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Research Article

DISTRIBUTION OF SUGARCANE SHIELD SCALE (*AULACASPIS TEGALENSIS*) AND COCCINELLID PREDATORS AGGREGATION ON SUGARCANE PLANTS

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ABSTRACT

The sugarcane shield scale (*Aulacaspis tegalensis*) is a pest of sugarcane plants that is difficult to control with pesticides. One effective control method involves using predators that are synchronized with the target pest. A study was conducted to observe the distribution pattern and aggregation of coccinellid predators targeting the shield scale. The sample units were sugarcane clumps consisting of 5-7 stalks, with one representative stalk selected from each clump for observation. Samples were collected from four blocks of productive sugarcane plants, with approximately 1000 m between blocks, covering an area of about 12 h. The research identified four potential species of coccinellid predators: *Scymnus* sp., *Chilocorus melanophthalmus*, *C. nigritus*, and *Telsimia* sp. These predators exhibited a distribution pattern synchronized with the shield scale. Among the four coccinellid predators, only *C. melanophthalmus* showed aggregation towards the shield scale population.

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INTRODUCTION

Sugarcane is a vital crop for sugar production due to its strategic importance, making it essential to enhance its yield. Efforts to increase production focus on expanding plantations and minimizing yield losses. However, a significant challenge in boosting production is the prevalence of pest attacks, particularly by the sugarcane shield scale (*Aulacaspis tegalensis*) (Sunaryo and Widyatmoko, 2002).

The infestation of the shield scale (*A. tegalensis*) affects all sugarcane varieties, with severity levels ranging from mild to severe. At the sugarcane plantations of PT Gunung Madu Plantations, infestations have shown an upward trend, likely due to the year-round availability of sugarcane plants at various growth stages. Effective chemical control is challenging because the scales attach themselves to stalks covered by leaf sheaths, which, if not removed, provide a conducive environment for their proliferation. Systemic pesticides are also less effective, as they struggle to penetrate the large stems of sugarcane plants older than four months (Sunaryo, 2003).

The sugarcane shield scale infests sugarcane plants from 4 months of age until just before harvest. The population of the sugarcane shield scale increases rapidly when the plant is between 6 and 10 months old. In susceptible plants, this infestation stunts stalk growth, resulting in smaller stalks and potentially causing plant death (Saefudin, 2014).

Sugarcane plants susceptible to shield scale infestations are characterized by tightly packed leaf sheaths that are difficult to open. Shoots or suckers with attached leaf sheaths are vulnerable to attacks, which target both the outer surface of the sheaths and the leaf blades. The shield scale population proliferates after the onset of rainfall and gradually spreads within the stalk (Samoedi, 1993).

A predator is considered a potential biological control agent if it meets specific criteria. According to Wagiman (2013), these criteria include the response of the predator to changes in prey population, its functional response involving physiological processes and behaviors, and synchronization, particularly the aggregation and distribution patterns of both the predator and the prey (Camacho and Chong., 2015; Chohan, et al., 2014; Camacho-Cervantes, et al., 2017).

The present study focused on varieties and clones commonly cultivated in the sugarcane plantations of PT Gunung Madu Plantations, recognized for their high yields. These include GMP 1, GMP 2, GMP 3, GMP 4, RGM 99.370, and RGM 97.8837 (Research and Development PT Gunung Madu Plantations, 2014). The primary objective of the research was to analyze the distribution patterns and aggregation of coccinellid predators of the shield scale. The study also aimed to identify potential coccinellid predators that could effectively control the shield scale pest population. It is hoped that these identified predators can be mass-reared to ultimately reduce the shield scale pest problem to non-damaging levels. The ultimate goal of this research is to develop an effective biological control agent for managing sugarcane scale insects.

MATERIALS AND METHODS

Research site

The research was conducted at the sugarcane plantations of PT Gunung Madu Plantations (PT GMP), located in Gunung Batin, Central Lampung, Lampung Province, from April 2022 to September 2023. The total plantation area covers approximately 35,000 hectares, with around 25,000 hectares allocated to productive plantations (Research and Development PT Gunung Madu Plantations, 2014).

Coccinellid predator survey and sample collection

The sampling unit was a sugarcane clump consisting of 5-7 stems. From each clump, one sugarcane stem, considered representative of the clump, was selected for sampling. Samples were collected from four blocks of productive sugarcane fields, each block covering an area of approximately 12 h, with a distance of about 1,000 m between blocks (Figure 1). Sampling was conducted systematically using a random sampling method. The number of samples per block varied based on the degree of clustering (ǩ), with a minimum of 45 plant samples per block for each observation (Figure 2).

