

Performance of *Chrysoperla externa* (Hagen, 1861) (Neuroptera: Chrysopidae) on artificial diets, natural and alternative prey: ontogenetic development and functional response

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Abstract

Biological control has become a sustainable and effective strategy for managing agricultural pests, offering alternatives that are less harmful to the environment and more compatible with the principles of integrated pest management. Among natural control agents, *Chrysoperla externa* (Hagen, 1861) (Neuroptera: Chrysopidae) stands out as a voracious predator whose effectiveness is directly related to diet quality and predator–prey dynamics. Therefore, this study aimed to evaluate the biological performance of *C. externa* reared on different diets: eggs of *Ephestia kuehniella* (Zeller, 1879) (Lepidoptera: Pyralidae) (standard diet), eggs of *Spodoptera frugiperda* (J.E. Smith, 1797) (Lepidoptera: Noctuidae), eggs of *Diatraea saccharalis* (Fabricius, 1794) (Lepidoptera: Crambidae), and an artificial diet based on chicken liver. The results showed that *D. saccharalis* eggs provided the highest survival rate (95%) and the greatest body growth, surpassing even the standard diet. In addition to prolonging larval development time, the artificial diet prevented completion of the life cycle, indicating nutritional limitations. Furthermore, the functional response of third-instar *C. externa* larvae was evaluated at different densities of *D. saccharalis* larvae to assess the predatory efficiency of this natural enemy. The results revealed a type II functional response, characterized by a high attack rate ($a = 0.7650$) and a short handling time ($T_h = 0.1900$ days), with predators exhibiting greater efficiency at low to moderate prey densities. Overall, the results reinforce the potential of *C. externa* as a biological control agent, owing to its ability to develop on alternative, readily available prey and its high predatory efficiency. These findings support the use of this natural enemy in more sustainable pest management programs, thereby reducing insecticide use and conserving agroecosystems.

Introduction

Biological control has become one of the main sustainable strategies for pest management in modern agriculture, reducing dependence on chemical insecticides and minimizing environmental impacts on agroecosystems. The use of natural enemies, especially predators and parasitoids, has been gaining increasing importance within Integrated Pest Management (IPM) programs, due to their ecological compatibility, long-term efficiency, and potential to keep pest insect populations below the economic injury level (Parra *et al.*, 2020; Sujii *et al.*, 2020). Among predatory insects, green lacewings of the family Chrysopidae stand out as important biological control agents because of their wide range of prey, capacity to adapt to different environmental conditions, and high predation capacity during the larval stage (Canard and Principi, 1984; Tauber *et al.*, 2000).

Among the green lacewings, *Chrysoperla externa* (Hagen, 1861) (Neuroptera: Chrysopidae) stands out as one of the most promising predatory species in South America, especially in tropical and subtropical agroecosystems. The larvae of *C. externa* exhibit high predatory potential, feeding on several pest insects of agricultural importance, including aphids, whiteflies, mites, and eggs and larvae of lepidopteran species (Freitas, 2001; Luna-Espino *et al.*, 2020). In addition to its broad feeding spectrum, this species shows high adaptation to laboratory conditions, an essential characteristic for mass-rearing programs and inundative releases in the field (Trivellato *et al.*, 2012; Carvalho, 2022). However, the

success of large-scale production of predatory insects depends directly on the nutritional quality and economic viability of the food source provided during the immature stages (Parra, 2000).

Currently, eggs of *Ephestia kuehniella* (Zeller, 1879) (Lepidoptera: Pyralidae) are widely used as standard prey in the mass-rearing of green lacewings due to their high nutritional value and the high survival rates they provide to predators (Pessoa *et al.*, 2010; Magro *et al.*, 2020). However, the high production cost of these eggs represents one of the main limiting factors for the commercial production of green lacewings, especially in developing countries (Pinto, 2019). Thus, the search for alternative prey that can maintain adequate biological performance while reducing production costs has become a priority in research aimed at improving biological control programs (Freitas *et al.*, 2022).

