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The Abundance of Potential Diurnal Predatory Insects of *Spodoptera frugiperda* in Klaten Cornfield, Central Java, Indonesia

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ABSTRACT

Spodoptera frugiperda is a maize plant pest that has caused significant losses in various parts of Indonesia, especially the Special Region of Yogyakarta (DIY). Since Klaten Regency is adjacent to DIY, the potential of Klaten to contribute to the country's demand for corn products needs to be extensively monitored, particularly by controlling the existence of *S. frugiperda* and it's predatory insects. This study was conducted to identify and analyse the abundance of diurnal predatory insects of *S. frugiperda* in Klaten Regency. The research was conducted in October 2023–May 2024 on maize fields in Klaten District. Sampling locations were determined using the survey method, while the villages used were determined based on the stratified method. Maize fields used for diurnal predator insect collection were investigated using a purposive method. The data obtained were analysed using correlation tests to reveal the relationship between the abundance of predatory insect species with abiotic factors. The analysis identified 14 species of diurnal predators, with the most species being *C. sexmaculatus* (86 individuals), while the least was *Rhynocoris* sp. (4 individuals). Coccinellidae was the insect predator family with the highest species of *S. frugiperda*. Coccinellids were the most weather-tolerant predatory insects against a wide range of environmental parameters. Furthermore, Coccinellids were found in all research sites. Biological control using natural enemies is a preferred approach for managing *S. frugiperda* populations, as it offers a straightforward and cost-effective solution.

Key words: abundance, diversity, Klaten District, predator, *S. frugiperda*

INTRODUCTION

Spodoptera frugiperda is a corn pest that originated in America and spread randomly through the distribution of export trade goods related to agricultural commodities (Early et al., 2018). This pest causes losses in various countries, with those in Brazil estimated at 34%, Zimbabwe at 11.57% (Baudron et al., 2019), Kenya at >30% (Groote et al., 2020), and India at 33% (Balla et al., 2019). In Indonesia, *S. frugiperda* exist in several regions, such as Lampung (Trisyono et al., 2019), Tasikmalaya (Firmansyah & Ramadhan 2021), Garut (Asfiya et al., 2020), Banyumas (Wulansari et al., 2022), Yogyakarta (Nurkomar et al., 2021; Putri & Putra 2021), Tuban (Megasari & Khoiri 2021), Bali (Listyawati et al., 2022), West Lombok (Jannah et al., 2021) and Central Sulawesi (Arfan et al., 2021). The level of damage caused by *S. frugiperda* ranges from 20–100% depending on the infestation severity (Trisyono et al., 2019; Firmansyah & Ramadhan 2021; Nurkomar et al., 2021; Wulansari et al., 2022). The attack of *S. frugiperda* on corn plants is one of the critical problems in corn cultivation (Nurkomar et al., 2024). The eco-friendly population control of *S. frugiperda* has not been studied.

Because it causes high losses, controlling the population of this pest has been widely practised, especially using chemical compounds (Bagariang et al., 2020). However, this control causes negative impacts on the environment (Heviyanti & Mulyani 2016) and humans (Rustam & Tarigan 2021). Therefore, there is a need for alternative control techniques that are environmentally friendly, one of which is by using natural enemies (Maharani et al., 2021), such as predatory insects (Heviyanti & Mulyani 2016; Fitriani

2018). Using natural enemies not only suppresses the population of *Spodoptera frugiperda*, but also reduces pest control costs incurred by maize farmers. Several predatory insects have been identified to attack *S. frugiperda* in various life stage, such as *Verania lineola* (Fabricius, 1775), *Coccinella transversalis* (Thunberg), *Menochilus sexmaculatus* (Fabricius, 1781), *Exochomus nigripennis* (Erichson, 1843), *Diacamma rugosum* (Le Guillou, 1842), *Odontomachus chelifer* (Latreille, 1802) and *Polistes* sp. (Nurkomar et al., 2021; Minarni 2023; Putra et al., 2023).

