Indian Journal of Agricultural Sciences **96** (4): 529–535, April 2026/Article
https://doi.org/10.56093/ijas.v96i4.167617

Species composition and abundance of predatory natural enemies of *Spodoptera frugiperda* at growth stages of maize (*Zea mays*) in conventional fields

ASIRI SINGHAMUNI[1], AZIDAH ABDUL AZIZ[1]* and NURUL ASHIKIN ABDULLAH[1]

Institute of Biological Science, Universiti of Malaya, Kuala Lumpur 50 603, Malaysia

Received: 06 June 2025; Accepted: 08 April 2026

ABSTRACT

Understanding the composition and abundance of predatory insects targeting *S. frugiperda* in maize (*Zea mays* L.) at various growth stages is crucial for developing effective management strategies. Therefore, the present study conducted from September 2023 to February 2025 investigates the species composition and abundance of predatory natural enemy insects at different growth stages of maize crops in conventional agricultural fields of Sungai Burung, Tanjung Karang, Selangor, Malaysia. Results revealed four predatory insect species: *Sycanus dichotomus* Stal (Hemiptera: Reduviidae), *Micraspis discolour* Fabricius, *Harmonia octomaculata* Fabricius, and *Cheilomenus sexmaculata* Fabricius (Coleoptera: Coccinellidae), which act as predators of *S. frugiperda*. Additionally, larvae of three coccinellids were identified as predators of *S. frugiperda* in the field. In contrast, *S. dichotomus* nymphs, which also prey on *S. frugiperda*, were not found in maize plantations. The composition of predatory insect species did not significantly change with the maize crop's growth stages, except for *S. dichotomus*. However, the mean abundance of predatory insects varied significantly ($F = 408.60$; $df = 9,290$; $p<0.001$) across different growth stages of the maize crop, with the crops at the flowering stage (8-weeks old) showing the highest mean abundance of predatory insects. The results indicate that the species composition and abundance are relatively linked to the different developmental phases of the maize crop, with the lowest abundance of predatory insects observed in the immature stages and the highest abundance recorded in mature maize plants.

Keywords: Coccinellids, Entomofauna, Fall Armyworm, Relative abundance

Maize (*Zea mays* L.) is one of the most economically significant cereal crops in Malaysia due to its high demand in the country's broiler, ruminant, and piggery industries (AgFlow 2022). Malaysia imports 4 mt of maize from the USA, Brazil, and Argentina to meet its requirements (Wahab 2017). Consequently, the Malaysian government has decided to reduce corn imports and accelerate the cultivation of land in the coming years (Mohammed *et al.* 2021). However, the cultivation of maize crops and the expansion of maize-cultivated lands are highly threatened by the invasive agricultural pest *Spodoptera frugiperda* (J.E Smith) (Lepidoptera: Noctuidae) which, significantly attacks maize plantations and is widespread in Peninsular Malaysia. *S. frugiperda* was first detected in Malaysia in early 2019 (IPPC 2019) in the northern state and was discovered throughout peninsular Malaysia (11 states) later that same year (Jamil *et al.* 2021). The total area affected by *S. frugiperda* is 246.35 ha with 50–100% damage severity to the immature stages of maize plants occurring in less than 40 days by 2019 (DOA 2019).

[1]Institute of Biological Science, Universiti of Malaya, Kuala Lumpur, Malaysia. *Corresponding author email: azie@um.edu.my

S. frugiperda, commonly known as Fall Armyworm (FAW), is one of the most serious pest species due to its strong migration ability, high fecundity, polyphagous behaviour, and large host range (Adhikari *et al.* 2020). Worldwide crop production is highly threatened by this pest species and farmers have tended to apply insecticides to control it (Abang *et al.* 2021). Though it is an easy control method, its overuse might cause negative impacts on nature (Kumar *et al.* 2022). Those negative consequences have accelerated attempts to discover sustainable eco-friendly options. Biological control is a sustainable and environment-friendly management method (Assefa and Ayalew 2019). The potential for the application of biological control to invasive species relies on its indigenous natural enemies that have built novel associations with *S. frugiperda* (Firake and Behere 2020).

Predatory natural enemies can attack different life stages of *S. frugiperda* (Abbas *et al.* 2022). Insect predators belonging to different insect orders such as Dermaptera, Coleoptera, Hymenoptera, and Hemiptera have been successfully used in America by augmentative release (Abbas *et al.* 2022). Many predatory insect group associated with *S. frugiperda* have been identified by different researchers in different regions of the world. The vast majority of recorded predatory species are in Asian countries from the order Coleoptera, which includes four distinct families: Coccinellidae, Carabidae, Cicindelidae, and Staphylinidae. The order Hemiptera also contributed to the suppression of *S. frugiperda*, with three families including Reduviidae (Hou *et al.* 2020), Pentatomidae (Tang *et al.* 2019), and Anthocoridae (Zeng *et al.* 2021). China reported a Dipteran family: Syrphidae (Hui *et al.* 2021), while India reported a Hymenopteran family: Vespidae (Firake and Behere 2020). As it is a newly invasive pest, very limited information is available on the natural enemy predatory species of *S. frugiperda* in Malaysia. Over time, some predatory natural enemies have greater potential to expand their niche by adapting to *S. frugiperda* in Malaysia. Therefore, the study investigated the beneficial predatory arthropods of *S. frugiperda.* Understanding the composition and abundance of predatory insects targeting *S. frugiperda* in maize at various growth stages is crucial for developing effective management strategies in conventional fields.

