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RESEARCH PAPER

Population dynamic and pheromone use for early monitoring of *Spodoptera exigua* Hübner (Lepidoptera: Noctuidae) in Indonesia

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ABSTRACT

Beet armyworm (*Spodoptera exigua*) poses a challenge for shallot production because it can exist in fields throughout the year. This study aims to observe the dynamic population during shallot off and on-seasons. Additionally, this study aims to determine the correlation between *S. exigua* moth captures and damage intensity. The research was conducted from November to May in Kretek Village, Parangtritis District, Bantul Regency, Special Region of Yogyakarta Province, Indonesia. Population dynamic observations of *S. exigua* during the off-season and on-season were conducted in a 100 × 100 m plot with ten pheromone traps installed. The early monitoring study consisted of two treatments: installed pheromone and control (without the installation of pheromones). The plots were separated by approximately 500 m and were approximately 3500 m^2 in size. The results showed that *S. exigua* exists and can survive during shallot off-season and on-season planting periods. The number of male *S. exigua* moths captured during the on-season was higher compared to the off-season. The fluctuation of rainfall and the number of *S. exigua* during the off and on-seasons were also observed, showing that rainfall significantly affected the number of *S. exigua* moths captured. However, the relationship between rainfall and *S. exigua* population needs further study. Strong positive correlations between population and damage intensity in pheromone-treated fields between three to seven days after observation (DAO) demonstrated that pheromone traps can be used as a monitoring tool for *S. exigua*. The close correlation between the *S. exigua* captured and the intensity of the damage that will occur can be prevented by controlling them by farmers.

Key words: Monitoring, pheromone, population, shallot, *Spodoptera exigua*

INTRODUCTION

Shallot (*Allium cepa*) is a horticultural crop with high economic value. Shallots are included in the unsubstituted spice group, which functions as a seasoning for food as well as traditional medicinal ingredients and contains several important compounds. Additionally, shallots are an important non-oil export commodity for Indonesia, with reported annual exports reaching Rp 2.7 billion (Marsadi et al., 2017). Shallot production over the past four years has exceeded domestic demand and has been exported. Indonesian shallots have the opportunity to be exported to Malaysia, Russia, and the United States, which should be pursued (Wahyuni et al., 2020). In Indonesia, one of the areas that produces shallots is Bantul Regency, Special Region of Yogyakarta.

Fulfilling shallot production demands has its challenges, and one of these challenges is *Spodoptera exigua*. *S. exigua* is a polyphagous insect pest that exists in fields year-round, requiring continuous monitoring. It has a wide host range and has been frequently reported as a pest in horticultural productions, including asparagus, beans, broccoli, cabbage, cauliflower, celery, corn, cowpea, eggplant, lettuce, peas, pepper, potato, turnips, spinach, sweet potato, tomato, alfalfa, cotton, groundnuts, safflower, sorghum, soybean, and tobacco. Several weed species have also been reported as hosts for this pest, such as *Amaranthus* spp., *Portulaca* spp., *Parthenium* sp., dan *Tidestromia* sp. (Binns & Nyrop, 1992; Capinera, 1969; Mujiono et al., 2015). However, *S. exigua* have feeding preferences to certain plant species (Ahmad et al., 2021; Arulkumar et al., 2017; Kumar et al., 2020; Marsadi et al., 2017; Mehta et al., 2021; Paparang et al., 2016). *S. exigua's* preference for shallots is caused by certain volatile compounds, such as n-propyl disulphide and methyl 1-(methyl sulfinyl) propyl disulphide, which are both organosulfur compounds (Lanzotti, 2006). These compounds produce a special scent and taste in Allium plants, attracting *S. exigua* to diethyl ether (Paparang et al., 2016).