In this context, the use of alternative prey associated with target cropping systems may represent an efficient and economically viable strategy for the mass production of predators. Eggs and larvae of economically important pest insects, such as *Spodoptera frugiperda* (J.E. Smith, 1797) (Lepidoptera: Noctuidae) and *Diatraea saccharalis* (Fabricius, 1794) (Lepidoptera: Crambidae), have been investigated as potential food sources for green lacewings and other natural enemies (Pessoa *et al.*, 2010; Bezerra, 2014; Haramboure *et al.*, 2016). In addition to the possibility of reducing costs, the use of prey associated with the target insect may favor the adaptation of the predator and improve its performance in the field after release, especially considering behavioral and physiological changes mediated by feeding experience across generations (Chen *et al.*, 2018; Robertson and Blumstein, 2019; Sarkar *et al.*, 2024).

Among the pests of the sugarcane crop, *D. saccharalis* stands out as one of the species of greatest economic importance in several producing regions of the world. The caterpillars produce perforations in the stalks, significantly reducing crop productivity and favoring the entry of phytopathogenic microorganisms associated with red rot of the stalk (Dinardo-Miranda *et al.*, 2011; Salgado *et al.*, 2022; Pérez *et al.*, 2023). Although biological control programs based mainly on the parasitoid *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae) are widely used, the incorporation of predatory species into integrated strategies may broaden the population suppression of the pest and contribute to greater ecological stability of the agroecosystems (Salles and Baldani, 1998; Nunes *et al.*, 2019).

In addition to evaluating the nutritional suitability of alternative prey for predator development, understanding the predatory capacity of natural enemies at different prey densities is essential for determining their efficiency in biological control programs. The analysis of the functional response is one of the most important ecological tools for understanding prey–predator interactions, as it describes the relationship between the density of available prey and the predator's consumption rate (Holling, 1959; Juliano, 2001). Predators that exhibit a type II functional response are often considered promising for inundative biological control programs, as they maintain high attack rates even at low prey population densities (Obrycki and Kring, 1998; Isikber, 2005). Several studies have shown that green lacewings predominantly show a type II functional response under laboratory conditions, reinforcing their potential

as efficient biological control agents (Atlihan *et al.*, 2004; Hassanpour *et al.*, 2009, 2015; Mahzoum *et al.*, 2020).

Despite studies separately evaluating alternative diets or functional responses in green lacewings, research that simultaneously assesses prey suitability for mass rearing and the predatory performance of *C. externa* on the same target species remains scarce. Evaluating whether prey can sustain both the biological development and the predatory efficiency of the natural enemy is fundamental to optimizing biological control programs and broadening the practical applicability of large-scale predator rearing. Thus, the present study aimed to evaluate the suitability of various food sources for the biological development of *C. externa* and to investigate the predatory performance of the natural enemy by analyzing its functional response to *D. saccharalis* caterpillars under laboratory conditions.

Material and Methods

Experimental area and rearing conditions

The experiments were conducted at the Entomology Laboratory (LEN), linked to the Center for Agricultural Sciences (CCA) of the Federal University of Paraíba, Campus II, located in the municipality of Areia. All bioassays were carried out under controlled conditions of temperature ($25 \pm 2^\circ\text{C}$), relative humidity ($70 \pm 10\%$), and a 12-hour photophase.

Rearing of *Chrysoperla externa*

Larvae of *Chrysoperla externa* (Hagen, 1861) (Neuroptera: Chrysopidae) used to establish the rearing were obtained from the company TopBio, located in the municipality of Mossoró, Rio Grande do Norte, Brazil. After colony establishment, the adults were kept in cylindrical PVC cages (10 cm in diameter $\times$ 23 cm in height), internally lined with white bond paper to facilitate egg collection, following the methodology of Auad *et al.* (2002).