MATERIALS AND METHODS

The present field study was carried out during September 2023 and February 2025 at Sungai Burung (3°30'0.36"N, 101°11'14.27"E), Tanjung Karang, Selangor, Malaysia. The experiment used a 5000 m^2 maize field, divided into five equal plots (each 1000 m^2). The study was carried out in a conventionally cultivated farmer's field so that the population trend of both pests and natural enemies under realistic farm conditions could be determined. The sweet corn maize variety, F1 351 (The Hulk) was selected for the study and the similar agronomic practices was followed during the experiment. Ten percent of the total number of plants were randomly sampled from each plot. Accordingly, 50 plants from each plot were randomly sampled while moving along the "W" shape design (Bakry and Abdel-Baky 2023). Sampling was conducted weekly from 7.30 a.m. to 11.30 a.m., from maize seedlings to the harvesting stage. Six entire maize crop cycles were sampled from 2023–2025 with 30 replicates. Each selected maize plant was examined for predatory natural enemies of *S. frugiperda*. Available predatory insects on the plants were counted and collected as live specimens. The collected predatory natural enemies were separately placed into clear plastic cups with muslin cloth lids (top diameter 95 mm, base diameter 55 mm, height 130 mm) and safely transported to the laboratory as soon as possible.

Predation of natural enemies was confirmed based on direct observation in the field and the laboratory feeding test (no-choice test). Predators were killed with ethyl acetate and dead specimens were dried in a hot air oven at 45–50°C for 48 h. The oven-dried specimens were mounted singly on insect pins through the thorax just to the right of the center of their body. The small insects were mounted with the help of white, thick cardboard triangular points. The paper cards with collection details were attached to the pin. The pin-mounted specimens were arranged inside the insect box for further identification. The species composition (which particular species are present) and their relative abundance (percent composition of an organism of a particular kind relative to the total number of organisms) of natural enemies of *S. frugiperda* were determined with the growth stages of maize crops. The relative abundance was calculated according to the natural enemy species composition in the maize plantation using the following formula described by Molina-Ochoa *et al.* (2001):

$$RA = \frac{Ni}{Nt} \times 100$$

Where, RA, Relative abundance (percentage composition); Ni, Number of individuals in natural enemy species i; Nt Total number of natural enemy species.

Data analysis: The mean values and standard error of the predatory insects from 30 replicates were analyzed using descriptive statistics, while the differences in mean abundance of predatory insects at various growth stages of the maize crop were evaluated using one-way ANOVA. Tukey's test at $p<0.05$ was employed to determine the significance of differences among means.

RESULTS AND DISCUSSION

Four predatory insect species, *Sycanus dichotomus* (Hemiptera: Reduviidae); *Micraspis discolor*; *Harmonia octomaculata* and *Cheilomenus sexmaculata* (Coleoptera: Coccinellidae), have been identified as natural enemies of *S. frugipera*. Furthermore, larvae of three coccinellids were found to be predators of *S. frugiperda* in the field. In contrast, *S. dichotomus* nymphs, also predators of *S. frugiperda*, were not discovered in maize plantations. Various researchers have also identified these predatory insect species as having previously attacked the immature stages of *S. frugiperda* in maize ecosystems across several Asian countries. For instance, *H. octomaculata* preyed on immature *S. frugiperda* larvae in India (Sharanabasappa *et al.* 2019), *C. sexmaculata* on immature *S. frugiperda* larvae in Indonesia (Sari *et al.* 2022), and *M. discolor* on immature *S. frugiperda* larvae in Malaysia (Jamil *et al.* 2021), *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) has been observed feeding on eggs and first instar larvae of *S. frugiperda* in China (Di *et al.* 2021). In Malaysia, *S. dichotomus* is the most common predator species belonging to the assassin bugs (Hemiptera: Reduviidae) attacking bagworms (*Metisa plana* Walker) in oil palm plantations (Halil *et al.* 2021). *S. dichotomus* has recently been identified as a predatory insect species of *S. frugiperda* larvae in Malaysia (Singhamuni *et al.* 2025). The experimental maize area was surrounded by oil palm plantations. Consequently, *S. dichotomus* adults have broadened their prey spectrum to include the newly invading *S. frugiperda* in Malaysia's maize ecosystem.

Investigating these predatory insect species and their relative abundance at different maize growth stages is critical for understanding population changes throughout the crop cycle under actual field circumstances. The one-week-old maize plant is the first growth stage of the maize crop and consists of 1–3 leaves just after emergence.

