parasitized hosts, the overall efficiency per individual parasitoid followed a different trend.

The efficiency of *D. striatalis*, measured as the percentage of parasitism, was inversely correlated with the population density of *C. auricilius*. This inverse density dependence suggests that higher parasitism rates occur at lower host densities because hosts are more easily detected or because the parasitoid can concentrate its efforts more effectively on limited targets (Fleury et al. 2009). As the host population increases, the proportion of parasitized individuals decreases, likely because the searching capacity of *D. striatalis* becomes saturated, making it difficult to locate and parasitize all available hosts (Crespo & Castelo 2008; Mao et al. 2025).

The observation that *D. striatalis* did not parasitize all available hosts highlights its regulatory role rather than an eradicative one. This performance characteristic is crucial for the ecological stability of natural enemy-pest populations (Cingolani et al. 2025). By maintaining a balance rather than causing the local extinction of the host, *D. striatalis* promotes food web stability and contributes to sustainable pest management strategies (Azim et al. 2020; Ratto et al. 2022; Segura et al. 2024).

The performance of *D. striatalis* regarding pupal formation was also highly dependent on host density. The higher rate of pupal formation at lower host densities correlates directly with higher parasitic efficiency. The formation of pupae outside the host body is a characteristic trait of Tachinidae (Feener & Brown 1997), which distinguishes them from many Hymenoptera whose pupae often develop inside the host (Asmoro et al. 2021). Our results align with the theory that successful development and pupal quality are dictated by both host density and the availability of nutrients (Godfray 1994; Saini et al. 2019).

Performance was further impacted by the occurrence of multiple parasitism, particularly under high host density conditions. The presence of two pupae in a single host often led to a reduction in quality; typically, only one viable pupa was formed while the other remained underdeveloped (Adamo 2023). This phenomenon triggers intraspecific competition, which significantly impairs the survival and developmental speed of the parasitoids (Hill et al. 2025). Such competition explains the observed reduction in pupal weight under high-density conditions, a trend also noted in other tachinid species such as *Exorista japonica* (Du et al. 2023).

The sex ratio of emerging adults, which is a key indicator of parasitoid performance, was also influenced by density. A higher proportion of female imagos emerged at lower host densities, whereas male imagos became more frequent as host density increased. This shift represents a common adaptive response where parasitoids often invest in higher-quality female offspring when hosts are scarce or of superior quality, while producing more males when competition is high or host quality is compromised (Du et al. 2023; Mao et al. 2025). Since a female-biased sex ratio is essential for the effectiveness of biological control in the field, these findings are vital for optimizing release strategies. While morphological examination remains essential for identifying *D. striatalis* and distinguishing between sexes (Nihei et al. 2022), the performance data provided here reduces the need for constant genetic validation by establishing clear morphological and developmental benchmarks.

Collectively, these findings have significant implications for biological control programs. In mass-rearing protocols, avoiding high host densities is crucial to prevent intraspecific competition, thereby ensuring the production of high-quality parasitoids with optimal pupal weight and vigor. For field application, the data suggest that release rates must be precisely calibrated according to the target pest density. An excessive release relative to the host population could inadvertently trigger multiple parasitism, weakening the subsequent generation of *D. striatalis* and diminishing the overall efficiency of the sugarcane stalk borer control program.

This study offers critical insights into the parasitic efficiency and performance of *D. striatalis* toward *C. auricilius* larvae. Our findings demonstrate that third-instar host larvae at a low population density of 20 individuals represent the optimal environment for maximizing parasitoid success. These parameters not only increase parasitism and emergence rates but also enhance pupal quality and favor a higher proportion of female offspring. These results underscore the viability of *D. striatalis* for large-scale production and reinforce its potential as a robust biological control agent.

CONCLUSION

Diatraeophaga striatalis demonstrates a significant preference for parasitizing third-instar *Chilo auricilius* larvae over second-instar larvae. The parasitic efficiency is inversely correlated with host population density, as higher densities lead to a marked reduction in parasitism rates. The optimal parasitic performance is achieved at a low host density of 20 individuals, which yielded a parasitism rate of 87.5% for third-instar larvae and a superior pupal formation rate of 95.75%. Furthermore, host density significantly dictates the developmental success and sex ratio of the parasitoid, where lower host densities facilitate higher rates of pupation and adult emergence. Notably, the emergence of female adults is favored at lower host densities, while higher densities result in a reduced proportion of females. These findings underscore that host instar stage and population density are critical determinants of the efficiency and reproductive success of *D. striatalis* as a biological control agent.

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AUTHORS DECLARATIONS

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Conflict of Interest

The authors declare that they have no conflict of interest.

Ethics Declarations

No ethical issue required for this research

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' Contributions

Chandra Irsan and Tite Amalia Adam conceived this research and designed experiments; Chandra Irsan, Suwandi Suwandi, Arsi Arsi and Titi Tricahyati participated in the design and interpretation of the data; Chandra Irsan, Suwandi Suwandi, Arsi Arsi and Titi Tricahyati performed experiments and analysis; Chandra Irsan, Suwandi Suwandi, Arsi Arsi and Titi Tricahyati wrote the paper and participated in the revisions of it. All authors read and approved the final manuscript.

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