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FUNCTIONAL RESPONSE OF *Sycanus croceovittatus* DOHRN (HEMIPTERA: REDUVIIDAE) TO LARVAE OF THE FALL ARMYWORM *Spodoptera frugiperda* J.E. SMITH (LEPIDOPTERA: NOCTUIDAE)

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ABSTRACT

The assassin bug *Sycanus croceovittatus* Dohrn (Hemiptera: Reduviidae) is a predatory insect with potential as a biological control agent of several agricultural pests. This study evaluated the functional response of *S. croceovittatus* to larvae of the fall armyworm, *Spodoptera frugiperda* J.E. Smith (Lepidoptera: Noctuidae). Experiments were conducted under laboratory conditions using a completely randomized factorial design with two factors and ten replications. The first factor consisted of six densities of third-instar *S. frugiperda* larvae (1, 3, 6, 9, 12, and 16 individuals), while the second factor was predator sex (female and male adults). Each prey density was introduced into a cage containing two-week-old maize plants and exposed to a single adult predator for 24 h. Prey consumption by *S. croceovittatus* increased with increasing prey density. At the highest prey density (16 larvae), female and male adults consumed an average of 12.8 and 12.1 larvae per 24 h, respectively. Regression analysis revealed a positive linear relationship between prey density and prey consumption for both sexes, indicating increased feeding activity with increasing prey availability within the tested density range. These findings demonstrate the predatory capacity of *S. croceovittatus* and support its potential as a biological control candidate against *S. frugiperda* larvae.

Keywords: Assassin bug; biological control; fall armyworm; prey consumption; predation rate

ABSTRAK

Kepinding pembunuh *Sycanus croceovittatus* Dohrn (Hemiptera: Reduviidae) merupakan serangga pemangsa yang berpotensi sebagai agen kawalan biologi terhadap beberapa perosak pertanian. Kajian ini bertujuan untuk menilai tindak balas fungsi *S. croceovittatus* terhadap larva ulat ratus jagung, *Spodoptera frugiperda* J.E. Smith (Lepidoptera: Noctuidae). Eksperimen telah dijalankan dalam keadaan makmal menggunakan reka bentuk rawak lengkap berfaktorial yang melibatkan dua faktor dengan sepuluh replikasi. Faktor pertama terdiri daripada enam aras kepadatan larva *S. frugiperda* instar ketiga (1, 3, 6, 9, 12 dan 16 individu), manakala faktor kedua ialah jantina pemangsa (dewasa betina dan dewasa jantan). Setiap kepadatan mangsa dimasukkan ke dalam sangkar yang mengandungi pokok jagung berumur dua minggu dan didedahkan kepada seekor pemangsa dewasa selama 24 jam. Penggunaan mangsa oleh *S. croceovittatus* meningkat dengan peningkatan kepadatan mangsa. Pada kepadatan mangsa tertinggi (16 larva), kepinding pembunuh dewasa betina dan jantan masing-masing menggunakan purata 12.8 dan 12.1 larva dalam tempoh 24 jam. Analisis regresi menunjukkan hubungan linear positif antara kepadatan mangsa dengan penggunaan mangsa bagi kedua-dua jantina, yang menunjukkan peningkatan aktiviti pemangsaan dengan peningkatan ketersediaan mangsa dalam julat kepadatan yang diuji. Hasil kajian ini menunjukkan keupayaan pemangsaan *S. croceovittatus* serta menyokong potensinya sebagai calon agen kawalan biologi terhadap larva *S. frugiperda*.

Kata kunci: Kepinding pembunuh; kawalan biologi; ulat ratus jagung; penggunaan mangsa; kadar pemangsaan

INTRODUCTION

The fall armyworm, *Spodoptera frugiperda* J.E. Smith (Lepidoptera: Noctuidae), is an invasive insect pest that has become a major threat to maize production in Indonesia. This species is highly polyphagous and attacks a wide range of host plants, including maize, rice, sorghum, and sugarcane (Maharani et al. 2019). Infestation by *S. frugiperda* causes severe damage to maize plants, characterized by leaf shredding and defoliation, which can significantly reduce plant growth and yield. The highest infestation levels typically occur during the vegetative stage, with attack intensities reaching 72–100% (Sari et al. 2021). Previous studies have reported that infestations occurring two weeks after planting can cause up to 100% plant damage under high population densities (Trisyono et al. 2019). Yield losses associated with early infestations may reach 34–38% and can result in complete crop failure when control measures are delayed (Nelly et al. 2021).