In Central Java, Klaten is the only district producing a hybrid corn variety seed. According to research by Nurkomar et al. (2021), *S. frugiperda* populations have been found and spread in the area near Klaten, particularly in Yogyakarta Province, such as Sleman, Bantul, and Gunungkidul Districts. The close location of Yogyakarta and Klaten makes it necessary to make detailed observations of the potential natural enemies of *S. frugiperda* in the Klaten cornfield. Until now, the data on the species and abundance of the predatory insect of *S. frugiperda* in Klaten Districts is limited. Therefore, conducting this study to inventory the species and abundance of predatory insects of *S. frugiperda* in Klaten Districts is essential. The results of this study are expected to serve as an initial database on predatory insects of *S. frugiperda* and a reference basis for the utilization of predatory insects in controlling the population of *S. frugiperda* in Klaten District.

MATERIALS AND METHODS

Materials

The predatory insects were collected with a sweep net with 80 cm stalk length and 30 cm mesh diameter [Hausdec] and preserved in 70% alcohol in 50 mL vials. The eggs of *S. frugiperda* were also collected and put in 8 × 13 cm plastic clips (C-Tik). The identification of predatory insects was done under a stereo microscope (Olympus), and pictures were taken with a mobile phone camera. The environmental parameters such as wind speed, light intensity, and temperature were collected with an anemometer (Benetech), lux meter (Smart sensor), and thermo-hygrometer (Dr. Gray), respectively.

Methods

Study Area and Specimen Collection Time

Samples were taken from 26 sub-districts in Klaten District. Three cornfields in the three villages from each sub-district were surveyed using a purposive method (Budiarti et al., 2019) by looking at the presence or absence of *S. frugiperda* infestation symptoms in the form of larval bite marks on the leaves. The predatory insects were collected between 06.00 and 13.00 Western Indonesian Time (WIB) following the active hours of predatory insects (Yusuf et al., 2021). The abiotic factors measured in this study were sunlight intensity, wind speed, air temperature, and humidity. Measurements were made three times upon arrival, during, and at the end of sampling. Sampling in this study was conducted twice a week, with one corn field per a sampling event (Diratika et al., 2020).

Sweeping and Hand-Picking Technique

Predatory insects were sampled at the sampling locations using a scouting system with a "W" pattern in 80 plants per field (Nonci et al., 2019). The scouting method in this study was modified by the Indonesia Ministry of Agriculture, with the addition of 30 plants observed at each location (Figure 1). Winged predatory insects were collected using a sweep net swung vertically from top to bottom while exploring the cornfields. Crawling predatory insects on the soil surface were collected directly by hand.

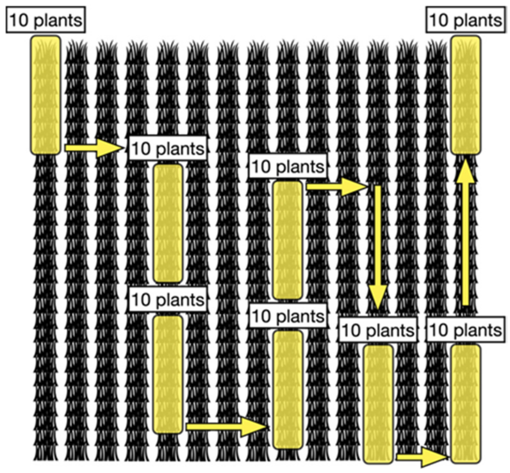

Fig. 1. Modified 'W' pattern sampling from Nonci et al. (2019) with the addition of 30 plants.

Identification of Predatory Insects of *S. frugiperda*

The identified predatory insects were characterized at the species level. Identification was done by observing the morphological characteristics of each insect using a stereo microscope. Morphological characteristics of predatory insects, including mouth shape, body colour, wing pattern, number of antenna segments, and rostrum, were compared with references from Omkar (2016), Bienkowski 2018), Rodríguez-Vélez et al. (2019), Nazarreta et al. (2021), Ndiaye et al. (2021), Muley and Chavan (2023), Poorani (2023) and Putra et al. (2023). The number of individuals of each predatory insect species was counted to determine the abundance of individuals.

Data Analysis

The data analysis that was conducted in this study was descriptive and inferential. Descriptive analysis was adopted to describe the type and distribution of diurnal predatory insects of *S. frugiperda* in Klaten Districts, Central Java. Inferential analysis was conducted using a correlation test using IBM SPSS version 25, while abiotic analysis based on the abundance of predatory insects was performed using the Orange software version 3.37.