The adults received a daily diet composed of brewer's yeast and honey, in a 1:1 ratio, provided *ad libitum*. The cages were closed with voile-type fabric, allowing adequate ventilation while preventing insect escape. The eggs obtained were collected daily and placed in Petri dishes until hatching. After emergence, the newly hatched larvae were individually housed in transparent plastic containers (3.5 cm in height $\times$ 2.5 cm in diameter) to avoid cannibalism.

Biological development of *Chrysoperla externa* under different diets

The experiment was conducted in a completely randomized design (CRD), composed of four treatments and 40 replicates per treatment. The diets evaluated were:

- EE – control (eggs of *Ephesia kuehniella*);

- ES – eggs of *Spodoptera frugiperda*;
- LD – chicken liver diet;
- ED – eggs of *Diatraea saccharalis*.

The eggs of *E. kuehniella* were obtained through a partnership with Koppert, placed in Piracicaba, São Paulo, Brazil. The eggs of *S. frugiperda* came from the rearing maintained in the laboratory itself, while the eggs of *D. saccharalis* were provided by the Sugarcane Planters Association of Paraíba (ASPLAN), Camaratuba experimental station, Paraíba, Brazil.

The artificial diet was formulated by adapting the diet originally proposed by Nalim (1991) for rearing *S. frugiperda*, replacing the bean with chicken liver to ensure nutritional adequacy for *C. externa*. The composition of the diet included ascorbic acid (0.17 g), sorbic acid (0.40 g), agar (4.58 g), chicken liver (25 g), wheat germ (12.83 g), nipagin (0.30 g), formaldehyde (0.2 mL), and distilled water (200 mL).

The diets were provided ad libitum throughout larval development. Evaluations were conducted daily to record larval instar durations, total larval period, survival, and pupal viability. Larval growth was monitored by measuring body length with a precision digital caliper. Measurements were taken at the end of each instar, identified by the presence of exuviae in the experimental containers.

Functional response of *Chrysoperla externa* on *Diatraea saccharalis*

To evaluate the functional response, third-instar larvae of *C. externa* that had previously fed on *E. kuehniella* eggs were used. The caterpillars of *D. saccharalis* used as prey were obtained from ASPLAN and kept in glass containers containing artificial diet until their use in the experiments.

The bioassay was conducted in a completely randomized design, with five prey densities (1, 2, 4, 8, and 16 third-instar caterpillars of *D. saccharalis* per predator) and 20 replicates per treatment.

Before the experiment, the larvae of *C. externa* were subjected to 24 h of starvation to standardize the feeding stimulus. Then, each predator was individualized in a plastic container containing the respective prey density. After 24 h of exposure, the number of caterpillars consumed was counted.

Statistical analyses

The data on biological development were initially subjected to a normality analysis. Due to the absence of a normal distribution, the non-parametric Dunn test ($P < 0.05$) was applied to compare treatments.

To determine the type of functional response, a generalized linear model with a quasi-binomial distribution and a complementary log-log link function was used. The type of functional response was determined by the sign of the logistic regression's linear coefficient, with negative values indicating a type II functional response.

The parameters of the functional response were estimated using the bootstrap method via the `frair_boot` function in the `frair` package in R (R Core Team, 2024). The estimated parameters included the attack rate (a) and the handling time (T_h), using the Holling type II disc equation:

$$N_e = aNT / (1 + aNT_h)$$

Where N_e = number of prey consumed; N = number of prey provided; a = attack rate; T_h = handling time; and T = predator exposure time to the prey (24 h).

Results

Different diets provided to *C. externa* significantly influenced their biological development, resulting in variations in development time, body size, and survival rate. Table 1 shows that the treatment with chicken liver diet (LD) resulted in the longest 1st-instar duration, which was statistically similar to ES (eggs of *S. frugiperda*) but different from the others. In the second instar, LD was the only one to stand out with a longer duration. In the third instar, *D. saccharalis* (ED) resulted in a shorter duration, while *S. frugiperda* (ES) resulted in the longest third-instar duration.