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Management using contact insecticides is considered ineffective in reducing damage intensity due to larvae behavior, as they tend to enter leaves and reduce their exposure to insecticides. Besides contact insecticides, systemic insecticides are not recommended to reduce residue accumulation in tubers (Acín et al., 2010; Witzgall et al., 2010). According to Hartini (2011), insecticide and fertilizer applications by farmers in Kersana, Brebes, have caused Pb contamination in shallot, reaching value close to the limits of 0.16–0.20 mg/kg. High pesticide residue levels in shallots have adverse effects on the environment and hinder exportation. Late management might cause management costs to be wasteful. Thus, *S. exigua* management should be done at the right time, and an early warning system together with monitoring is required (Ishtiaq et al., 2012; Valentino & Thaha, 2019).

The sex pheromone traps are helpful for the early detection and monitoring of pest infestation and can potentially control the pest. The sex pheromone trap effectively captured *S. exigua* moths (Kusumawati et al., 2022). The appropriate number of traps to monitor pest infestation was three units per 2000 m^2 (Lestari et al., 2020). Moekasan et al. (2013) also explained that the threshold for *S. exigua* pest control, based on the capture of moth populations using Pheromone Exi was ten or more individuals per trap per day. Applying this control threshold can reduce the use of insecticides by 35.71%, with a yield of 13.46 t/ha, equivalent to using insecticides twice a week. Research related to *S. exigua* monitoring using pheromones, as conducted by Lestari et al. (2020) and Moekasan et al. (2013), has not proven whether the capture of *S. exigua* imago using pheromone traps is closely related to the level of plant damage, and this study intends to prove this. Additionally, this research also aims to demonstrate that *S. exigua* is present throughout the year, both during the off-season and during the shallot season.

MATERIALS AND METHODS

Research site. The location for the population dynamics and early monitoring study of *S. exigua* was carried out in different fields. Separate location were chosen to facilitate data collection and management. The research was conducted from November to May in Parangtritis Village, Kretek District, Bantul Regency, Yogyakarta, Indonesia. The population dynamics study lasted for seven months, while the monitoring lasted for two months. The pheromone used in this study was Pheromone EXI RB (Z-9-tetradecanol: 10 µg/dispenser; Z-E-9-12-tetradecadienyl acetate: 90 µg/dispenser) produced by CV. Nusagri. The pheromone trap installed in the field consisted of a 1.2 m bamboo stick, wire, pheromone dispenser, and sticky trap.

***Spodoptera exigua* population dynamic observation**. Observation of *S. exigua* population dynamic was conducted in a 100 × 100 m field equipped with ten pheromone traps. *S. exigua* population observations were carried out during the off-season (when fields were planted with chili, rice, or non-cultivated) and during the on-season (when fields were planted with shallot) for a duration of two months. The number of moths was observed every four days during both the off-season and on-season periods. Pheromones were replaced every two months once the traps reached their capacity to catch *S. exigua*. In addition to observing the *S. exigua* population during the on-season and off-season, rainfall data were also collected from the Water Resources Office of the Regional Government of Bantul Regency.

Early monitoring of *Spodoptera exigua*. Population observations were conducted in other plot consisting of two treatments: pheromone and control (no pheromone installment). The fields were approximately 500 m apart and covered an area of approximately 3500 m^2. Observation of *S. exigua* populations was conducted using 15 pheromone traps placed diagonally with a distance of 15 m between traps. Observations were carried out twice a week starting seven days after shallot planting and continuing until 50 days after planting (DAP). Pheromones were replaced every month. The damage intensity of shallots was observed twice a week from plants that were seven days old until 50 DAP. Observations of damage intensity used seven shallot plants as a sample unit, which were selected diagonally from 15 sample plots per treatment. Therefore, the total number of plant samples in each treatment was 105 plants. The damage intensity caused by *S. exigua* was calculated using the following formula (Moekasan et al., 2013):

$$P = \frac{a}{b} \times 100\%$$

P = Damage intensity (%),
a = Number of leaves damaged,
b = Total number of leaves on plant.

Data analysis. Data were analyzed using Microsoft Excel 2013 software. Damage intensity between treated and control plots were analyzed using a t-test with a confidence levels of 95%. The correlation between damage intensity from *S. exigua* damage and moth populations was conducted using data from fields with pheromone traps, using Pearson correlation analysis.

