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Predator communities associated with *Spodoptera exigua* in tropical shallot agroecosystems

Komunitas predator yang berasosiasi dengan *Spodoptera exigua* pada agroekosistem bawang merah tropis

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ABSTRACT

Spodoptera exigua Hübner is a major pest of shallot (*Allium ascalonicum* L.) that can significantly reduce productivity in tropical agroecosystems. Pest control in shallot cultivation still relies heavily on synthetic insecticides, which may lead to pest resistance and negatively affect natural enemy populations. This study identified predator communities associated with *S. exigua* in tropical shallot agroecosystems in Bangli Regency, Bali, Indonesia. Field observations were conducted in four shallot-producing villages (Trunyan, Buahan, Kedisan, and Songan) from June to September 2025. Predator abundance, pest population, and infestation levels were analyzed using ecological indices including Shannon diversity (H′), evenness (E), species richness (R), and dominance (D). Seven predator groups were identified, with moderate to high diversity (H′ = 1.51–1.77) and high evenness (E > 0.78). Predator abundance showed a strong negative correlation with *S. exigua* population (r = −0.76; R^2 = 0.58). These results highlight the importance of predator conservation in sustainable integrated pest management for tropical shallot production.

ABSTRAK

Spodoptera exigua Hübner merupakan salah satu hama utama pada tanaman bawang merah (*Allium ascalonicum* L.) yang dapat menurunkan produktivitas pada agroekosistem tropis. Pengendalian hama pada budidaya bawang merah masih banyak bergantung pada insektisida sintetis yang berpotensi menimbulkan resistensi hama serta berdampak negatif terhadap musuh alami. Penelitian ini bertujuan mengidentifikasi komunitas predator yang berasosiasi dengan *S. exigua* pada agroekosistem bawang merah tropis di Kabupaten Bangli, Bali, Indonesia. Observasi lapangan dilakukan pada empat desa sentra produksi bawang merah (Trunyan, Buahan, Kedisan, dan Songan) pada Juni–September 2025. Kelimpahan predator, populasi hama, dan tingkat serangan dianalisis menggunakan indeks ekologi Shannon (H′), kemerataan (E), kekayaan spesies (R), dan dominansi (D). Tujuh kelompok predator berhasil diidentifikasi dengan tingkat keanekaragaman sedang hingga tinggi (H′ = 1.51–1.77) dan kemerataan tinggi (E > 0.78). Kelimpahan predator menunjukkan korelasi negatif yang kuat dengan populasi *S. exigua* (r = −0.76; R^2 = 0.58). Hasil ini menegaskan pentingnya konservasi predator dalam pengelolaan hama terpadu yang berkelanjutan pada produksi bawang merah tropis.

INTRODUCTION

Shallot (*Allium ascalonicum* L.) is one of the most economically important horticultural commodities in Indonesia and plays a significant role in supporting farmers' income, particularly in highland production areas such as Bali. However, shallot cultivation is frequently constrained by insect pest infestations, among which the beet armyworm *Spodoptera*

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exigua Hübner is considered one of the most destructive pests. This species attacks shallot leaves throughout the crop growth stages and may cause substantial yield losses. Previous studies reported that infestations of *S. exigua* can reduce shallot production by 34–54% and, under severe outbreaks during dry seasons, may even lead to total crop failure (Supyani et al., 2014; Marhaen et al., 2016).

Pest management in shallot cultivation is still largely dependent on the intensive use of synthetic insecticides. Although chemical control can suppress pest populations in the short term, excessive and repeated applications may lead to pest resistance, environmental contamination, and disruption of natural enemy communities in agricultural ecosystems. Such conditions often reduce the effectiveness of biological regulation processes that naturally occur in agroecosystems (Sugiura, 2020; Purnama et al., 2023; Jalloh et al., 2025). Predatory insects represent an important component of biological control in agricultural systems. Various predator groups such as Chrysopidae, Coccinellidae, Formicidae, and Staphylinidae have been reported to prey on different stages of agricultural pests, including eggs and larvae of *Spodoptera* species (Ehler, 2004; Evans & Toler, 2007; Dirgayana et al., 2021). The presence of diverse predator communities may enhance pest suppression through complementary predation strategies and increased ecological stability within the agroecosystem (Sugiura, 2020; Ghosh & Borzée, 2024).