Table 1 Mean duration (± standard error) in days of the three larval instars of <i>Chrysoperla externa</i> fed with different diets			
Treatment	1st Instar (days)	2nd Instar (days)	3rd Instar (days)
EE – Eggs of <i>Ephestia kuehniella</i>	2.42 ± 0.17 b	2.40 ± 0.20 b	2.47 ± 0.24 b
ES – Eggs of <i>Spodoptera frugiperda</i>	4.27 ± 0.22 a	2.25 ± 0.27 b	3.12 ± 0.42 a
LD – Chicken liver diet	4.60 ± 0.21 ab	4.22 ± 0.55 ab	1.35 ± 0.44 ab
ED – Eggs of <i>Diatraea saccharalis</i>	3.02 ± 0.02 b	3.85 ± 0.17 a	2.30 ± 0.16 b
Note: Means followed by the same letter in the column do not differ from each other by the Dunn test ($P < 0.05$).			

The larvae fed with eggs of *D. saccharalis* (**ED**) showed the greatest larval length, especially in the first and third instars. Treatment with liver (**LD**) resulted in reduced growth, particularly in the third instar (Table 2).

Table 2

Mean length ($\pm$ standard error) of the three larval instars of *Chrysoperla externa* fed with different diets

Treatment	1st Instar (mm)	2nd Instar (mm)	3rd Instar (mm)
EE – Eggs of <i>Ephestia kuehniella</i>	4.39 $\pm$ 0.24	6.02 $\pm$ 0.36 ab	7.33 $\pm$ 0.50 ab
ES – Eggs of <i>Spodoptera frugiperda</i>	4.33 $\pm$ 0.18	5.17 $\pm$ 0.49 ab	5.87 $\pm$ 0.62 ab
LD – Chicken liver diet	4.20 $\pm$ 0.12	4.53 $\pm$ 0.41 b	1.38 $\pm$ 0.44 b
ED – Eggs of <i>Diatraea saccharalis</i>	5.02 $\pm$ 0.09	7.38 $\pm$ 0.25 a	8.66 $\pm$ 0.33 a
Note: Means followed by the same letter in the column do not differ from each other by the Dunn test ($P < 0.05$).			

The highest survival rate was observed with eggs of *D. saccharalis* (ED) as shown in Table 3, followed by *E. kuehniella* (EE). The liver diet (LD) prevented completion of the life cycle. The total cycle was longer for *D. saccharalis*, while the shortest was with *E. kuehniella*. Although the liver diet prolonged the larval period, it resulted in total mortality of the larvae.

Table 3

Mean duration ($\pm$ standard error) in days of the larval stage and survival rate of *Chrysoperla externa* fed with different diets

Treatment	Larval Period (days)	Survival (%)
EE – Eggs of <i>Ephestia kuehniella</i>	7.30 $\pm$ 0.46 c	85
ES – Eggs of <i>Spodoptera frugiperda</i>	9.65 $\pm$ 0.62 a	68
LD – Chicken liver diet	10.17 $\pm$ 0.79 a	0
ED – Eggs of <i>Diatraea saccharalis</i>	9.17 $\pm$ 0.22 b	95
Note: Means followed by the same letter in the column do not differ from each other by the Dunn test ($P < 0.05$).		

The treatment with *E. kuehniella* (EE) provided 100% viability in the pupal stage, as did *D. saccharalis* (ED). While *S. frugiperda* (ES) allowed lower viability (70.37%). The chicken liver (LD) was not sufficient for complete pupae formation (Table 4).

Table 4
Pupal viability (%) of *Chrysoperla externa* fed with different diets

Treatment	Pupal Viability (%)
EE – Eggs of <i>Ephestia kuehniella</i>	100
ES – Eggs of <i>Spodoptera frugiperda</i>	70.37
LD – Chicken liver diet	0
ED – Eggs of <i>Diatraea saccharalis</i>	100
Note: Means followed by the same letter in the column do not differ from each other by the Dunn test ($P < 0.05$).	