RESULTS AND DISCUSSION

Population dynamic of *Spodoptera exigua* During off-season and on-season. The average number of *S. exigua* captured during periods when fields were cultivating chili, rice, or non-cultivated was lower compared to the shallot periods. Specifically, the average number of *S. exigua* captured was 0.4 moth/trap/day during the chili period, 0.7 moth/trap/day during the rice period, 0.8 moth/trap/day during first non-cultivated period, 2.4 moth/trap/day during the shallot period, and 2.1 moth/trap/day during the second non-cultivated period (Figure 1). The on and off-season observations lasted for seven months and totalled 26 off-season observations and 18 on-season observations.

Results from November to Mei showed that *S. exigua* was found during both the on and off-seasons. These results align with research by Ujiyani et al. (2019), which showed that *S. exigua* males were found throughout the year, both during on- and off-shallot planting seasons. The number of trapped males increased and peaked at the end of the first planting season to begin the off-shallot planting season (Ujiyani et al., 2019). This indicates that *S. exigua* could survive on other hosts even though the population captured in traps was smaller than during the season because host plants can affect the fitness and development of *S. exigua*. According to Ahmad et al. (2021), the longest larval and pupal periods (16.35 and 9.95 days, respectively) were observed on spinach, while the shortest periods were recorded on okra (13 days) and cauliflower (8.4 days), respectively.

Rainfall and population of *S. exigua* during off and on-season. When the conditions are off-season (chili and rice plants), non-cultivated, and on-season (shallots) until non-cultivated again, rainfall significantly affects the number of male *S. exigua* captured. During the off-season, when the rainfall is high, the number of *S. exigua* captured decreases, and when the rainfall is low, the number increases again (Figure 2). This result aligns with Hidayah et al. (2023), who found that the number of male *S. exigua* captured tends to decrease on rainy days. Meanwhile, in the on-season conditions, the number of *S. exigua* captured is also high when the rainfall is high, and when the rainfall is low, the number of captured individuals is also low. Plant availability and the impact of rainfall on humidity are likely factors that affected moth captured during both the off-season and on-season. According to Ramesh & Singh (2022), a 1% increase in humidity impacts the incidence of *S. exigua* larvae.

Early monitoring of *Spodoptera exigua*. Shallot damage intensity fluctuated in both control and pheromone treatments (Figure 3). Damage intensity in the no-pheromone plots was higher compared to the pheromone plots, even though damage intensity in the pheromone plot tended to increase over time. Damage intensity in both the no-pheromone and pheromone