Predatory insects of *S .frugiperda* were not discovered in the one-week-old maize crop. At the two-week-old stage, maize plants consisted of 5–7 leaves and had all three coccinellid species, including adults and larvae; however, *S. dichotomus* was not observed in the two-week-old maize crop. *M. discolor* adults had the highest relative abundance (30.44%), followed by *H. octamaculata* adults, *C. sexmaculata* larvae, *M. discolor* larvae, *C. sexmaculata* adults, and *H. octamaculata* larvae at 15.08%, 14.38%, 13.54%, 13.4%, and 13.12%, respectively.

Maize plants had 5–7 leaves during the third week of growth. In this stage, the highest relative abundance was observed in *M. discolor* adults (30.97%), followed by *C. sexmaculata* adults (17.69%), *H. octamaculata* adults (14.15%), *C. sexmaculata* larvae (13.66%), *M. discolor* larvae (11.89%), and *H. octamaculata* larvae (11.60%). Additionally, *S. dichotomus* was not found in three-week-old maize crops, just like in the first and second week old maize crops. The maize plants had 6–8 leaves during the fourth week of growth. Although *S. dichotomus* was not detected in the fourth week, coccinellids were observed with the highest relative abundance being *M. discolor* adults (33.35%), followed by *C. sexmaculata* adults (21.43%), *H. octamaculata* adults (13.23%), *C. sexmaculata* larvae (12.38%), *M. discolor* larvae (9.9%), and *H. octamaculata* larvae (9.67%), respectively. Five-week-old maize plants had 8–10 leaves. Like the previous stages, *M. discolor* adults had the highest relative abundance (32.59%), followed by *C. sexmaculata* adults (23.04%), *H. octamaculata* adults (11.52%), *C. sexmaculata* larvae (9.48%), *H. octamaculata* larvae (8.52%), *S. dichotomus* (7.82%), and *M. discolor* larvae (7.0%). However, *S. dichotomus* was present in the maize crops at this stage. A six-week-old maize plant had 10–12 leaves, and the last branch of the tassel was initiated. *M. discolor* adults exhibited the highest relative abundance at 33.1%, followed by *C. sexmaculata* adults (16.78%), *M. discolor* larvae (11.69%), *C. sexmaculata* larvae (11.37%), *H. octomacuata* larvae (10.44%), *S. dichotomus* (8.36%), and *H. octomaculata* adults (8.22%). The maize plant was seven-weeks old and displayed 10–12 leaves. The terminal branch of the tassel was visible but had not yet opened. At this stage, similar to the previous ones, *M. discolor* adults were found as the dominant species with the highest relative abundance (27.29%), followed by *C. sexmaculata* adults (18.06%), *M. discolor* larvae (13.4%), *C. sexmaculata* larvae (11.75%), *H. octomacuata* larvae (10.55%), *H. octomacuata* adults (9.93%), and *S. dichotomus* (8.98%).

By eight-weeks old, the maize crop reached the blooming stage, showcasing the highest abundance of predatory insects. *M. discolor* adults had the greatest relative abundance (30.15%), followed by *C. sexmaculata* adults (15.16%), *S. dichotomus* (11.79%), *M. discolor* larvae (11.73%), *C. sexmaculata* larvae (11.70%), *H. octomacuata* larvae (9.81%), and *H. octomacuata* adults (9.63%). The pod silk had slightly dried by the 9th week of the maize crop. *M. discolor* adult (27.36%) had the highest abundance, followed by *C. sexmaculata* adult (14.37%), *M. discolor* larva (14.34%), *S. dichotomus* (11.84%), *C. sexmaculata* larva (11.48%), *H. octomacuata* adult (10.8%), and *H. octomacuata* larva (9.77%). The 10th week of the maize crop is the ultimate growth and harvesting stage. As in all the previous stages, the highest abundance was observed in *M. discolor* adult (21.44%), *M. discolor* larva (16.1%), *C. sexmaculata* larva (14.68%), *H. octamaculata* adult (13.00%), *S. dichotomus* (11.63%) *H. octamaculata* larva (11.58%), and *C. sexmaculata* adult (11.53 %).

The result revealed *M. discolor* adult as the dominant predatory insect species in all the growth stages of the maize crop except 1st week because the predatory insects of *S. frugiperda* were not detected in the 1st week old maize crop. However, the predatory insect species composition was not drastically changed with the growth stages of the maize crop except for *S. dichotomus.* During the first four weeks, *S. dichotomus* was not observed in the maize plantation (Table 1). However, when the canopy height increased, *S. dichotomus* was found on the maize plants. That could be associated with the feeding behaviour of *S. dichotomus* because its feeding ground is the higher canopy level of the oil palm plantation and it attacks bagworms (*Metisa plana*) in oil palm plantations in Malaysia (Halil *et al.* 2021).