Functional response of *Chrysoperla externa* on *Diatraea saccharalis*

The number of *D. saccharalis* larvae consumed by *C. externa* increased with prey density (Fig. 2). According to the sign of the linear coefficient in the logistic regression proposed by Rogers (1972), where negative values indicate a type II functional response (Table 5), the predator exhibited a type II functional response, characterized by an increase in prey consumption as prey density increased.

Table 5
Parameters of the logistic regression model for verification of the functional response of *Chrysoperla externa*

Parameter	Coefficient	SE
Intercept	-0.5093	0.0730
Linear	-5.0949	0.6538
Quadratic	1.5010	0.6765
Cubic	-0.5678	0.7099
Note: ¹ Coefficients from the complementary log-log quasi-binomial generalized linear model. A negative value of the linear coefficient indicates a type II functional response.		

The estimated attack rate (a) was 0.7650 (95% CI: 0.5800–0.9800), whereas the handling time (T_h) was 4.56 h (95% CI: 3.36–5.76 h), with the model explaining 97% of the observed variation ($R^2 = 0.97$) (Table 6).

Table 6
Functional response parameters from the Holling type II disc equation

Parameter	Coefficient	95% CI
a	0.7650	0.5800–0.9800
T _h	0.1900	0.1400–0.2400
T	1.0000	-

Note: $N_e = aNT/(1 + aNTh)$, where N_e = number of prey consumed. N is the density of prey offered. T is the time available for the predator to feed on the prey, in this case 1 day, a is the attack rate and Th is the handling time.

The observed predation increased quadratically with density, ranging from 0.75 ($\pm$ 0.09) caterpillars (density 1) to 3.80 ($\pm$ 0.29) caterpillars (density 16) (Table 7).

Table 7
Predation observed experimentally and predicted by the type II functional response model

Density (prey/predator)	Observed Mean $\pm$ SE	Estimated Mean (95% CI)
1	0.75 $\pm$ 0.09	0.66 (0.53–0.79)
2	1.10 $\pm$ 0.14	1.18 (0.99–1.33)
4	1.90 $\pm$ 0.19	1.93 (1.75–2.01)
8	2.75 $\pm$ 0.21	2.82 (2.72–2.81)
16	3.80 $\pm$ 0.29	3.68 (3.29–4.03)

Discussion

The efficiency of a natural enemy in biological control programs depends not only on its predatory capacity, but also on the availability of food sources that support its development, survival, and reproduction in large-scale rearing systems. In this context, the results demonstrate that *D. saccharalis* has high potential as an alternative prey for *C. externa*, while simultaneously promoting satisfactory biological development and high predatory efficiency in the predator.

The eggs of *D. saccharalis* provided the highest larval survival rate (95%), pupal viability of 100%, and the greatest body lengths observed during the development of *C. externa*. These results indicate a high nutritional suitability of this prey for the predator, even surpassing the standard treatment consisting of *E. kuehniella* eggs. Previous studies have shown that the nutritional quality of the prey directly influences biological parameters of green lacewings, including growth, survival, fecundity, and predation capacity (Canard and Principi, 1984; Pessoa *et al.*, 2010; Magro *et al.*, 2020; Freitas *et al.*, 2022). Thus, the

observed performance suggests that *D. saccharalis* has a nutritional composition that adequately meets the physiological requirements of *C. externa* during its larval development.

Although the larval period was slightly longer than that observed for *E. kuehniella*, the high survival and increased body size observed with *D. saccharalis* indicate that this prolongation did not negatively affect predator performance. On the contrary, larger individuals frequently show greater capacity to search for, capture, and consume prey, as well as better reproductive performance after adult emergence (Bueno et al., 2020). Hagen (1976) emphasized that the quality of food ingested during the larval stage can directly affect adult reproductive performance, since a large portion of the energy reserves required for reproduction is accumulated during the immature stages.

This aspect becomes even more relevant when considering the work of Rousset (1984), who demonstrated that nutritional deficiencies occurring during the larval stage cannot be completely compensated by the food received in the adult stage. According to the author, pre-vitellogenesis begins as early as the pupal stage, using reserves accumulated during larval development to form the ovaries. Thus, the high body growth and high survival observed in individuals fed *D. saccharalis* suggest a potential positive impact on reproductive characteristics as well, although this variable was not evaluated in the present study.