RESULTS

The results obtained in this study found four orders, five families, and 13 species of *S. frugiperda* predatory insects in maize fields in Klaten District (Table 1).
The fewest species were detected in the families Staphylinidae, Forficulidae, and Reduviidae, with one species each (n: 16, 10, 4 individuals; Figure 2).
The predator species found dominant in Klaten District were from the Coccinellidae family, and seven species were identified in this study (Figure 3).
In this study, Coccinellids species appeared to be influenced by temperature, humidity, light intensity, and wind speed at the study site (Figure 4).

Table 1. Diurnal predatory insect species of *S. frugiperda* in Klaten District.

Orders	Family	Species
Coleoptera	Coccinellidae	*Verania lineata* (Thunberg) *Exochomus nigromaculatus* (Erichson, 1843) *Coccinella transversalis* (Fabricus, 1781) *Harmonia axyridis* (Pallas, 1773) *Harmonia octomaculata* (Fabricius, 1781) *Coleophora inaequalis* (Fabricius, 1775) *Cheilomenes sexmaculata* (Fabricius)
	Staphylinidae	*Paederus fuscipes* (Curtis, 1826)
Hymenoptera	Formicidae	*Camponatus rufipes* (Fabricius, 1775) *Anoplolepis gracilipes* (Smith, 1857) *Formica* sp.
Dermaptera	Forficulidae	*Forficula auricularia* (Linnaeus, 1758)
Hemiptera	Reduviidae	*Rhinochoris* sp.

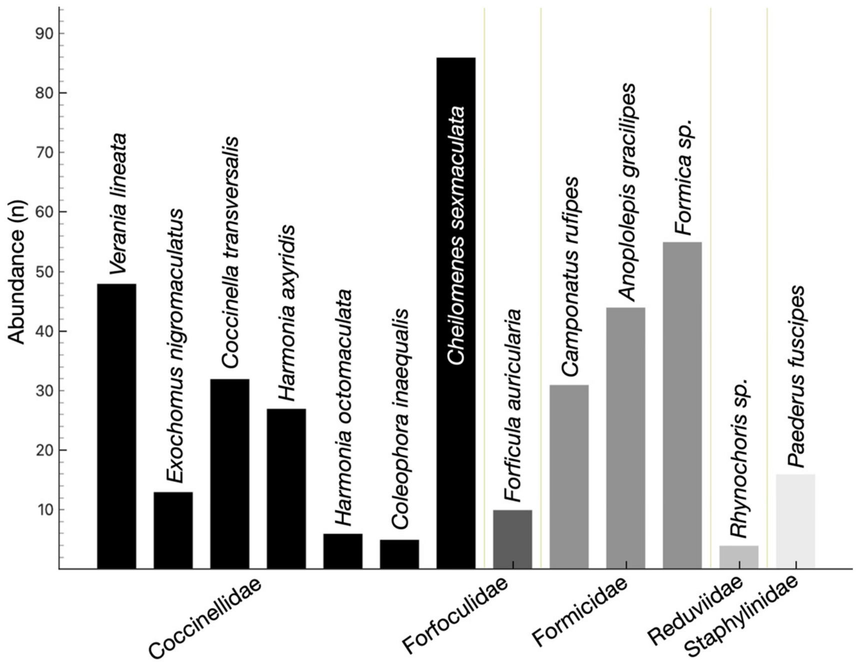

Fig. 2. Abundance of the predatory insect *S. frugiperda* in maize fields in Klaten District.