Management of *S. frugiperda* in many agricultural systems still relies heavily on synthetic insecticides (Houngbo et al. 2020). Intensive and repeated applications of these chemicals may accelerate the development of insecticide resistance in fall armyworm (FAW) populations (Tambo et al. 2020). Excessive insecticide use may adversely affect agroecosystems by contaminating the environment and reducing populations of beneficial organisms, including natural enemies. Therefore, environmentally sustainable management strategies are urgently needed to mitigate the negative impacts associated with chemical control. Biological control using predatory insects represents one of the most promising alternatives for sustainable pest management.

The assassin bug *Sycanus croceovittatus* Dohrn (Hemiptera: Reduviidae) is a predatory insect with considerable potential as a biological control agent in food crop, horticultural, and plantation systems. Species of the genus *Sycanus* are polyphagous predators capable of attacking a wide range of insect prey from several orders, including Lepidoptera, Diptera, Coleoptera, and Hemiptera (Sahid 2019). The predatory behaviour of *S. croceovittatus* is associated with its piercing–sucking mouthparts. The predator captures prey by inserting its rostrum into the prey body and injecting digestive enzymes that immobilize and liquefy the internal tissues, enabling the predator to suck out the prey's body fluids (Pratama 2021).

Several studies have demonstrated the potential of *Sycanus* species as effective predators for regulating pest populations. Members of the family Reduviidae are known for their adaptability to diverse environments, ease of laboratory rearing, and predatory activity during both immature and adult stages (Wardani & Lina 2016). Various insect pests have been reported as prey of *S. croceovittatus*, including *Setothosea asigna* Van Eecke (Afandi et al. 2019), *Spodoptera exigua* Hübner (Mariana et al. 2020), *Spodoptera frugiperda* J.E. Smith (Wang et al. 2020), *Crocidolomia pavonana* Fabricius, and *Plutella xylostella* Linnaeus (Yuliadhi et al. 2021).

The effectiveness of predatory insects as biological control agents in the field is largely determined by their ability to locate and exploit prey under varying environmental conditions, including fluctuations in prey density. Prey density is a critical factor influencing predation rates and predator performance. Changes in prey availability can alter predator feeding capacity and, consequently, its effectiveness in suppressing pest populations. One of the key ecological indicators used to evaluate predator efficiency is the functional response (Nelly et al. 2012; Rogers 1972).

The functional response describes the relationship between prey density and the number of prey consumed by a predator within a given period. Functional responses are generally classified into three types. Type I (linear) is characterized by a proportional increase in prey consumption with increasing prey density. Type II (hyperbolic) occurs when prey consumption increases at a decreasing rate as prey density increases because of constraints such as handling time, resulting in maximum prey mortality at relatively low prey densities. Type III (sigmoid) is characterized by a slow initial increase in prey consumption, followed by a rapid increase before reaching a plateau at higher prey densities (Holling 1959). Understanding predator functional responses is essential for evaluating the potential effectiveness of natural enemies in biological control programmes (Efendi 2023). Functional response analysis also provides valuable insights into predator–prey interactions and helps determine the capacity of predators to regulate prey populations (Nelly et al. 2005).

Functional responses of predators within the genus *Sycanus* have been reported in several studies. Yuliadhi et al. (2021) reported that the predation rate of *Sycanus aurantiacus* increased with increasing prey density of *Crocidolomia pavonana*, with the predator consuming two larvae at a prey density of two individuals and up to eight larvae at a density of twelve individuals within 24 h. These findings indicate that *Sycanus* species may exhibit an increasing predation rate in response to higher prey availability, highlighting their potential as biological control agents.