On the other hand, the artificial diet based on chicken liver showed unsatisfactory performance, resulting in total mortality of the individuals before the pupal stage. Although it prolonged larval development, this diet did not provide the nutrients necessary to complete the biological cycle. Similar results have already been reported for artificial diets nutritionally inadequate for green lacewings (Cohen and Smith, 1998; Lee and Lee, 2005; Torres et al., 2019). However, Bezerra (2014) obtained viable adults of *C. externa* using artificial formulations containing chicken liver, indicating that the success of these diets depends strongly on the composition and the nutritional balance employed.

In addition to the suitability of the prey for the predator's development, evaluating the functional response allows assessment of the natural enemy's potential to suppress the pest population at different pest densities. The results demonstrated that third-instar larvae of *C. externa* showed a type II functional response when preying on caterpillars of *D. saccharalis*, characterized by an initial increase in consumption followed by stabilization at higher prey densities.

This pattern is considered the most common among generalist predators and has frequently been recorded for green lacewings (Atlihan et al., 2004; Hassanpour et al., 2009; Hassanpour et al., 2015; Mahzoum et al., 2020). According to Holling (1959), the type II functional response occurs when the increase in prey density is accompanied by an increase in the consumption rate until the predator reaches a physiological limit imposed by the time necessary to locate, capture, handle, and consume its prey.

The results corroborate the observations of Hull et al. (1976), who argued that linear, unbounded increases in prey consumption are not biologically plausible, since no predator has an infinite appetite.

Thus, there is a prey density at which the consumption capacity tends towards saturation, regardless of additional food availability. This behavior was evident in the present study, in which consumption increased progressively with *D. saccharalis* density but showed a tendency towards stabilization at the highest densities evaluated.

The high attack rate observed ($a = 0.7650$) reinforces the predatory potential of *C. externa* on *D. saccharalis*. According to Obrycki and Kring (1998), predators with high attack rates are particularly desirable in inundative biological control programs, since they can locate and consume prey even when prey populations occur at low densities. In addition, the reduced handling time recorded in this study demonstrates high efficiency in capturing and consuming prey.

Similar results were reported by Auad *et al.* (2002), who observed reduced prey-searching and handling times in *C. externa*, and by Palomares-Pérez *et al.* (2019), who reported high predatory efficiency of the species on different prey species. Nordlund and Morrison (1990) also verified reduced handling times of caterpillars by green lacewing species, suggesting that this characteristic is an important ecological adaptation associated with the group's predatory success.

Another relevant aspect is the potential relationship between prey nutritional quality and the predatory efficiency of the natural enemy. Although the experiments were conducted separately, the results suggest that *D. saccharalis* not only favors the biological development of *C. externa* but also serves as adequate prey for the expression of its predatory potential. This integration between biological performance and predation efficiency is particularly important for large-scale rearing programs, since it enables the use of the same species for both colony maintenance and field releases.

From an applied perspective, the results reinforce the potential of using *C. externa* as a complementary component in the integrated management of *D. saccharalis*. Currently, the biological control of the sugarcane borer is based mainly on the use of parasitoids such as *C. flavipes* (Salles and Baldani, 1998). However, the incorporation of generalist predators can broaden the mortality pressure on the pest and contribute to greater ecological stability of the agricultural systems (Nunes *et al.*, 2019).

In general, the results demonstrate that *D. saccharalis* combines desirable characteristics for use as alternative prey in the large-scale rearing of *C. externa* and as a target of biological control programs. The combination of high survival, adequate body development, and a type II functional response demonstrates the potential of this interaction for application in sustainable integrated pest management programs, contributing to the reduction of dependence on insecticides and the conservation of agroecosystems.

Conclusion

Eggs of *S. frugiperda* and *D. saccharalis* can be used as alternative prey in the rearing of *C. externa*, replacing *E. kuehniella*.