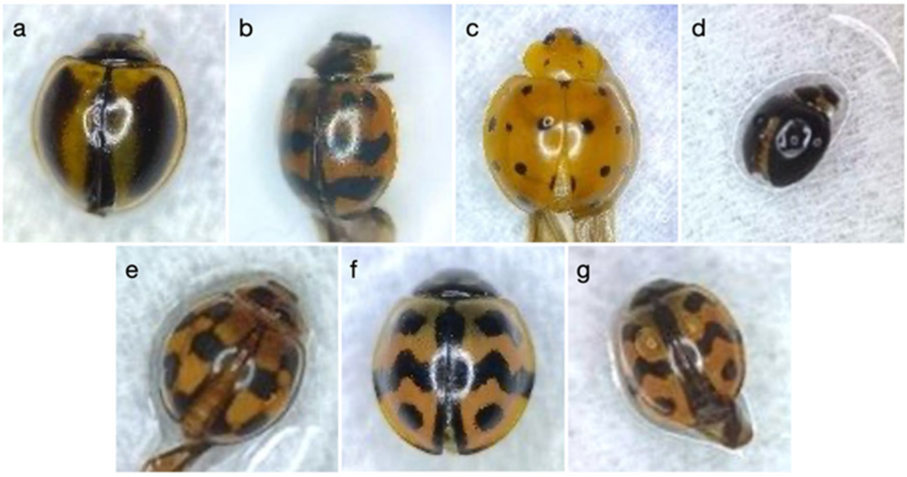

Fig. 3. Coccinellidae species of *S. frugiperda* predators found in Klaten District; (**a**) *V. lineata*, (**b**) *E. nigromaculatus*, (**c**) *C. transversalis*, (**d**) *H. octomaculata*, (**e**) *H. axyridis*, (**f**) *C. sexmaculata*, and (**g**) *C. inaequalis*.

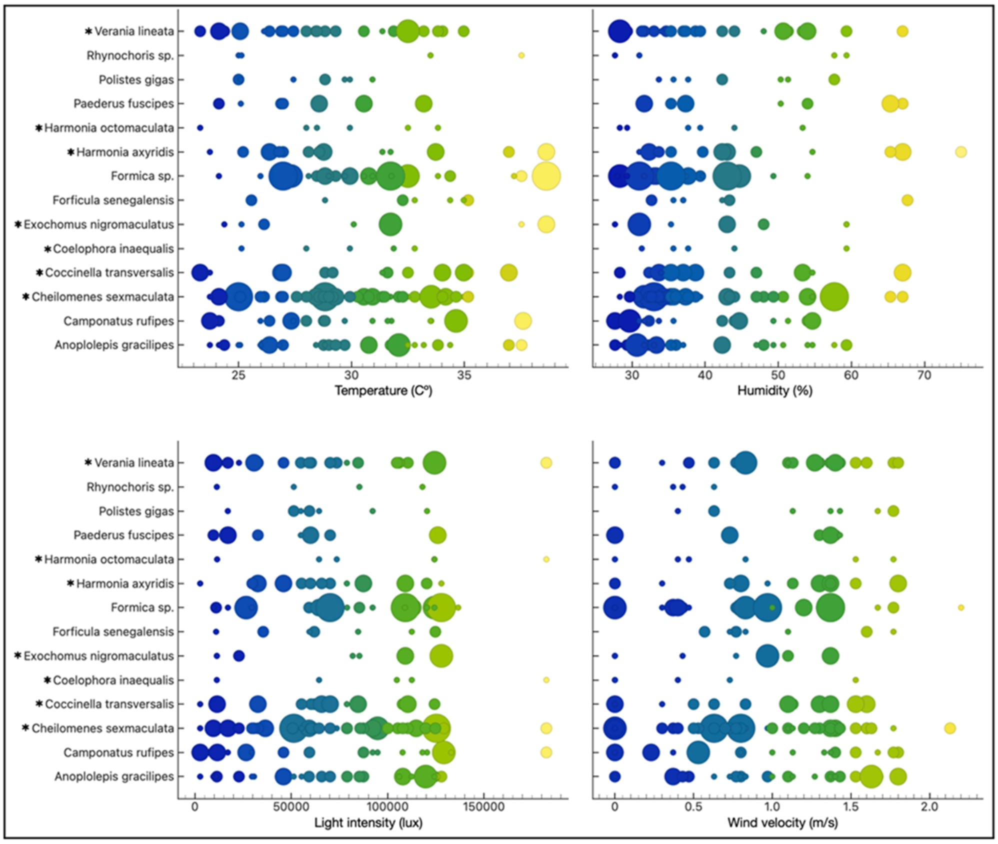

Fig. 4. Coccinellidae abundance (*) at various environmental parameters such as temperature, humidity, light intensity, and wind speed.