Despite the growing interest in *Sycanus* species as biological control agents, information on the functional response of *S. croceovittatus* to *S. frugiperda* remains limited. Understanding the predation capacity and functional response characteristics of this predator is essential for assessing its potential role in fall armyworm management. Therefore, this study was conducted under laboratory conditions to evaluate the functional response of *S. croceovittatus* Dohrn towards larvae of *S. frugiperda* J.E. Smith.

MATERIALS AND METHODS

Study Site

The experiment was conducted under controlled laboratory conditions at the Integrated Pest Management Laboratory, Department of Plant Protection, Faculty of Agriculture, Universitas Andalas, Padang, Indonesia, from October 2024 to February 2025.

Rearing of *Spodoptera frugiperda*
Larvae of *S. frugiperda* were initially collected from maize fields owned by farmers in Kuranji District, Padang City, Indonesia. The larvae were transported to the laboratory and individually reared in plastic cups (6.5 cm diameter, 5 cm height). Each larva was fed fresh maize leaves daily. When larvae reached the prepupal stage, wood powder was added to the container to facilitate pupation. Newly emerged adults were transferred to insect cages (50 × 50 × 50 cm) for mating and oviposition. Adult moths were fed with a 10% honey solution absorbed on cotton and suspended inside the cage. Fresh maize leaves were placed in plastic containers filled with water and introduced into the cage as oviposition substrates. Eggs were collected daily and transferred to plastic cups until hatching. The larvae were reared until the third instar, which was used for the functional response experiments.

Rearing of *Sycanus croceovittatus*
Adult *S. croceovittatus* were collected from oil palm plantations in Payakumbuh, Lima Puluh Kota Regency, West Sumatra, Indonesia. The adults were maintained individually in plastic cups (6.5 cm in diameter, 5 cm in height) and fed daily with 5 larvae of *Hermetia illucens*. Male and female adults were paired in plastic containers (9 cm in diameter, 12 cm in height) to facilitate mating. After copulation, females were separated and allowed to oviposit individually. Eggs laid by females were transferred to plastic cups and maintained until hatching.

Newly emerged nymphs were reared in groups of three per container during the first instar and then separated individually from the second instar onward to prevent cannibalism. Nymphs were fed daily with *H. illucens* larvae until reaching adulthood. The number of prey larvae provided increased according to nymphal instar: one larva per day for first instar, two for second instar, three for third instar, four for fourth instar, and five for fifth instar. Before the experiment, adult predators were fed with *S. frugiperda* larvae for one week to allow acclimatization.

Experimental Design
The experiment was arranged in a completely randomized factorial design with two factors and ten replications. The first factor was the prey density of *Spodoptera frugiperda* larvae (1, 3, 6, 9, 12, and 16 individuals), and the second factor was predator sex (female and male adults of *Sycanus croceovittatus*). Third-instar larvae of *S. frugiperda* were used as prey in all experiments. The total number of experimental units was 120, with each experimental unit consisting of one combination of *S. croceovittatus* sex and *S. frugiperda* density. The experiment was conducted under laboratory conditions with a temperature ranging from 28°C to 30°C, relative humidity of 76–78%, and a photoperiod of 12:12 (light: dark).

Maize Plants
Maize plants (hybrid variety F1 Paragon) were used as a food source for *S. frugiperda* larvae and as the experimental host plant. Maize seeds were grown in polybags containing a mixture of soil and cattle manure (3:1, v/v). Three seeds were planted per polybag at a depth of 2–5 cm. Plant maintenance included watering, weed removal, and mechanical pest control. To ensure a continuous supply of fresh foliage, ten polybags were planted every 15 days throughout the experimental period. For functional response experiments, maize plants were used at two weeks after planting.

Functional Response Experiment

Maize plants (two weeks old) were infested with third-instar *S. frugiperda* larvae according to the assigned prey densities (1, 3, 6, 9, 12, and 16 individuals). Each plant was enclosed in a transparent plastic cylinder cage (25 cm in diameter, 25 cm in height) covered with fine-mesh cloth. The larvae were allowed to acclimate inside the cage for 1 h before predator introduction. A single adult *S. croceovittatus* (either female or male) was then released into each cage and allowed to forage for 24 h. Before the experiment, predators were starved for 24 h to standardize hunger levels and ensure active predation behavior (Wang et al. 2020). Each treatment was replicated ten times.