The diet based on chicken liver is not recommended for large-scale rearing of *C. externa* in the composition used, as it negatively affects the predator's biological development.

The species *C. externa* shows potential as a biological control agent against *D. saccharalis* in the laboratory, based on the analysis of its functional response to third-instar caterpillars.

The functional response of predation of the 3rd-instar larvae of *C. externa* in relation to third-instar caterpillars of *D. saccharalis* is of type II, given the rapid increase in consumption followed by stabilization.

Declarations

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Authors' contributions

E.M.C. Alves: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing – original draft.

S.L. Souza Junior: Methodology, Investigation, Data curation, Validation, Writing – review & editing.

J.L. Batista: Conceptualization, Methodology, Supervision, Project administration, Writing – review & editing.

L.V.Q. Oliveira: Investigation, Data curation, Writing – review & editing.

E.V.B. Carmo: Investigation, Data curation, Writing – review & editing.

I.V.I. Silva: Investigation, Methodology, Writing – review & editing.

R.B. Silva: Investigation, Resources, Methodology, particularly related to the maintenance and supply of *Diatraea saccharalis*, Writing – review & editing.

C.L.C.M. Silva: Investigation, Validation, Writing – review & editing.

J.B. Malaquias: Formal analysis, Software, Validation, Visualization, Writing – review & editing.

All authors read and approved the final manuscript.

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Data availability

Data generated or analyzed during this study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that they have no conflicts of interest.