Recent studies have highlighted the ecological importance of arthropod predator diversity in supporting sustainable pest management. For example, Susanto et al. (2024) reported that increased diversity of predatory arthropods significantly contributed to the reduction of pest populations in horticultural agroecosystems in East Java. Similarly, Ginting et al. (2024) demonstrated that the presence of refugia vegetation could increase predator abundance and reduce infestation levels of *Spodoptera* species in shallot fields. These findings indicate that predator communities may play an important role in regulating pest populations in agricultural landscapes (Wulandari & Syarifah, 2021; Vălean et al., 2025; Nève de Mévergnies et al., 2026).

From an ecological perspective, predator potential can be interpreted through the structure and diversity of predator communities and their relationships with pest populations. High predator diversity generally increases ecosystem stability because different predator species may perform complementary ecological roles in suppressing herbivore populations (Hairston et al., 1960; Boldorini et al., 2024). In addition, negative correlations between predator abundance and pest population density are commonly used as indicators of potential biological control processes occurring in the field (Ghosh & Borzée, 2024).

Despite the importance of predator communities in biological pest regulation, field-based ecological studies focusing on predator–pest relationships in shallot agroecosystems remain limited, particularly in highland tropical production areas such as Bangli Regency, Bali, Indonesia. This region represents one of the major shallot production centers in Bali and possesses specific agroecological characteristics, including high elevation (approximately 1,267 m above sea level), distinct climatic conditions, and local cultivation practices. Therefore, this study aimed to identify predator communities associated with *Spodoptera exigua* populations in tropical shallot agroecosystems and to evaluate their potential ecological role in suppressing pest populations in Bangli Regency, Bali, Indonesia. The findings of this study are expected to contribute to the development of sustainable Integrated Pest Management strategies through the conservation of natural predator communities.

MATERIALS & METHODS

Study area and sampling design

Field observations were conducted from June to September 2025 in four major shallot-producing villages in Bangli Regency, Bali, Indonesia, i.e., Trunyan, Buahan, Kedisan, and Songan. These locations represent tropical highland shallot agroecosystems situated at approximately 1,267 m above sea level. The study employed a field survey approach to examine predator communities associated with *S. exigua* populations in shallot cultivation areas.

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In each village, one shallot field with an area of approximately 0.05 ha was selected as the observation plot. Sampling locations were determined using purposive sampling following procedures commonly applied in field-based entomological studies (Supartha et al., 2022). Within each plot, ten shallot plants were selected as sample plants, and observations were repeated five times during the study period. For each sample plant, the abundance of *S. exigua* larvae and predatory arthropods present on the plant canopy was recorded.

Pest and predator observations

Observations of *S. exigua* were conducted by recording larval populations present on sample plants. Larvae observed in the field were collected using plastic containers, labeled, and counted to determine pest population density expressed as individuals per plant. Observations included larvae from early to late larval stages. Predatory insects encountered on the sample plants were also collected during field observations. Specimens were placed in labeled plastic containers and subsequently identified in the Laboratory of the Faculty of Agriculture and Business, Dwijendra University using standard insect identification references (Borror et al., 1989). Predator identification was conducted at the family level.

Ecological indices of predator communities

The structure of predator communities was evaluated using commonly applied ecological indices, including Shannon–Wiener diversity (H′), evenness (E), species richness (R), and Simpson dominance (D). These indices are widely used to describe species diversity, distribution patterns, and dominance structures in arthropod communities within agricultural ecosystems (Shannon & Weaver, 1949; Magurran, 1988; Simpson, 1949). The use of these indices allows assessment of predator community stability and its potential role in regulating pest populations in agroecosystems (Purwaningsih et al., 2023).