Behavioral Observations

Predatory behavior of *S. croceovittatus* was directly observed and simultaneously video-recorded during the first hour following predator introduction to ensure accuracy of behavioral documentation. The observed behaviors included prey searching, prey approach, and prey attack. Behavioral observations were conducted on one randomly selected replicate per treatment and described qualitatively.

Predation Capacity

Predation capacity was defined as the total number of *S. frugiperda* larvae consumed by a predator within a 24-h period. The number of prey larvae killed or consumed in each replicate was recorded.

Searching Time

Searching time was defined as the time required by the predator to locate and attack its prey. It was measured during 24 hours, from the moment the predator was introduced into the cage until it inserted its rostrum into the prey's body. Time was recorded in minutes and seconds and later converted into decimal minutes for analysis.

Handling Time

Handling time was defined as the time from the moment the predator captured the prey until the predator completed feeding on it (Dirgayana et al. 2021). Time was recorded in minutes and seconds and converted to decimal minutes before analysis.

Predation Rate

The predation rate of *S. croceovittatus* at different prey densities was estimated using regression analysis: linear, exponential, and logarithmic. The regression equations used were (Nelly et al. 2012):

Linear : $Y = a+bX$
Exponential : $Y = a.e^{bX}$
Logarithmic : $Y = a+b.\ln(X)$
Notes:
Y = number of prey consumed
a= constant/intercept
b= regression coefficient/slope
x = prey density
e = Euler's number (2.718)
ln = natural logarithm

Next, the r value for each formula is calculated; the one closest to 1 determines the type of functional response. r is calculated using the formula:

$$r = \sqrt{\frac{[\sum(x - \bar{x})(y - \bar{y})]^2}{\sum(x - \bar{x})^2 \sum(y - \bar{y})^2}}$$

Handling time is calculated based on observations during the first 60 minutes. The Holling formula is used to calculate the attack rate (a) as follows (Holling 1959):

$$\mathrm{a} = \frac{aTN}{1 + aThN}$$

$$\mathrm{a} = \frac{Na + a.Na.Th.N}{T.N}$$

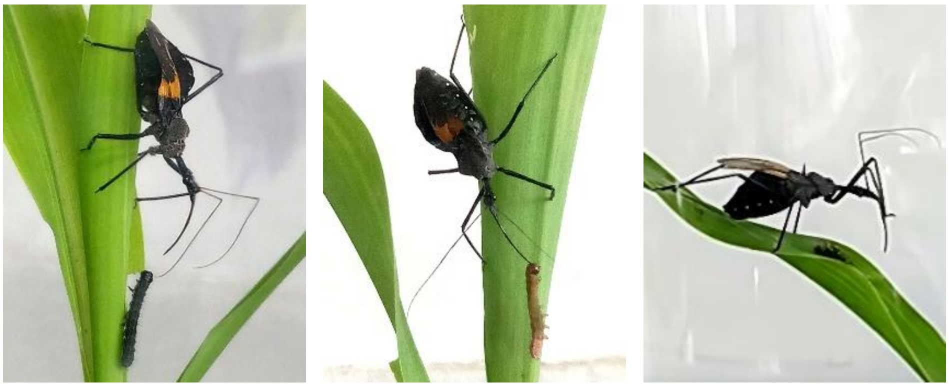
Na= number of prey consumed
a= attack rate
T = total experimental time
N= prey density
T_h= handling time per prey.

Data Analysis
Predatory behavior was described qualitatively. Quantitative data, including predation capacity, searching time, handling time, and predation rate, were analyzed using regression and analysis of variance (ANOVA). When significant differences were detected, means were separated using the Least Significant Difference (LSD) test at the 5% significance level in Statistix 8. The functional response type was determined by regression analysis of the number of prey consumed on prey density in Microsoft Excel 2021. The regression coefficient (r) was used to evaluate the strength of the relationship between prey density and predation rate. A coefficient value approaching 1 indicated the predator's functional response type.