When considering the total number of predatory insects at various growth stages of the maize crop, the mean abundance of predatory insects significantly varied among these stages (F = 408.60; df = 9,290; p<0.001). The maize crop in the flowering stage (8-week old) displayed the highest mean abundance of predatory insects, which was 112.77 ± 1.63, followed by the 9th week (93.43 ± 1.86), 7th week (80.83 ± 2.22), 6th week (72.23 ± 1.74), 10th week (65.60 ± 1.63), 5th week (52.37 ± 1.73), 4th week (43.07 ± 2.16), 3rd week (33.90 ± 1.61), and 2nd week (23.87 ± 1.16). Previous researchers revealed that the highest insect abundance in maize plants occurs at the flowering stage (Sylvain *et al.* 2017). Ndiaye *et al.* (2023) also reported a similar phenomenon in their entomofauna study within the maize ecosystem. Their study noted the highest abundance and diversity of entomofauna associated with the transition from flowering to ear maturation. Similar phenomenon was observed with the highest abundance of predatory insects recorded during the maize plants' flowering stage to ear maturation (8th and 9th week) (Fig. 1).

The results indicate that the lowest abundance of predatory insects was detected in the first week up to the fifth week of the maize crop. These findings align closely with those reported by Ndiaye *et al.* (2023), who noted the lowest entomofauna diversity and abundance during the seedling to rising stage (immature stage) of the sweet corn field. The low abundance of predatory insects during this stage may indicate limited natural control of *S. frugiperda* (the pest) in the field, as pest abundance increased during this time (Fig. 1).

According to the data, 76.03% of *S. frugiperda* larvae were identified in maize plants that were one to six weeks old (approximately 42 days). This suggests that immature maize plants, particularly those under 40 days old, are

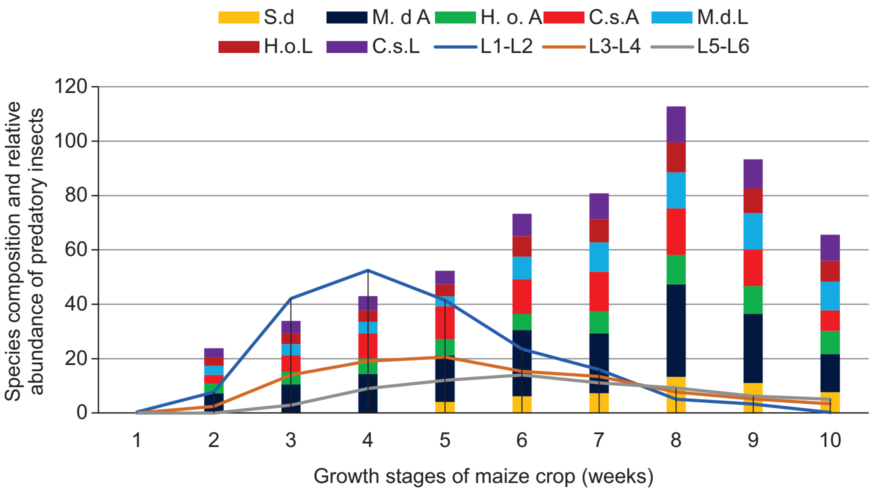

Fig. 1 The mean abundance of insect predators and *S. frugiperda* larvae with different growth stages of the maize crop.
S.d, *Sycanus dichotomus*; M.d.A, *Micraspis discolor* adult; H.o.A, *Harmonia octomaculata* adult; C.s.A, *Cheilomenus sexmaculata* adult; M.d.L, *Micraspis discolor* larva; H.o.L, *Harmonia octomaculata* larva; C.s.L, *Cheilomenus sexmaculata* larva.

extremely vulnerable to attacks by *S. frugiperda* larvae. In 2019, the Department of Agriculture (DOA) conducted an island-wide survey of conventional maize fields in Malaysia, making similar observations. However, after six week old maize crops, the mean abundance of coccinellids and *S. dichotomus* considerably increased. This clearly reflects the reduction of *S. frugiperda* abundance during this stage (Fig. 1).

Understanding pest dynamics and tri-trophic interactions throughout the cropping season can reduce infestation rates, yield losses, and unnecessary pesticide applications. Furthermore, the diversity and abundance of natural enemy populations during certain crop growth phases may help to conserve and enhance them over time (Durocher-Granger *et al.* 2021). Indiscriminate application of synthetic insecticides leads to pest resurgence, pesticide resistance, secondary pest outbreaks, and the decline of beneficial insect populations (Bakker *et al.* 2020). Farmers rely solely on insecticides, unaware of the existence of natural enemies. They lack an understanding of the population fluctuations of *S. frugiperda* and its natural predators. Consequently, they apply insecticides at any time during the crop cycle. Our results (Fig. 1) demonstrated a higher abundance of predatory natural enemies in the later stages of the crop cycle. If farmers apply insecticides during this latter part, it may adversely affect the natural enemy population.