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Figures

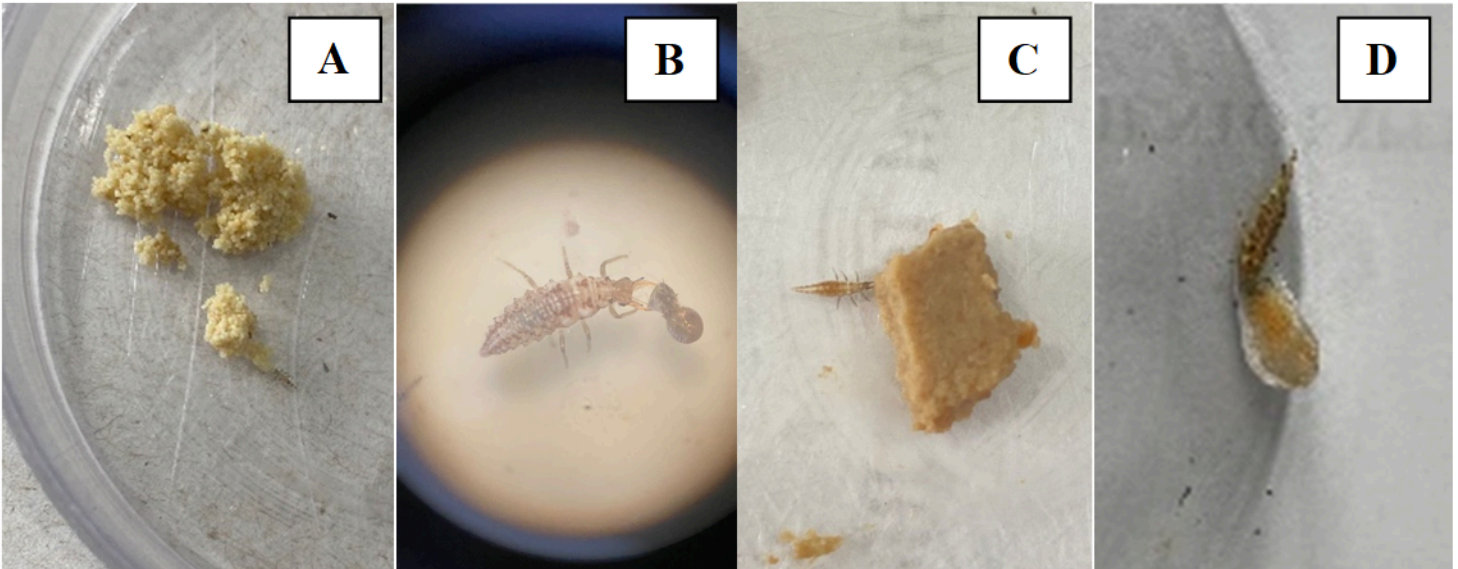


Figure 1

Chrysoperla externa larvae fed different diets during larval development. (A) *Ephesia kuehniella* eggs (EE treatment – control); (B) *Spodoptera frugiperda* eggs (ES treatment); (C) artificial diet based on chicken liver (LD treatment); and (D) *Diatraea saccharalis* eggs (ED treatment).

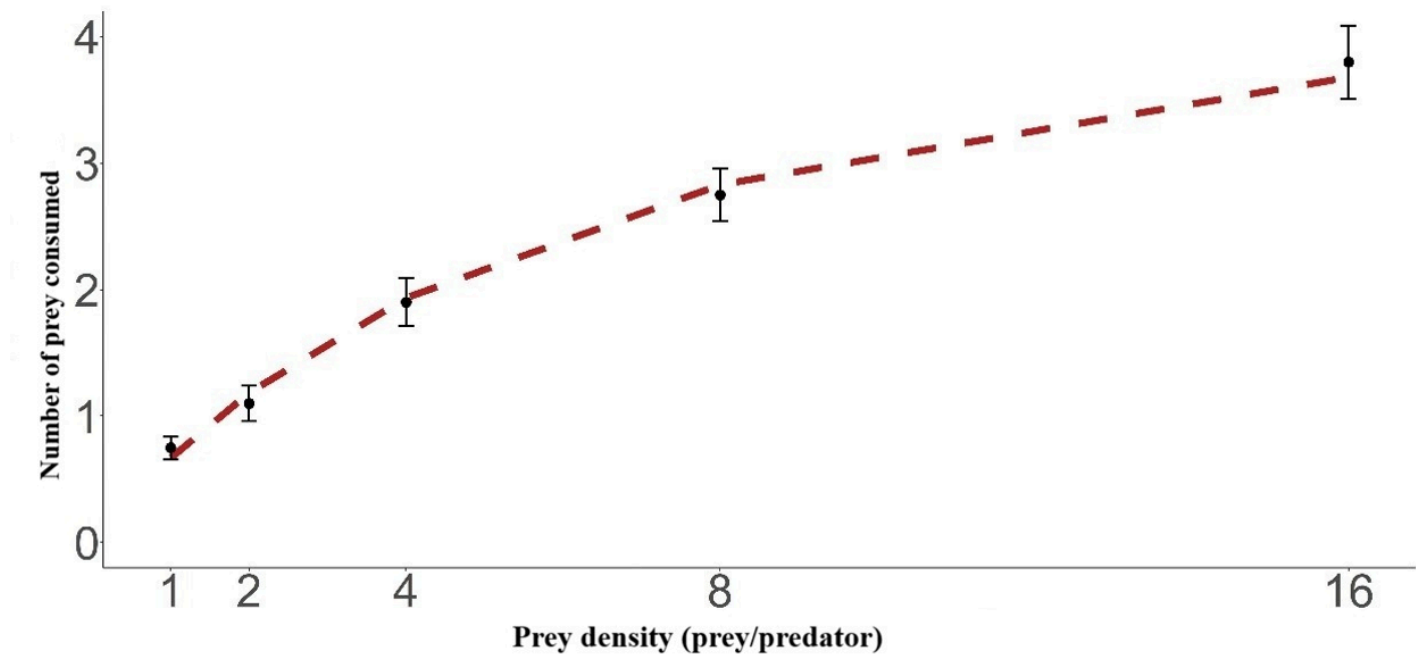


Figure 2

Functional response of *Chrysoperla externa* on *Diatraea saccharalis*

Note: Bars = standard error. Dashed lines = predation data predicted by the nonlinear regression model = $0.76*N/(1+0.76*N^{0.1900})$, where N = density.