RESULTS AND DISCUSSION

Predatory Behavior
Observations of predation behavior revealed a clear sequence of actions exhibited by *Sycanus croceovittatus* when attacking *Spodoptera frugiperda* larvae. The predation process consisted of prey searching, prey approach, prey attack by rostrum insertion, feeding, and post-feeding grooming behavior. After completing feeding, the predator cleaned its rostrum using its forelegs.
During the prey-searching phase, *S. croceovittatus* actively moved across both the upper and lower surfaces of maize leaves as well as along the plant stem. The predator appeared to detect prey movements using its antennae and rostrum. When prey movement was detected, the predator approached slowly while maintaining its antennae bent forward and the rostrum extended toward the prey (Figure 1A). Once within striking distance, *S. croceovittatus* inserted its rostrum into the prey body to initiate predation (Figure 1B).

After being pierced by the rostrum, the prey initially exhibited defensive movements but gradually became immobilized before feeding was completed. Upon finishing feeding, the predator retracted its rostrum and released the prey. The final behavioral phase involved rostrum grooming, during which the predator used its forelegs to remove remaining food residues from the rostrum by repeatedly sweeping from the base toward the tip (Figure 1C).



A B C

Figure 1. Predatory behavior of *S. Croceovittatus*. (A) Approaching Prey, (B) Puncturing the rostrum into the prey's body, (c) Cleaning the rostrum with both front legs

The predation mechanism observed in this study is consistent with the typical feeding behaviour of assassin bugs. *Sycanus croceovittatus* attacks its prey by inserting its piercing–sucking mouthparts into the prey's body, followed by the injection of salivary enzymes that immobilize the prey and liquefy the internal tissues before the body fluids are extracted. This predatory mechanism is consistent with the feeding behaviour reported by Wang et al. (2020). The findings indicate that this feeding strategy may be conserved across geographically separated populations, while providing new quantitative evidence of the predation efficiency of *S. croceovittatus* against *Spodoptera frugiperda*, which is relevant to biological control programmes in Indonesia. The use of piercing–sucking mouthparts during predation is a characteristic feature of members of the family Reduviidae (Wardani & Lina 2016).

The sequential predatory behavior observed in *S. croceovittatus* reflects an efficient prey exploitation strategy typical of reduviid predators. The ability to rapidly detect prey movement and immobilize it through enzymatic injection likely contributes to this species' high predation capacity, supporting its potential role as a biological control agent against *S. frugiperda* in maize agroecosystems.

Predation Capacity

Predation capacity of *S. croceovittatus* was significantly influenced by prey density. The number of *S. frugiperda* larvae consumed increased with increasing prey density (Table 1). This result indicates that higher prey availability increases the probability of predator–prey encounters, thereby enhancing predation efficiency. Similar patterns have been reported for other predatory insects, where predation rates increase with increasing prey abundance (Syahrawati et al. 2021).

Table 1. Predatory ability of *S. croceovittatus* adults on *S. frugiperda* larvae at different prey densities for 24 hours

Density of Larvae *S. frugiperda*	**Predatory Ability (x̄±SD) (Larvae/24 Hours)**	
	Female Adult	**Male Adult**
1	1.0±0.0eA	1.0±0.0eA
3	3.0±0.0dA	2.6±0.4dA
6	5.6±0.4cA	4.5±1.4cB
9	7.9±1.1bA	6.9±1.5bA

Density of Larvae *S. frugiperda*	**Predatory Ability (x̄±SD) (Larvae/24 Hours)**	
	Female Adult	**Male Adult**
12	10.8±1.2aA	8.6±2.1bB
16	12.8±3.2aA	12.1±3.4 aA

Numbers in the same column followed by the same lowercase letter and numbers in the same row followed by the same uppercase letter are not significantly different based on the results of the LSD test at the 5% level.