Investigating the species-wise relative abundance of predatory insects at different growth stages of maize is crucial for understanding whether they are linked to the crop cycle's growth stages. The maize plant's growth during the first 1 to 4 weeks features a lower canopy level, making it difficult to observe *S. dichotomus* in maize plantations. However, it can be observed from the 5th week onward, up until the harvesting stage. The abundance of *S. dichotomus* adults varied significantly with the maize crop's growth stage (F = 130.83; df = 9,290; p<0.001). The highest mean abundance was recorded in the 8th week old maize plant at 13.3 ± 0.54, followed by the 9th week old plant (11.06 ± 0.63), the 10th week old plant (7.63 ± 0.62), the 7th week old plant (7.26 ± 0.58), the 6th week old plant (6.03 ± 0.43), and the 5th week old plant (4.10 ± 0.50) (Fig. 2).

This study revealed that *M. discolor* adults are more abundant than *H. octomaculata* and *C. sexmaculata* adults. The mean abundance of *M. discolor* adults also varied significantly with maize crop growth stage (F = 162.77; df = 9,290; p<0.001). The highest mean abundance was noted in the 8th week (flowering stage) of maize crops (34.0 ± 0.88), followed by the 9th week (25.56 ± 0.94), the 6th week (24.33 ± 0.87), the 7th week (22.06 ± 0.94), the 5th week (17.06 ± 0.87), the 4th week (14.36 ± 0.81), the 10th week (14.06 ± 0.68), the 3rd week (10.50 ± 0.65), and the 2nd week (7.26 ± 0.61). *M. discolor* adults were the most abundant predatory species across all growth stages of the maize crop (Fig. 2). The mean relative abundance of *H. octomaculata* adults varied significantly with maize crop growth stages (F = 31.0; df = 9,290; p<0.001). The 8th week of maize crops had the highest mean abundance (10.86 ± 0.42), followed by the 9th (10.10 ± 0.59), 10th (8.53 ± 0.61), 7th (8.03 ± 0.66), 5th (6.03 ± 0.73), 6th (5.93 ± 0.62), 4th (5.70 ± 0.70), 3rd (4.80

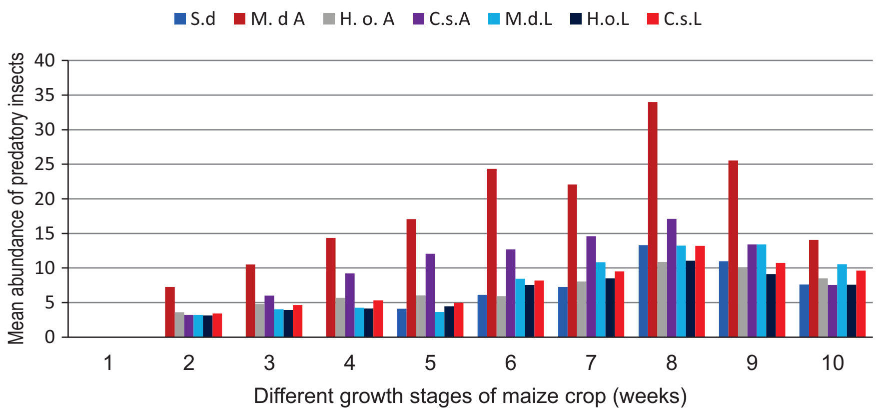

Fig. 2 Species-wise mean abundance of predatory insects at different growth stages of maize crop.
S.d, *Sycanus dichotomus*; M.d.A, *Micraspis discolor* adult; H.o.A, *Harmonia octomaculata* adult; C.s.A, *Cheilomenus sexmaculata* adult; M.d.L, *Micraspis discolor* larva; H.o.L, *Harmonia octomaculata* larva; C.s.L, *Cheilomenus sexmaculata* larva.

Table 1 Mean abundance of predatory insects at different growth stages of maize crop

Stage week	(Mean abundance ± Standard error)							Total
	S.d	M.d.A	H.o.A	C.s.A	M.d.L	H.o.L	C.s.L	
1	-	-	-	-	-	-	-	-
2	-	7.26 ± 0.61e	3.6 ± 0.45e	3.20 ± 0.40e	3.23 ± 0.42d	3.13 ± 0.39c	3.43 ± 0.46e	23.87 ± 1.16h
3	-	10.5 ± 0.65e	4.8 ± 0.58e	6.0 ± 0.70de	4.03 ± 0.52d	3.93 ± 0.43c	4.63 ± 0.35de	33.9 ± 1.61g
4	-	14.36 ± 0.81d	5.7 ± 0.70de	9.23 ± 0.68c	4.26 ± 0.45d	4.16 ± 0.38c	5.33 ± 0.37d	43.07 ± 2.16f
5	4.10 ± 0.50d	17.06 ± 0.87d	6.03 ± 0.73cde	12.06 ± 0.65b	3.66 ± 0.43d	4.46 ± 0.41c	4.96 ± 0.33de	52.37 ± 1.73e
6	6.13 ± 0.42c	24.33 ± 0.87bc	5.93 ± 0.62de	12.70 ± 0.69b	8.43 ± 0.57c	7.53 ± 0.51b	8.20 ± 0.45c	72.23 ± 1.74d
7	7.26 ± 0.58c	22.06 ± 0.94c	8.03 ± 0.66bcd	14.60 ± 0.70aba	10.83 ± 0.39b	8.53 ± 0.38b	9.50 ± 0.51bc	80.83 ± 2.22c
8	13.3 ± 0.54a	34.0 ± 0.88a	10.86 ± 0.42a	17.1 ± 0.72a	13.23 ± 0.58a	11.06 ± 0.45a	13.20 ± 0.51a	112.7 ± 1.63a
9	11.0 ± 0.63b	25.56 ± 0.94b	10.10 ± 0.59abb	13.43 ± 0.59b	13.40 ± 0.61a	9.13 ± 0.53b	10.73 ± 0.50b	93.43 ± 1.86b
10	7.63 ± 0.62c	14.06 ± 0.68d	8.53 ± 0.61abc	7.56 ± 0.73cd	10.56 ± 0.42b	7.60 ± 0.50b	9.63 ± 0.44bc	65.60 ± 1.63d