Discussion

Species Richness and Abundance of Predatory Insects

Four orders, five families, and 13 species of predatory insects of *S. frugiperda* were identified in the maize fields in Klaten Districts (Table 1). The Coccinellidae, which has seven species, was the most frequently observed predatory insect (n: 217 individuals). The fewest species were found from the Staphylinidae, Forficulidae, and Reduviidae Families, with one species each (n: 16, 10, 4 individuals, respectively; Figure 2.

The results of this study were different from research conducted by Putra et al. (2023) in Sleman and Gunungkidul regencies, which found three orders, seven families, and 15 species of insect predators, and research by Jannah et al. (2021) in Ireng Village, West Lombok which found six families and eight species of insect predators of *S. frugiperda*. The different results may be due to the various growth phases of maize plants. In this study, the observed phase of maize plants was the vegetative phase, which is 3–6 weeks after planting (MST), compared to the generative phase identified in two previous studies. Maize plants in the generative phase have increasingly hard tissues that are less likely to be eaten by pests (Jannah et al., 2021). So, in the generative phase of maize plants, a few larvae of *S. frugiperda* were found, and they are prey for insect predators.

The prey of insect predators are generally herbivorous insects, one of which is the egg and larvae of *S. frugiperda* (Nonci et al., 2019; Nelly et al., 2015). According to Sumiati et al. (2023), diurnal insect predators were found in the vegetative phase compared to the generative phase of corn plants because the prey were easily found during the vegetative phase. Generally, the highest attack of *S. frugiperda* larvae on corn plants occurs at 3–4 weeks after planting (MST) (vegetative phase) (Nonci et al., 2019; Supartha, 2020). This is because the female of *S. frugiperda* starts laying eggs on maize plants aged 1–2 weeks after planting. The eggs will then hatch into 1st instar larvae in 1 week, so the larvae of *S. frugiperda* will be found at 3–4 MST. This study found that Coccinellidaefamiliy was the most abundant. Their role was controlling the population of egg and larval phase of *S. fugiperda*.

Coccinellidae was dominant in most of the sampling fields. Seven species were collected (Figure 3), namely *V. lineata*, *E. nigromaculatus*, *C. transversalis*, *H. octomaculata*, *H. axyridis*, *C. sexmaculata*, and *C. inaequalis*. Although the main prey of all predatory Coccinellids found in this research was *S. litura*, they were also active as predators on early instar larvae or eggs of *S. frugiperda* in maize fields (Hodek et al., 2012; Islam et al., 2020). Several factors affect the abundance of the Coccinellidae population. Coccinellidae has a wide range of prey, such as aphids, scale insects, mealybugs, whiteflies, spider mites, and migratory pests, particularly *S. frugiperda*. Coccinellidae also feeds on honeydew, pollen, and nectar when there is a bit of abundant prey on the field (Iperti 1999). Coccinellidae conservation is essential as its adult and larval stages have a substantial impact on controlling agricultural pest populations in the field (Hesler & Beckendorf 2021). The various growth phases of maize plants also affect the abundance of Coccinellidae. Maize plants in the vegetative phase (3–6 weeks after planting) are vulnerable to the attack of pest, while maize plants in the generative phase have increasingly hard tissues and developed epidermal structures that are less likely to be eaten by pests (Elisa 2013; Jannah et al., 2021). Consequently, the fewer larvae of the *S. frugiperda* population in the maize plants, the lower the abundance of predatory insects. Predatory insect diversity of the generative phase of maize plantation in Sleman, Gunungkidul, and Ireng village showed lower species richness and abundance than in the current study (Jannah et al., 2021; Putra et al., 2023).