The highest predation rate occurred at a prey density of 16 larvae, where female adults consumed an average of 12.8 larvae per 24 h, while male adults consumed 12.1 larvae per 24 h. These findings are comparable to previous studies on other species within the genus *Sycanus*. Yuliadhi et al. (2021) reported that *Sycanus aurantiacus* consumed up to 11 *Plutella xylostella* larvae, 10 *Crocidolomia pavonana* larvae, and 8 *Tenebrio molitor* larvae per 24 h. Differences in predation capacity among studies may be influenced by factors such as prey species, prey density, and prey quality, which can affect predator feeding behaviour (Sudarjat et al. 2009).

Female adults consistently exhibited higher predation capacity than males. This difference is likely associated with females' greater nutritional requirements for reproductive processes. Female predators generally require higher energy intake to support egg production and reproductive fitness (Sahid & Natawigena 2018). Consequently, female predators often exhibit higher feeding activity than males. Similar findings were reported by Duran Prieto et al. (2016), who observed higher predation rates in female predators due to their greater energy requirements for reproduction.

Searching Time

Prey density significantly influenced the searching time of *S. croceovittatus*. Increasing prey density reduced the time the predator took to locate prey (Table 2). This pattern indicates that higher prey abundance increases encounter rates between predator and prey, thereby reducing the time required for prey detection.

Table 2. Searching time by *S. croceovittatus* adults on *S. frugiperda* larvae at different prey densities

Density of Larvae *S. frugiperda*	**Searching Time (x̄±SD) (Minute)**	
	Female Adult	**Male Adult**
1	59.61±0.39aA	192.80±0.29aB
3	34.09±0.37abA	50.05±0.41bA
6	32.97±0.34abA	38.97±0.13bA
9	18.69±0.28abA	28.47±0.20bA
12	10.16±0.17bA	22.37±0.28bA
16	08.15±0.15bA	11.39±0.20bA

Numbers in the same column followed by the same lowercase letter and numbers in the same row followed by the same uppercase letter are not significantly different based on the results of the LSD test at the 5% level.

This finding is consistent with ecological theory, which predicts that predator searching time decreases as prey density increases. This pattern is supported by Syahrawati et al. (2021), who reported that *Phidippus* sp. required less time to locate *Nilaparvata lugens* when prey density was higher.

Female predators located prey more rapidly than males. This difference may be associated with greater foraging activity or searching efficiency in females. The shorter searching time observed in females in the present study may have contributed to their higher predation capacity, suggesting that females were more efficient in locating prey under the experimental conditions.

Handling Time

Handling time was also affected by prey density. As prey density increased, the time required by *S. croceovittatus* to handle prey tended to decrease (Table 3). This pattern may reflect increased feeding efficiency when prey are abundant, as predators become more aggressive and efficient at capturing and consuming them.

Table 3. Handling time by adult *S. croceovittatus* on *S. frugiperda* larvae at different prey densities

Density of Larvae *S. frugiperda*	**Handling Time (x̄±SD) (Minute)**	
	Female Adult	**Male Adult**
1	28.24±7.11aA	36.88±24.73aB
3	25.36±3.64aA	35.79±20.34abA
6	24.24±6.03aA	34.87±11.83abA
9	24.59±4.86aA	29.64±11.19abA
12	21.18±5.10aA	25.92±07.47bA
16	17.15±7.49bA	18.35±04.60cA

Numbers in the same column followed by the same lowercase letter and numbers in the same row followed by the same uppercase letter are not significantly different based on the results of the LSD test at the 5% level.

Handling time is closely related to predator feeding behavior and prey characteristics. When prey density is low, predators often spend more time manipulating and consuming individual prey items. In contrast, when prey density is high, predators tend to handle prey more rapidly, resulting in shorter handling times. Similar patterns have been reported for other predators. Dirgayana et al. (2021) found that the predator *Chrysoperla carnea* required shorter handling times when preying on *Phenacoccus manihoti* at higher prey densities.

Female adults also exhibited shorter handling times compared with males. This result suggests that female predators may have higher feeding efficiency, possibly associated with their greater nutritional demands. Similar observations were reported for the predatory stink bug *Eocanthecona furcellata*, where females handled prey more rapidly than males when feeding on *Setora nitens* larvae (Gani et al. 2019).