Figure 1. Distance between blocks (around 1,000 m).

Figure 2. Sampling of plants attacked by *Aulacaspis tegalensis* and its predators.

The distribution pattern was analyzed using the Morisita Index of Dispersion (ID) model for both the sugarcane shield scale and its predators, applying the formula provided by Ludwig and Reynolds (1988) as follows.

$$ID = \frac{s2}{\chi}$$

Description:

ID = *dispersion index*

s^2 = *sample of varians*

$\bar{\chi}$ = *average of the sample*

When predators are present in sugarcane plants, their distribution relative to prey can be classified as asynchronous in the absence of prey or synchronous in its presence. The faster predators colonize plants after the colonization of prey, the more effectively the prey population is controlled. The distribution pattern of predators and prey is considered synchronous when both exhibit the same spatial distribution pattern. These distribution patterns, random, regular, or clustered, are determined based on the χ^2 and s^2 values, as calculated using Morisita's Index of Dispersion (ID) (Ludwig and Reynolds, 1988). Predator aggregation refers to the tendency of predators to group on plants with the highest prey population, a behavioral response documented by Hassel (1978) and Singh et al. (2015).

$\beta_i = c\alpha_i{}^{\mu}$

Description:

β_i *: Proportion of predator presence in each sample*

c : konstanta

α_i *: Proportion of shield bug presence in each sample*

μ *: Predator aggregation index*

RESULTS AND DISCUSSION

The results of the observations and analysis of the Morisita Index of Dispersion indicate that the population distribution of the sugarcane shield scale and its predators generally shows synchronization (Figure 3). This suggests that the four species of coccinellid predators of the sugarcane shield scale found on the GMP 2 variety of sugarcane, namely *Chilocorus melanophthalmus*, *Scymnus* sp., *C. nigritus*, and *Telsimia* sp., have the potential to be developed as biological control agents.

Figure 3. Shield scale (*Aulacaspis tegalensis*).

The predator *C. melanophthalmus* was found on sugarcane plants aged 8.0 to 12.0 months (Figure 4). The predator *Scymnus* sp. was found on sugarcane plants aged 8.0 to 12.0 months. The predator *C. nigritus* was found on sugarcane plants aged 8.0 to 12.0 months. *Telsimia sp.* predators were no longer found on sugarcane plants aged 10.5 to 12.0 months, although they were present on plants aged 6.0 to 10.5 months.

Figure 4. *Chilocorus melanophthalmus*.

The population distribution of the sugarcane shield scale on GMP 2 variety sugarcane plants aged 6.0 to 7.0 months was uniform (ID < 1), whereas plants aged 7.5 to 12.0 months showed aggregation (ID > 1). The population distribution of predators on sugarcane plants aged 6.0 to 12.0 months was consistently aggregated. The distribution of the shield bug population and its predators was synchronized when the sugarcane plants were aged 7.5 to 12.0 months. This synchronization is beneficial because the presence of predators coincides with the availability of prey, allowing predators to suppress the growth of the sugarcane shield bug population (*A. tegalensis*).

Based on the Morisita distribution index, the predators that are synchronized with the distribution of sugarcane shield bugs are *C. melanophthalmus*, *Scymnus* sp., and *C. nigritus*. *Telsimia* sp. predators have limited potential as biological control agents because their presence is inconsistent. When sugarcane plants are 11.0 months old, *Telsimia* sp. predators are no longer found. More details are presented in Table 1. The monoculture sugarcane plantation environment, with its vast expanse, is less suitable for the habitat of *Telsimia* sp. predators. The presence of *Telsimia* sp. predators is strongly influenced by the plant ecosystem. Sugarcane plants near rural borders, where there are many types of plants, both flowering and non-flowering, have a more abundant population of *Telsimia* sp. beetles. This is consistent with the findings of Chandran et al. (2019), which state that the presence of predators is influenced by the types of plants and the seasons in a given area.

Table 1. Morisita Index of dispersion for predators and sugarcane shield scale.