Coccinellidae as Weather-tolerant Diurnal Predatory Insects of *S. frugiperda*

The prey of predatory insects are generally herbivorous insects, including the egg and larvae of *S. frugiperda* (Nonci et al., 2019; Nelly et al., 2015). According to Sumiati et al. (2023), diurnal predatory insects were easily found during the vegetative phase. Generally, the highest attack of *S. frugiperda* larvae on corn plants occurs 3–4 weeks after planting (MST) (vegetative phase) (Nonci et al., 2019; Supartha et al., 2020). This is because the female of *S. frugiperda* starts laying eggs on maize plants aged 1–2 weeks after planting. The eggs will then hatch into 1st instar larvae in 1 week, so the larvae of *S. frugiperda* will be found at 3–4 MST (Putra et al., 2024). This study found several diurnal predatory insects and Coccinellids group was quickly seen as the most abundant diurnal predatory insect group and was a predator of the egg and larval phase of *S. fugiperda*. Coccinellids can also withstand a wide range of environmental conditions and are known as weather-tolerant insects. In this study, Coccinellids appeared in a wide range of temperature, humidity, light intensity, and wind velocity (Figure 4).

Insects from the Coccinellidae family, including *C. transversalis* and *V. lineata*, have an optimal air temperature range of 15–35 °C, with an optimum air temperature of 28 °C, air humidity range of 66–85% (Bista 2020), and light intensity of 2.140–6.700 lux. This is in accordance with the abiotic factors measured at the research location to support the survival of Coccinellids predatory insects.

Families Staphylinidae, Forficulidae, and Reduviidae were found to be the least species found as predatory insects of *S. frugiperda*, with one species each. The family Coccinellidae under the class Hexapoda includes up to 30,000 species (Nelly et al., 2015). These predatory insects have the potential to control *S. frugiperda* populations, especially in the egg phase and early instar larvae of *S. frugiperda* (Kundoo & Khan 2017; Nonci et al., 2019; Jaraleño-Teniente et al., 2020; Jannah et al., 2021; Nurkomar et al., 2021).

The abundance of diurnal predatory insect individuals was subsequently tested for correlation with abiotic factors measured at the sampling location. In contrast to air temperature and humidity, the abundance of predatory insect individuals with light intensity has a value of Sig. 0.003 (<0.05) indicates a correlation between the abundance of diurnal predatory insect individuals and light intensity. The higher the light intensity, the higher the abundance of predatory insect individuals. According to Windriyanti et al. (2023) and Maisyaroh et al. (2012), light is an abiotic factor determining insect visitation. One of them from the Coccinellidae family is a diurnal insect that requires optimal light for its activity and distribution (Pratiwi & Apriyadi 2023). This is in accordance with the results of this study, which show that members of the Coccinellidae family have the highest number of individuals. From the findings in this research, the advantage for farmers is that they can reduce the use of synthetic pesticides because there are predators that can control the population of *S. frugiperda* on their land. In addition, farmers will also be more aware of the presence of beneficial insects on their land so that agricultural land management can be carried out more environmentally. According to Meena et al. (2017), Cabasan et al. (2019), and Busse et al. (2021) beneficial insects, such as predatory insects, can provide effective pest control and reduce the cost of pest mitigation. Moreover, the implementation of this research, which uses predatory insect for controlling *S. frugiperda* population, will be greater in the future, reducing the cost of pest controlling process and supporting organic farming.

CONCLUSIONS

The major conclusions of this study are: (1) The diurnal predatory insect species of *S. frugiperda* found in Klaten Regency consisted of 14 species and (2) The species of diurnal predatory insects of *S. frugiperda* obtained with the highest number of individuals was *C. sexmaculata* while the lowest was *Rhynochoris* sp. Coccinelids were the most potential weather-tolerant predatory insects in Klaten District. In future, we suggest mass rearing of the abundance predatory insect, such as *C. sexmaculata,* in laboratory settings. In addition, researchers should is to investigate the functional and numeric responses of *C. sexmaculata* to *S. frugiperda* density.

AUTHOR CONTRIBUTIONS

I.L.I.P and B.W. designed the research. I.L.I.P. supervised all the processes, D.P.S. collected the data. I.L.I.P., N.S. and D.P.S. analyzed the data. I.L.I.P., S.N.Y., N.S., W.M., and B.W. wrote the manuscript. S.N.Y., B.W. and W.M. translate the manuscript. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors state no conflicts of interest.

DATA AVAILABILITY

All data generated or analyzed during this study is present in its full form in this manuscript.

ETHICS APPROVAL

Not applicable.

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