Pest infestation assessment

The level of *S. exigua* infestation was determined by calculating the percentage of attacked leaves on each sample plant. Infestation levels were expressed as the proportion of damaged leaves relative to the total number of leaves observed on the plant following the procedure described by Putrasamedja & Suwandi (1996).

Statistical analysis

The relationship between predator abundance and *S. exigua* population was evaluated using correlation analysis. When the data met normality assumptions, Pearson correlation was applied; otherwise, Spearman rank correlation was used as a non-parametric alternative. To further examine the influence of predator abundance on pest population levels, simple linear regression analysis was conducted with pest population as the dependent variable and predator abundance as the independent variable.

To account for variation among observation locations, a linear mixed-effects model was also applied, with location treated as a random effect and predator abundance treated as a fixed effect. Normality of the data distribution was assessed using the Shapiro–Wilk test. All statistical analyses were performed using SPSS (IBM Corp., USA) or R statistical software with a significance level of $\alpha = 0.05$.

RESULTS & DISCUSSION

Field observations conducted in four shallot-producing villages in Bangli Regency, Bali—Trunyan, Buahan, Kedisan, and Songan—revealed variation in the population of *S. exigua*, predator abundance, and ecological indices of predator communities (Table 1). These differences indicate that agroecosystem conditions among the study sites influence pest–predator interactions within shallot cultivation systems. The highest population of *S. exigua* was recorded in Songan village, reaching an average of 3.8 individuals per plant with an infestation level of 52%. In contrast, the lowest pest population occurred in Trunyan village, with an average of 2.1 individuals per plant and a lower infestation level of 32%. This pattern was inversely related to predator abundance observed in the field. Trunyan exhibited the highest predator

abundance (3.3 individuals per plant), whereas Songan had the lowest predator abundance (2.2 individuals per plant). These results suggest a negative association between predator presence and pest population density, a pattern commonly reported in agroecosystems where natural enemies contribute to the suppression of herbivorous pest populations (Boldorini et al., 2024; Yu et al., 2020).

Table 1. Population density of *Spodoptera exigua*, predator abundance, and ecological indices in shallot agroecosystems.

Location	Pest population (individuals plant^{-1})	Infestation (%)	Predator abundance (individuals plant^{-1})	Diversity index (H′)	Evenness (E)	Species richness	Dominance index (D)
Trunyan	2.1	32	3.3	1.77	0.91	7	0.19
Buahan	2.5	37	2.6	1.60	0.82	7	0.12
Kedisan	2.9	47	2.4	1.51	0.78	7	0.10
Songan	3.8	52	2.2	1.51	0.78	7	0.07

Note: H′ = Shannon–Wiener diversity index; E = Pielou evenness index; D = Simpson dominance index.

Such ecological patterns are consistent with the concept of biological control in agroecosystems, where natural predators can suppress herbivore populations through predation pressure. Previous studies have demonstrated that higher predator abundance may reduce pest outbreaks by increasing mortality of eggs and larvae in agricultural systems (Landis et al., 2000; Sugiura, 2020; Boldorini et al., 2024). Although the present study is observational and does not establish causality, the observed patterns support the ecological role of natural enemies in regulating pest populations in shallot agroecosystems.

The diversity of predator communities across the four villages was categorized as moderate, with Shannon–Wiener diversity index (H′) values ranging from 1.51 to 1.77. The highest diversity was observed in Trunyan (H′ = 1.77) with a high evenness value (E = 0.91), indicating a relatively balanced distribution of individuals among predator taxa. Communities with higher evenness are generally considered more stable because ecological functions are not dominated by a single species (Magurran, 1988; Tscharntke et al., 2005). In contrast, lower diversity and evenness values in Kedisan and Songan suggest that predator communities in these locations are less balanced, which may reduce the overall effectiveness of natural pest suppression.