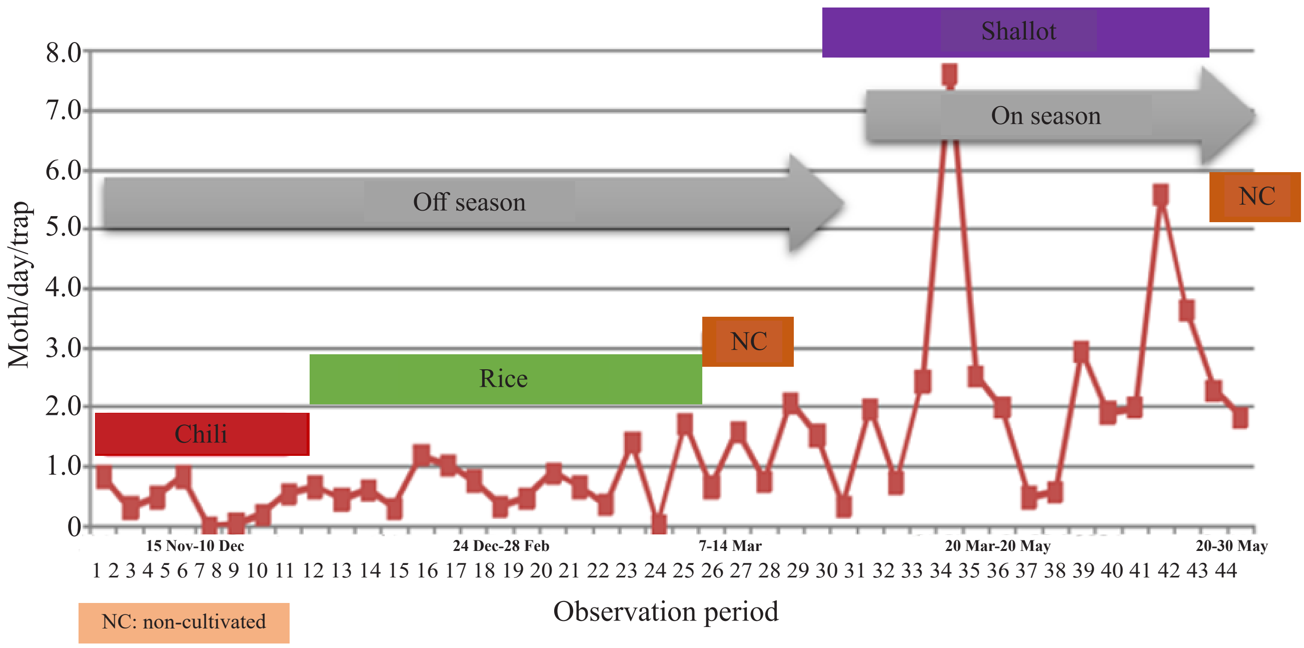

Figure 1. Average of *Spodoptera exigua* captured during chili, rice, shallot, and non-cultivated periods.

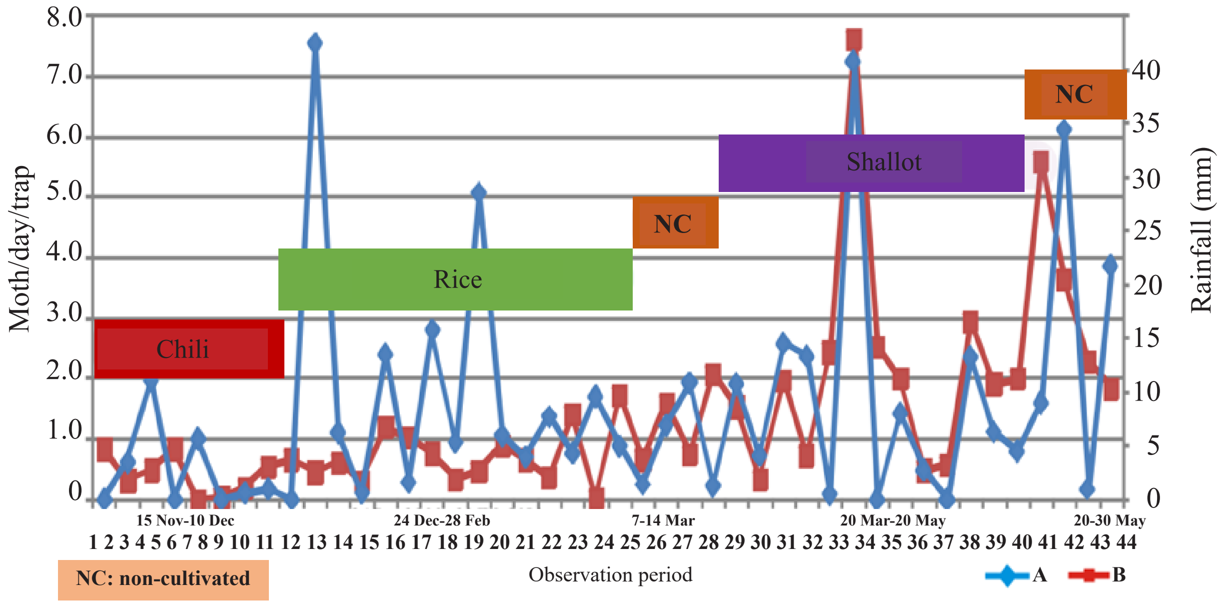

Figure 2. Average of *Spodoptera exigua* captured and rainfall data. A. Rainfall; B. Number of moths capture.