Predation Rate

Prey density did not significantly affect the predation rate of *S. croceovittatus* within the 60-minute observation period (Table 4). During this short observation period, predators likely spent most of their time searching for and handling prey, resulting in relatively few prey consumed.

Table 4. Predation rate of *S. croceovittatus* adults on *S. frugiperda* larvae at different prey densities

Density of Larvae *S. frugiperda*	**Predation Rate (x̄±SD) (Larvae/60 Minutes)**	
	Female Adult	**Male Adult**
1	0.0182±0.0035aA	0.0057±0.0024aA
3	0.0148±0.0028aA	0.0045±0.0010aA
6	0.0140±0.0037aA	0.0027±0.0010aA
9	0.0117±0.0040aA	0.0023±0.0004aB
12	0.0069±0.0007aA	0.0023±0.0005aB
16	0.0098±0.0020aA	0.0019±0.0003aB

Numbers in the same column followed by the same lowercase letter and numbers in the same row followed by the same uppercase letter are not significantly different based on the results of the LSD test at the 5% level.

Predation rate is strongly influenced by predators' ability to detect and process prey efficiently within a given time interval. Similar results were reported by Efendi et al. (2016), who found that prey density did not significantly influence the predation rate of *Menochilus sexmaculatus* feeding on several aphid species. Likewise, Syahrawati et al. (2021) reported that prey density did not significantly affect the predation rate of *Phidippus* sp. feeding on *Nilaparvata lugens* within a 60-minute observation period. These findings suggest that predation rate is closely related to the predator's searching and handling capacities within a limited time frame rather than prey density alone (Efendi & Awaluddin 2024).

Functional Response

Regression analysis showed that consumption of both female and male adult individuals of *S. croceovittatus* increased linearly across the tested density range (Table 5). This response type is characterized by a linear increase in the number of prey consumed with increasing prey density.

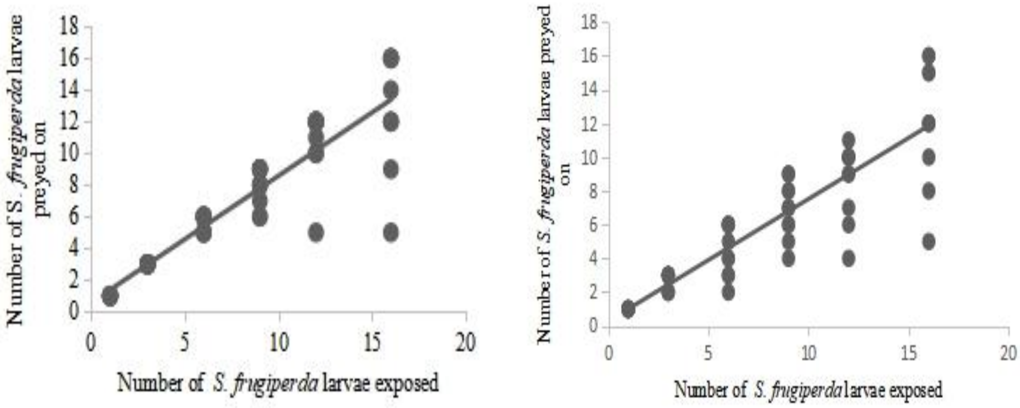
Table 5. Functional response types of *S. croceovittatus* adults to *S. frugiperda* larvae based on regression analysis results and r values

S. croceovittatus	**Regression Equation**	**r Value**	**Type of Functional Response**
Female adult	Linear $y = 0.8005x + 0.5792$	0.8442	Type I
	Exponential $y = 1.537e^{0.152x}$	0.7206	
	Logaritmic $y = 4.2028\ln(x) – 0.3963$	0.7721	
Male adult	Linear $y = 0.7243x + 0.276$	0.7961	Type I
	Exponential $y = 1.3496e^{0.1497x}$	0.7348	
	Logaritmic $y = 3.6896\ln(x) – 0.4115$	0.6853	

The functional response observed in the present study differs from that reported by Wang et al. (2020), who found a Type II functional response for *S. croceovittatus* feeding on *S. frugiperda*. Such differences may arise from variations in experimental conditions, including prey density, environmental conditions, plant structure, experimental arena size, and prey developmental stage. Environmental factors such as temperature and host plant characteristics can also influence predator–prey interactions and functional response patterns.