*Mean accompanied by the same letter is not significantly different. S.d, *Sycanus dichotomus*; M.d.A, *Micraspis discolor* adult; H.o.A, *Harmonia octomaculata* adult; C.s.A, *Cheilomenus sexmaculata* adult; M.d.L, *Micraspis discolor* larva; H.o.L; *Harmonia octomaculata* larva; C.s.L, *Cheilomenus sexmaculata* larva.

± 0.58), and 2nd (3.60 ± 0.45) (Table 1).

The mean abundance of *C. sexmaculata* adults varied significantly across maize crop growth stages (F = 73.69; df = 9,290; p<0.001). The eighth week of maize had the highest mean abundance (17.10 ± 0.72), followed by the seventh week (14.60 ± 0.70), ninth week (13.43 ± 0.59), sixth week (12.70 ± 0.69), fifth week (12.06 ± 0.65), fourth week (9.23 ± 0.68), tenth week (7.56 ± 0.73), third week (6.0 ± 0.70), and second week (3.2 ± 0.40) (Table 1). The mean abundance of *M. discolor* larvae was significantly different across various growth stages of maize (F = 99.22; df = 9,290; p<0.001). The highest mean abundance was recorded in the ninth week of maize (13.40 ± 0.61), followed by the eighth week (13.23 ± 0.58), seventh week (10.83 ± 0.39), tenth week (10.56 ± 0.42), sixth week (8.43 ± 0.57), fourth week (4.26 ± 0.45), third week (4.03 ± 0.52), fifth week (3.66 ± 0.43), and second week (3.23 ± 0.42) (Table 1). The mean abundance of *H. octomaculata* larvae varied considerably with maize crop growth stages (F = 61.62; df = 9,290; p<0.001). The eighth week of maize crops had the highest mean abundance (11.06 ± 0.45), followed by the ninth (9.13 ± 0.53), seventh (8.53 ± 0.38), tenth (7.60 ± 0.50), sixth (7.53 ± 0.51), fifth (4.46 ± 0.41), fourth (4.16 ± 0.38), third (3.93 ± 0.43), and second (3.13 ± 0.39) (Table 1). The mean abundance of *C. sexmaculata* larvae varied significantly with maize crop growth stages (F = 73.69; df = 9,290; p<0.001). The eighth week of maize crop had the highest abundance (17.10 ± 0.72), followed by the ninth week (14.60 ± 0.70), tenth week (13.43 ± 0.59), seventh week (12.70 ± 0.69), sixth week (12.06 ± 0.65), fourth week (9.23 ± 0.68), fifth week (7.56 ± 0.73), third week (6.0 ± 0.70), and second week (3.43 ± 0.46) (Table 1).

The highest mean abundance of predatory natural enemies can be observed after the 6th week of the maize crop throughout the sampling period (Fig. 1). This indicates that the maize growth stages affect the abundance of predatory natural enemies of *S. frugiperda.* The result revealed that the highest abundance of coccinellid adults and larvae was discovered in the flowering stage (eighth week) of the maize crop (Fig. 1). In this stage, the maize plants are full of pollen. Many predatory ladybird beetles rely on pollen as a major part of their diet (Giorgi *et al.* 2009, Lundgren 2009). When aphids and other prey arthropods are in short supply pollen has been identified as the most crucial food source for coccinellids (Lundgren 2009).

The maize blossoming stage contains the greatest richness and diversity of insects (Sylvain *et al.* 2017). Moreover, entomofauna diversity and abundance are relatively linked to the different development phases of the maize crop, with the lowest entomofauna diversity and abundance observed in the immature stages of the maize plant and the highest entomofauna diversity and abundance observed in mature maize plants (Ndiaye *et al.* 2023). A similar phenomenon can be observed in these results, indicating that the highest abundance of predatory insects was detected after the six-week-old maize plant. Most of the favourable parameters for these predatory insects correlate with the maturity of the maize crop as predicted by these results.

This study showed that the predatory species composition and abundance of *S. frugiperda* were closely related to the development stages of maize plants. However, the predatory insect composition did not drastically change with the growth stages except for *S. dichotomus,* but the abundance of predatory insects significantly varied with the development stages of maize, with the highest abundance detected in the mature plants and the lowest abundance detected in the immature stages of the maize crop. Hence, these findings reflect the population trend of predatory insects at different growth stages of the maize ecosystem.