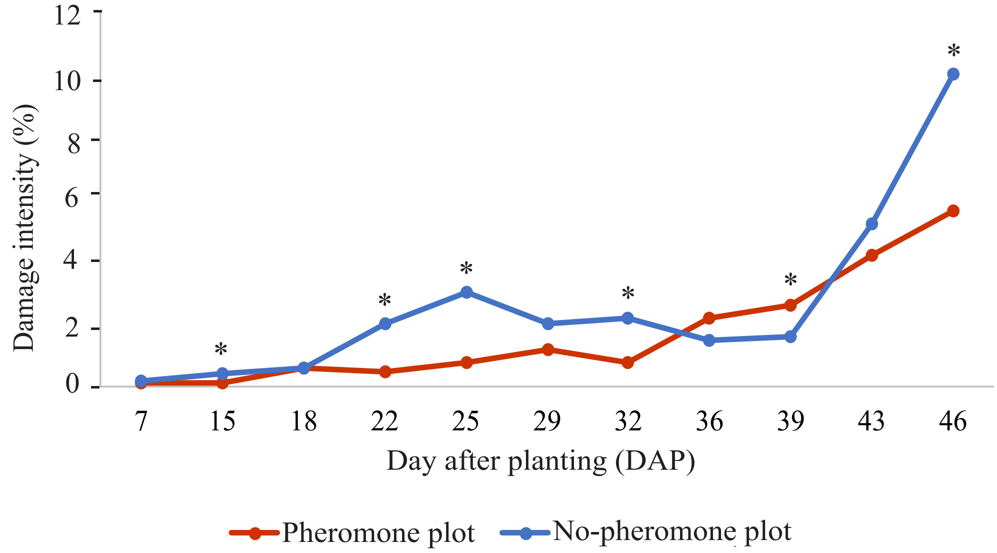

Figure 3. Damage intensity due to *Spodoptera exigua* on shallot. *= The asterisk on the graph indicates significant difference based on the T test (α= 0.05).

plots was considered very low and low for the control plots, based on the criteria by Moekasan et al. (2013), where 0–10% is considered very low, while >10–20% is considered low. The damage intensity values between the non-pheromone and pheromone plots were only significantly different at 15, 22, 25, 32, 39, and 46 DAP.

The number of *S. exigua* captured fluctuated, although it tended to increase up to 32 DAP, and the number was highest between 32 and 43 DAP (Figure 4). At the highest number of *S. exigua* captured, the intensity of damage also increased. This indicates the possibility that 32 to 43 DAP was the mating season and egg-laying for female *S. exigua*. The eggs laid then hatch into larvae, thereby increasing crop damage. The increase in pest population is linearly related to the intensity of damage. This is related to the life cycle of *S. exigua,* with eggs being laid in the first week and growing into first and second instar larvae in the following week (Greenberg et al., 2001).

Pearson correlation analysis conducted to determine the strength of the relationship between moth populations and damage intensity. According to the analysis, the correlation between moth population and damage intensity 7 days after observation (DAO) (r= 0.940 (p= 0.017)) is stronger than the correlation observed 3 DAO (r= 0.630 (p= 0.038)).

Pest monitoring using pheromone traps can assist in making management decisions. Management