Table 2. Mean abundance of predator families associated with *S. exigua* (individuals plant^{-1})

Predator Family	Trunyan	Buahan	Kedisan	Songan
Chrysopidae	0.3	0.2	0.2	0.1
Formicidae	0.9	0.6	0.7	0.4
Staphylinidae	0.8	0.5	0.6	0.4
Oxyopidae	0.6	0.7	0.4	0.5
Coccinellidae	0.3	0.2	0.2	0.3
Forficulidae	0.1	0.2	0.2	0.3
Lampyridae	0.3	0.2	0.1	0.2
Total predator abundance	3.3	2.6	2.4	2.2

The dominance index (D) values ranged from 0.07 to 0.19, indicating that no single predator taxon strongly dominated the community. However, slightly higher dominance in Trunyan may reflect the stronger presence of particular predator groups that are more adapted to local agroecosystem conditions. According to ecological theory, predator communities with moderate diversity and low dominance tend to provide more resilient pest regulation because different predator taxa may exploit different prey stages and ecological niches (Yu et al., 2020). Seven predator families were recorded during

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field observations: Chrysopidae, Formicidae, Staphylinidae, Oxyopidae, Coccinellidae, Forficulidae, and Lampyridae (Table 2). These taxa represent common predatory arthropods found in tropical agricultural ecosystems. Among them, Formicidae and Staphylinidae showed relatively higher abundance across all locations. In Trunyan village, Formicidae reached an average of 0.9 individuals per plant, while Staphylinidae averaged 0.8 individuals per plant. These groups are known to act as opportunistic predators capable of attacking eggs and early larval stages of lepidopteran pests.

Predatory lacewings (Chrysopidae), particularly Chrysoperla species, are widely recognized as effective biological control agents because their larvae actively prey on soft-bodied insects and caterpillar eggs (Dirgayana et al., 2021). In the present study, Chrysopidae were detected in all locations but at relatively low abundance (0.1–0.3 individuals per plant). Low predator abundance may be associated with agricultural practices such as frequent pesticide applications, which can negatively affect beneficial arthropod populations. Intensive pesticide use can reduce the abundance and diversity of natural enemies and may disrupt ecological interactions that support biological pest control in agroecosystems (Pandey et al., 2022; Quandahor et al., 2024; Lisi et al., 2025).

Ants (Formicidae) also contributed significantly to the predator community. Ants function as generalist predators capable of attacking a wide range of arthropods, including eggs and larvae of Lepidoptera. Their presence may therefore contribute to the suppression of early stages of *S. exigua*. Similarly, rove beetles (Staphylinidae) are known to prey on small insects and larvae in crop environments. Species of the genus Paederus, for example, have been reported as important predators in tropical cropping systems. Spiders belonging to the family Oxyopidae were also recorded in the study sites. Although their abundance was lower than that of ants or rove beetles, spiders contribute to pest suppression by capturing mobile insects on plant surfaces. Previous research has highlighted the important role of spiders as generalist predators that enhance biological control in agroecosystems (Taradipha et al., 2019). Other predator groups such as Coccinellidae and Forficulidae were also present, although their population densities were relatively low.

Table 3. Correlation between predator abundance and *S. exigua* population in shallot agroecosystems.

Variable X	Variable Y	Correlation coefficient (r)	Coefficient of determination (R^2)	Relationship	Strength
Predator abundance	Pest population (*S. exigua*)	-0.76	0.58	Negative	Strong

Note: Correlation analysis indicates a strong negative relationship between predator abundance and pest population density.

Differences in predator abundance among villages may reflect variations in environmental conditions and crop management practices. Trunyan village showed the highest predator abundance and the lowest pest population, suggesting that local agroecosystem conditions may support natural enemy communities more effectively. Factors such as reduced pesticide use, higher vegetation diversity, or the presence of semi-natural habitats may enhance predator survival and reproduction (Landis et al., 2000). Conversely, the relatively low predator abundance observed in Songan village may contribute to the higher pest population recorded at that site.