ACKNOWLEDGEMENTS

The authors acknowledge the Kementerian Pengajian Tinggi for awarding the Malaysia International Scholarship (KPT.B(S) 700-4/2/1JLD.4 (84). We would like to express our gratitude to the staffs of the Department of Agriculture, Sungai Burung, Selangor, particularly Mrs. Nor Mah Binti Ahmad and Mr. Encik Adi Indralli Bin Hamsun, for providing the research facilities and resources. We would like to thank Prof. Christiane Weirauch and Dr. Michael Lee from the Department of Entomology, University of California, United States, for the verification of *S. dichotomus* identification. We also would like to thank Dr. Jeffrey Lim Seng Heng (Deputy Director, Programme of Biological Control) and staff members for their assistance in the verification of the identities of *H. octomaculata*, *C. sexmaculata*, and *M. discolor* using the repository specimen available at the Agrobiodiversity and Environment Research Centre MARDI, Malaysia. We are also grateful to Dr. Janakiraman Poorani, National Research Centre for Banana, Tamil Nadu, India, for the identification of *H. octomaculata* and *C. sexmaculata*.

REFERENCES

Abang A, Nanga S N, Fotso A K, Kuate A F, Kouebou C, Suh C, Masso C, Saethre M G and Fiaboe K K M. 2021. Natural Enemies of Fall armyworm *Spodoptera frugiperda* (Lepidoptera:Noctuidae). *Insects* **12**(6): 509. https://doi.org/10.3390/insects12060509

Abbas A, Ullah F, Hafeez M, Han X, Dara M, Gul H and Zhao C R. 2022. Biological Control of fall armyworm, *Spodoptera frugiperda*. *Agronomy* **12**(11): 2704. https://doi.org/10.3390/agronomy12112704

Adhikari K, Bhandari S, Dhakal L and Shrestha J. 2020. Fall armyworm (*Spodoptera frugiperda*): A threat in crop production in Africa and Asia. *Peruvian Journal of Agronomy* **4**(3): 121–33. https://doi.org/10.21704/pja.v4i3.1495

AgFlow. 2022. AgFlow from Malaysia aims to reduce corn import independency-AgFlow. https://www.agflow.com/agricultural-markets-news/malaysia-aims-to-reduce-corn-import-independency/

Assefa F and Ayalew D. 2019. Status and control measures of fall armyworm (*Spodoptera frugiperda*) infestations in maize fields in Ethiopia: A review. *Cogent Food and Agriculture* **5**(1): 1641902. https://doi.org/10.1080/23311932.2019.1641902

Bakker L, Van Der Werf W, Tittonell P, Wyckhuys K A and Bianchi F J. 2020. Neonicotinoids in global agriculture: Evidence for a new pesticide treadmill. *Ecology and Society* **25**(3): 26. https://doi.org/10.5751/ES-11814-250326

Bakry M M S and Abdel-Baky N F. 2023. Population density of the fall armyworm, *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) and its response to some ecological phenomena in maize crop. *Brazilian Journal of Biology* **83**: e271354. https://doi.org/10.1590/1519-6984.271354

Di N, Zhang K, Xu Q, Zhang F, Harwood J D, Wang S and Desneux N. 2021. Predatory ability of *Harmonia axyridis* (Coleoptera: Coccinellidae) and *Orius sauteri* (Hemiptera: Anthocoridae) for suppression of fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Insects* **12**(12): 1063. https://doi.org/10.3390/insects12121063

DOA. 2019. Report on new pest: Fall armyworm in Malaysia. Malaysia. https://www.ippc.int/static/media/files/pestreport/219/www.ippc.int/static/media/files/pestreport/

Durocher-Granger L, Mfune T, Musesha M, Lowry A, Reynolds K, Buddie A, Giovanni C, Offord L, Chipabika G, Dicke M and Kenis M. 2021. Factors influencing the occurrence of fall armyworm parasitoids in Zambia. *Journal of Pest Science* **94**(4): 1133–46. https://doi.org/10.1007/s10340-020-01320-9

Firake D M and Behere G T. 2020. Natural mortality of invasive fall armyworm, *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) in maize agro ecosystems of northeast India. *Biological Control* **148**: 104303. https://doi.org/10.1016/j.biocontrol.2020.104303

Giorgi J A, Vandenberg N J, McHugh J V, Forrester J A, Ślipiński S A, Miller K B, Shapiro L R and Whiting M F. 2009. The evolution of food preferences in Coccinellidae. *Biological Control* **51**(2): 215–31.

Halil M F M, Hussain M H, Nasir D M, Jalinas J, Yusop R M, Fauzi M, Muzamil M and Ghani I A. 2021. Predation efficiency and feeding preferences of laboratory-reared *Sycanus dichotomus* (Hemiptera: Reduviidae) on oil palm bagworm, *Metisa plana* (Lepidoptera: Psychidae). *Journal of Sustainability Science and Management* **16**(8): 81–90.