Age (month)	Shield scale	*C.*	*Scymnus* sp.	*C. nigritus*	*Telsimia* sp.
4,0	~	~	~	~	~
4,5	~	~	~	~	~
5,5	~	~	~	~	~
6,0	0,05	0	0	0	1,62
6,5	0,08	0	0	0	12,59
7,0	0,04	0	0	0	14,11
7,5	1,11	0	0	0	17,30
8,0	5,47	11,00	12,00	5,00	9,51
8,5	3,11	0	0	0	9,33
9,0	456,95	0	17,00	8,00	1,88
9,5	6,99	4,32	6,60	14,74	0,42
10,0	259,18	113,10	4,05	0,98	62,18
10,5	24,41	17,70	112,24	99,17	19,67
11,0	276,49	46,36	24,17	0	~
11,5	104,90	1041,43	19,56	3,00	~
12,0	81,21	2,80	55,08	3,00	~

Description: ID (distribution index), ID = 1 random distribution, ID < 1 uniform distribution, ID > 1 clustered distribution, ~: not found.

The population distribution of predators on sugarcane plants aged 6 to 12 months was consistently aggregated (Table 2). The distribution of the shield bug population and its predators between 7.5 and 12 months of age is synchronized. This synchronization is beneficial because the presence of predators aligns with the availability of their prey, allowing the predators to effectively suppress the growth of the sugarcane shield bug population (*A. tegalensis*). This is demonstrated by multivariate regression analysis using SPSS, which reveals significant differences among predator species. The regression results show that the highest aggregation index (μ) belongs to the coccinellid predator *C. melanophthalmus*.

The results of the predator aggregation test on the prey population (sugarcane shield scale) showed significant differences among coccinellid predators. *C. melanophthalmus* was the only species that showed predator aggregation on sample plants with high sugarcane shield scale populations.

C. melanophthalmus is a well-established predator, as it is native to the region and has adapted to the large, monoculture sugarcane plantation environment over the years. The presence of *C. melanophthalmus* and the sugarcane shield aphid *A. tegalensis* has a very close relationship. It is evident that when the population of the sugarcane shield scale increases rapidly, there is a corresponding increase in the predator population of *C. melanophthalmus*.

Table 2. Aggregation of predator species in the highest population of sugarcane shield scale.

Variety/Clone	μ value in predator species			
	C. melanophthalmus	*Scymnus* sp.	*C. nigritus*	*Telsimia* sp.
GMP 1	6,003*)	2,644	1,341	- 0,220
GMP 2	1,571	1,128	- 3,110	2,826
GMP 3	0,029	- 0,330	- 0,670	- 0,00001
GMP 4	0,626	0,363	0,745	- 0,1
RGM 99.370	- 0,870	0,274	- 0,270	- 0,01
RGM 97.8837	- 0,520	0,091	- 0,070	- 0,0001

*) = The μ value is significant.

The analysis of predator aggregation on the highest population of sugarcane shield scale across four sugarcane varieties and two clones revealed a significant value of μ in the GMP 1 variety for the predator *C. melanophthalmus* (μ = 6.033). This indicates that the coccinellid predator *C. melanophthalmus*, which preys on the sugarcane shield scale present on GMP 1 sugarcane plants, exhibits aggregation. In the GMP 1 variety, when the population density of the shield bug was highest, a concentration of the predator population of *C. melanophthalmus* was observed. This phenomenon suggests that *C. melanophthalmus* is the most suitable predator for selection and development as a biological control agent.

For the predators *C. nigritus* and *Telsimia* sp., an anomaly was observed: as the population of the sugarcane shield scale increased, the proportion of these predator populations decreased. This is suspected to be due to competition with rival predators, leading to migration to other areas. Such occurrences typically happen during prey competition in the same niche, where one of the weaker predators is outcompeted and subsequently leaves the area in search of other prey.

Further development, after recognizing the potential of *C. melanophthalmus* as a predator, involves mass breeding. The maintenance of predators in the laboratory and their application in the field when sugarcane plants are attacked by sugarcane shield scale will help prevent losses due to attacks by sugarcane shield scale.

CONCLUSION

The present study demonstrates that four species of coccinellid predators viz. *Scymnus* sp., *Chilocorus melanophthalmus*, *C. nigritus*, and *Telsimia* sp. exhibit a distribution pattern synchronized with the sugarcane shield scale (*Aulacaspis tegalensis*). Moreover, population aggregation of predators and the sugarcane shield scale occurs only with the coccinellid predator *C. melanophthalmus*.

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AUTHOR'S CONTRIBUTIONS

SP designed, formulated and laid out the study, conducted the experiments, collected, arranged and analyzed the data, wrote the manuscript, and proofread the paper.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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