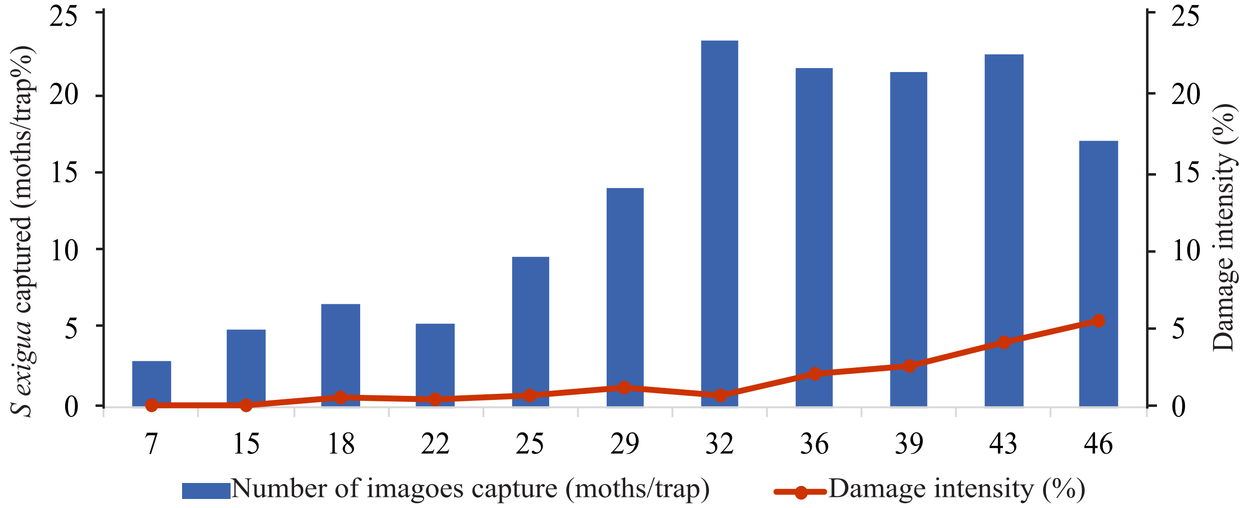

Figure 4. Comparison of the number of *Spodoptera exigua* captured and the damage intensity.

based on monitoring results is hoped to employ environmentally friendly techniques. Sex pheromones are chemical compounds produced by individuals to attract mating partners from distance (Tewari et al., 2014). Sex pheromones can be used to monitor pest populations early in the field or for mass trapping of males (Lestari et al., 2020). Additionally, pheromones can be utilized for mating disruption (Benelli et al., 2019; Mujiono & Putra, 2015). Pheromone traps are an important component of Integrated Pest Management as they can monitor populations, serve as an early warning system against migrating pests, and assist in decision-making for further pest management (Reddy & Tangtrakulwanichs, 2014).

Occurrences of *S. exigua* year-round should be monitored to reduce damage intensity on shallots. Monitoring is an effective way to determine insect population and is important for pest management programs (Hong et al., 2020). Behavior manipulation using pheromones has been developed as pest monitoring tools that utilize synthetic pheromones formulated and installed in dispensers to attract and catch pests (Tewari et al., 2014). From this research, correlation results between *S. exigua* populations and damage intensity of shallots at 3 DAO and 7 DAO show positive results. The estimation of damage intensity three days after observation is in line with the recommendation of Moekasan et al. (2013), which states that observations of moth populations in traps are carried out from 5 DAP at 3-day intervals. If the *S.exigua* moth population reaches ≥ 30 individuals/trap/three days, the plants are sprayed with the recommended insecticide (Moekasan et al., 2013). This indicates that the *S. exigua* captured with pheromone traps can be used as population monitoring for decision-making in controlling the use of insecticides. The close correlation between the captured and the intensity of the damage that will occur can be prevented by controlling them by farmers. Efficiency in monitoring will help farmers optimize the energy and time needed. Routine monitoring will determine correct periods for management. Several benefits of monitoring using pheromones are its low cost, ease of use, and high sensitivity (Laurent & Frérot, 2007; Falsafi et al., 2022). Over long periods, monitoring results can be used to determine changes in population dynamics and pest behavior.

CONCLUSION

S. exigua still exist and survive during shallot's off-season and on-season, although the population during the off-season is lower than during the on-season. *S. exigua's* year-long presence in fields should be detected as soon as possible to minimize damage to shallots. Strong positive correlations between populations and damage intensity in pheromone-treated field from 3–7 days after observation indicate that pheromone traps can be used for *S. exigua* monitoring.

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AUTHORS' CONTRIBUTIONS

W carried out conceptualization, funding acquisition, methodology, project administration. resources, supervison, writing original draft, YAT carried supervision, writing review and editing. HRT and ZA carried out data curation, formal analysis, investigation, software, validation, visualization. All the authors have read and approved the final manuscript.

COMPETING INTEREST

The authors declare that there are no conflicts of interest.

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