Hou Z R, Sun B B, Liu X J, Yin Z, Li J P and Guo X. 2020. Predatory functional response of assassin bug *Sycanus falleni* to the larvae of fall armyworm *Spodoptera frugiperda. Journal of Plant Protection* **47**(4): 852–58.

Hui L I, Jiang S S, Zhang H W, Ting G E N G and Wyckhuys K A. 2021. Two-way predation between immature stages of the hoverfly *Eupeodes corollae* and the invasive fall armyworm (*Spodoptera frugiperda* JE Smith). *Journal of Integrative Agriculture* **20**(3): 829–39. https://doi.org/10.1016/S2095-3119(20)63291-9

IPPC. 2019. Fall Armyworm *(Spodoptera frugiperda)* in Malaysia. https://www.ippc.int/en/countries/malaysia/pestreports/2019/11/fall-armyworm-spodoptera-frugiperda-control/

Jamil S Z, Saranum M M, Saleh Hudin L J and Anuar Wan Ali W K. 2021. First incidence of the invasive fall armyworm, *Spodoptera frugiperda* (JE Smith, 1797) attacking maize in Malaysia. *BioInvasions Record* **10**(1): 81–90. https://doi.org/10.3391/bir.2021.10.1.10

Kumar R M, Gadratagi B G, Paramesh V, Kumar P, Madivalar Y, Narayanappa N and Ullah F. 2022. Sustainable management of invasive fall armyworm, *Spodoptera frugiperda*. *Agronomy* **12**(9): 2150. https://doi.org/10.3390/agronomy12092150

Lundgren J G. 2009. Nutritional aspects of non-prey foods in the life histories of predaceous Coccinellidae. *Biological Control* **51**(2): 294–305. https://doi.org/10.1016/j.biocontrol.2009.05.016

Mohammed M A, Aman-Zuki A and Asrina W W Y. 2021. Report on an invasive pest, the fall armyworm *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) on maize cultivation in Bintulu, Sarawak. *Serangga* **26**(2): 97–106.

Molina-Ochoa J, Hamm J J, Lezama-Gutiérrez R, López-Edwards M, González-Ramírez M and Pescador-Rubio A. 2001. A survey of fall armyworm (Lepidoptera: Noctuidae) parasitoids in the Mexican states of Michoacán, Colima, Jalisco, and Tamaulipas. *Florida Entomologist* **84**: 31–36.

Ndiaye A, Mbow B, Diallo I, BA I, Faye M, Diome T, Brevault T and Sembene M. 2023. Inventory of the entomofauna associated with the cultivation of sweet corn in Senegal: Report of the fall armyworm *Spodoptera frugiperda*. *Journal of Entomology* *and Zoology Studies* **11**(3): 19–23. https://doi.org/10.22271/j.ento.2023.v11.i3a.9194

Sari W, Nelly N, Hidrayani and Yaheswandi. 2022. Natural enemies of *Spodoptera frugiperda* JE Smith (Lepidoptera: Noctuidae) on corn plants in West Sumatera. *(In) IOP Conference Series: Earth and Environment Science,* 2nd Agrifood system International Conference, Padang, Indonesia, November 08–09, Vol. **1160**(1): 012045.

Sharanabasappa D, Kalleshwaraswamy C M, Poorani J, Maruthi M S, Pavithra H B and Diraviam J. 2019. Natural enemies of *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae), a recent invasive pest on maize in South India. *Florida Entomologist* **102**(2): 619−23. https://doi.org/10.1653/024.102.0335

Singhamuni A, Azidah A A and Abdullah N A. 2025. Biology and predation of assassin bug (Sycanus dichotomus) on fall armyworm (Spodoptera frugiperda) larvae. *The Indian Journal of Agricultural Sciences* **95**(11): 1393–99. https://doi.org/10.56093/ijas.v95i11.155179

Sylvain T B C, Adamou U D M and Yao T A N O. 2017. Diversity and abundance of insect pests of corn (*Zea mays* Poaceae) grown in a rural environment in the city of MBahiakro (East Central Cte dIvoire). *Journal of Ecology and the Natural Environment* **9**(5): 77–86.

Tang Y T, Li Y Y, Liu C X, Mao J J, Chen H Y, Zhang L S and Zhang M Q. 2019. Predation and behavior of *Arma chinensis* (Fallou) to *Spodoptera frugiperda* (JE Smith). *Plant Protection* **45**(4): 65–68.

Wahab A G. 2017. *GAIN REPORT: Malaysia Grain and Feed Annual 2017*. USDA Foreign Agriculture Service, Washington, USA.

Zeng G, Zhi J R, Zhang C R, Zhang T, Ye J Q, Zhou L and Ye M. 2021. *Orius similis* (Hemiptera: Anthocoridae): A promising candidate predator of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Journal of Economic Entomology* **114**(2): 582–89. https://doi.org/10.1093/jee/toaa318