Similar variability in functional response types has been reported in other predator species. For instance, Nelly et al. (2012) reported that *Menochilus sexmaculatus* exhibited a Type I functional response on two-week-old chili plants but shifted to a Type III response on older plants. Younger plants generally have simpler structures, which may facilitate predator movement and prey detection.

The Type I functional response observed in this study suggests that *S. croceovittatus* can increase its predation rate in proportion to prey density (Figure 2). Figure 2 illustrates the relationship between prey density and the number of *Spodoptera frugiperda* larvae consumed by adult male and female *Sycanus croceovittatus*. In both sexes, prey consumption increased proportionally with increasing prey density throughout the experimental range (1–16 larvae). The regression lines indicated a positive linear relationship between prey density and the number of prey consumed. Male adults (Figure 2A) exhibited a steady increase in prey consumption as prey density increased. Likewise, female adults (Figure 2B) displayed a similar pattern but consistently consumed slightly more larvae than males at comparable prey densities. No evidence of prey saturation was observed within the tested prey densities because the number of prey consumed continued to increase linearly without approaching an asymptote.



A B

Figure 2. Type I functional response curve; (A) Male adult of *S. croceovittatus*, (B) Female adult of *S. croceovittatus*

This characteristic indicates that the predator may be particularly effective in suppressing pest populations when prey density is high. Similar findings were reported for the predatory stink bug *Podisus nigrispinus*, which also exhibited a Type I functional response when feeding on *S. frugiperda* larvae (Zanuncio et al. 2008). Overall, the functional response pattern observed in this study highlights the strong predatory potential of *S. croceovittatus* as a biological control agent against *S. frugiperda* in maize agroecosystems. The predator's ability to increase prey consumption with increasing prey density suggests it could play an important role in regulating FAW populations under field conditions.

CONCLUSION

This study demonstrates that *Sycanus croceovittatus* has potential as a predator of Spodoptera frugiperda larvae. Predation capacity increased with increasing prey density, indicating that the predator can respond positively to higher prey availability. Both female and male adults of *S. croceovittatus* exhibited a Type I functional response, characterized by a linear increase in predation rate with increasing prey density. This response pattern suggests that the predator can efficiently exploit increasing prey populations across the tested density range. Overall, the high predation capacity and positive functional response of *S. croceovittatus* highlight its potential as a promising biological control agent against *S. frugiperda* in maize agroecosystems. These findings provide an ecological basis for further studies evaluating the field performance and integration of this predator into sustainable pest management strategies.

AUTHORS DECLARATIONS

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study. All authors have read and approved the final version of the manuscript and agree to its submission for publication.

Ethics Declarations

This study did not involve human participants, human tissues, or vertebrate animals requiring ethical approval. The research was conducted using insect species (*Sycanus croceovittatus* and *Spodoptera frugiperda*) under laboratory conditions in accordance with institutional guidelines for scientific research and good laboratory practices.

Data Availability Statement

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

Author Contributions

Muhammad Haidil Aswir contributed to investigation, resources, and data curation by conducting insect rearing, maintaining *Sycanus croceovittatus* and *Spodoptera frugiperda* colonies, and collecting data. Novri Nelly contributed to conceptualization, methodology, supervision, project administration, funding acquisition, validation, and writing review and editing by designing and supervising the study, managing resources, and revising the manuscript. Munzir Busniah contributed to supervision and validation by overseeing experiments, verifying procedures, and revising the manuscript. Eka Candra Lina contributed to methodology, investigation, data curation, formal analysis, visualization, and writing the original draft by conducting experiments, analyzing data, preparing figures, and drafting the manuscript. Astri Harnov Putri contributed to investigation, data curation, formal analysis, visualization, and writing the original draft by conducting observations, analyzing data, preparing figures, and assisting with manuscript preparation.

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