Correlation analysis further supported this ecological pattern. A strong negative correlation was observed between predator abundance and *S. exigua* population density ($r = -0.76$), indicating that higher predator abundance was associated with lower pest populations (Table 3). The coefficient of determination ($R^2 = 0.58$) suggests that approximately 58% of the variation in pest population observed in this study may be statistically associated with predator abundance. While this relationship does not imply direct causation, it highlights the potential ecological role of predators in influencing pest population dynamics in shallot agroecosystems. The negative relationship between predator abundance and pest population is further illustrated in Figure 1. These findings align with the top-down control concept proposed by Hairston et al. (1960), which states that predators can regulate herbivore populations through trophic interactions. In agricultural systems, the presence of diverse natural enemy communities may therefore reduce the likelihood of pest outbreaks.

Diverse predator assemblages are often more effective than single dominant predators because different species may target different pest stages or occupy different ecological niches (Sugiura, 2020).

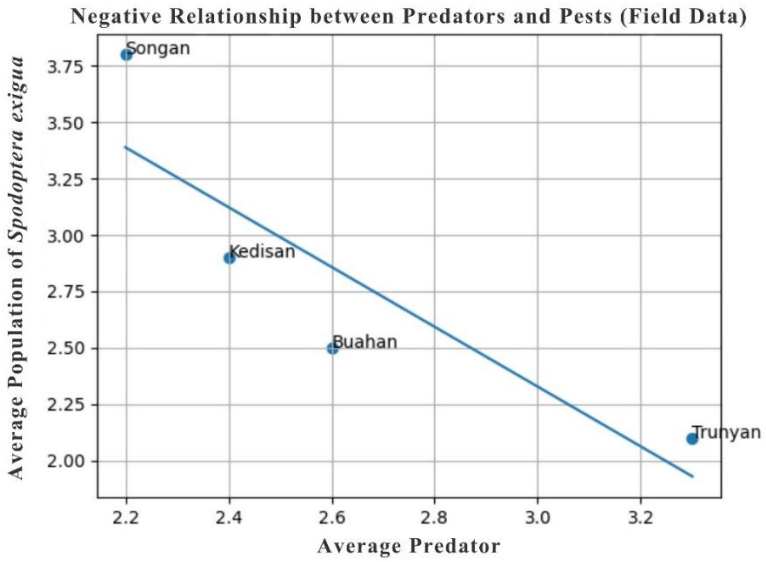

Figure 1. Relationship between predator abundance and *S. exigua* population across four shallot-producing villages in Bangli Regency, Indonesia.

However, the effectiveness of biological control also depends on environmental management practices. Excessive use of chemical pesticides can reduce predator populations and disrupt natural pest regulation. In contrast, agroecosystem management strategies that conserve natural enemies—such as reduced pesticide use, habitat diversification and ecological farming practices can enhance predator populations and strengthen natural pest regulation in agricultural landscapes (Tamburini et al., 2020; Tscharntke et al., 2005).

Taken together, the present study demonstrates that predator abundance and diversity are closely associated with *S. exigua* populations in tropical shallot agroecosystems in Bangli Regency. Although the study is observational, the results highlight the ecological importance of predator communities in supporting biological pest control in agricultural systems (Tamburini et al., 2020; Masson et al., 2025). Future experimental studies are needed to quantify predator–pest interactions more precisely and evaluate the effectiveness of conservation biological control strategies in shallot production systems.

CONCLUSIONS

The present study identified *S. exigua* as the major pest affecting shallot cultivation in Bangli Regency, Bali. Field observations revealed the presence of seven groups of natural predators associated with shallot agroecosystems, i.e., Chrysopidae (*Chrysoperla carnea*), Formicidae, Coccinellidae, Staphylinidae, Oxyopidae, Forficulidae, and Lampyridae. The results demonstrated that predator communities play an important ecological role in pest regulation, as indicated by their abundance, diversity, and the negative relationship observed between predator abundance and pest population levels. A strong negative correlation between predator abundance and *S. exigua* population suggests that higher predator presence is associated with lower pest infestation levels. These findings highlight the ecological importance of natural enemy communities in shallot agroecosystems and support the implementation of conservation-based integrated pest management (IPM) strategies to enhance sustainable pest control.

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