

Leaf beetle *Phyllotreta striolata* (Coleoptera: Chrysomelidae): Biology and infestation on Chinese flowering cabbage *Brassica rapa* var. *parachinensis* in Bogor, West Java, Indonesia

DIAN AGUNG SANORA LAIA¹, NINA MARYANA²*, I WAYAN WINASA²

¹Program Study of Entomology, Graduate School, Institut Pertanian Bogor. Jl. Kamper, Kampus Dramaga, Bogor 16680, West Java, Indonesia

²Department of Plant Protection, Faculty of Agriculture, Institut Pertanian Bogor. Jl. Kamper, Kampus Dramaga, Bogor 16680, West Java, Indonesia.
Tel.: +62-2518622642, *email: ninama@apps.ipb.ac.id

Manuscript received: 19 February 2024. Revision accepted: 15 July 2024.

Abstract. Laia DAS, Maryana N, Winasa IW. 2024. Leaf beetle *Phyllotreta striolata* (Coleoptera: Chrysomelidae): Biology and infestation on Chinese flowering cabbage *Brassica rapa* var. *parachinensis* in Bogor, West Java, Indonesia. *Biodiversitas* 25: 3099-3105. Chinese flowering cabbage (*Brassica rapa* var. *parachinensis* L.) holds significant economic value and provides essential nutrition. Bogor District, a primary region for vegetable production in Indonesia, faces a severe issue due to the leaf beetle *Phyllotreta striolata* Fabricius 1803 infestation on Chinese flowering cabbage plants. However, research on this pest in Indonesia is still limited. Observations on the biological aspects of *P. striolata* involved collecting and identifying adult *P. striolata* from Chinese flowering cabbage fields, along with biological observations focusing on the beetle's morphology and developmental stages. Population calculations of adult beetles and evaluation of *P. striolata* infestation intensity on Chinese flowering cabbage plants were conducted in four sub-districts in Bogor District. The average life cycle of this beetle was 27.15 days. The study revealed that the adult stage lasted an average of 119.10 days, with an average preoviposition period of 3.08 days. Adult populations tended to decrease with the age of Chinese flowering cabbage plants due to environmental factors and food source availability. Infestation intensity varied across locations, with Leuwimalang showing the lowest intensity (23.56%) and Laladon the highest (48.76%). These differences suggest that the environment in Leuwimalang may support the resistance of Chinese flowering cabbage plants to leaf pest attacks.

Keywords: Attack intensity, Bogor District, Brassicaceae, flea beetle, rearing

INTRODUCTION

The Chinese flowering cabbage, *Brassica rapa* var. *parachinensis* L., originates from the Brassicaceae family and is a vegetable commodity widely cultivated by farmers, boasting high economic value. This vegetable is famous for its delicious taste and rich nutritional content, including vitamin C, carotenoids, dietary fiber, minerals, glucosinolates, phenolic acids, and flavonoids. The demand for Chinese flowering cabbage continues to rise in tandem with the increasing human population and growing awareness of its health benefits (Wang et al. 2022). Its advantages are its sweet taste, suitability for culinary preparations and high nutritional (Telaumbanua et al. 2016). Bogor District, one of Indonesia's crucial areas for vegetable production, includes Chinese flowering cabbage. According to BPS (2019), the harvested area of cabbage vegetables in Bogor District, covering each district and various Brassicaceae plant types, reached 767 hectares, experiencing an increase compared to previous years. However, vegetable farming, particularly Chinese flowering cabbage, faces significant challenges due to the severe flea beetle *Phyllotreta striolata* Fabricius 1803 infestation. This issue causes disruptions for local farmers and the agricultural sector.

The *P. striolata* originates from Eurasia and has been documented in the Afrotropical, Oriental, Palearctic, and

Nearctic regions up to the present (Gikonyo et al. 2019). The *P. striolata* is frequently found in Asia, Europe, and North America (Cao et al. 2017; Atirach et al. 2021). The *P. striolata* is widely distributed in the northern and western regions of the United States and is gradually spreading throughout the continent (Soroka et al. 2018); it has emerged as a significant pest affecting brassica crops across Southeast Asia (Pipithsangchan et al. 2001). This pest, also known as the flea beetle of cabbage plants, is recognized for its preference for plants within the *Brassica* genus, including Chinese flowering cabbage. This beetle is considered oligophagous, primarily attacking plants belonging to the Brassicaceae family and causing damage at both the larval and adult stages. The *P. striolata* infests cruciferous plants such as brussels sprouts, canola, cabbage, cauliflower, wasabi, kale, mustard, turnip, white radish, and watercress across its distribution range (Raghunandan et al. 2023). The striped flea beetle is a serious pest of cruciferous crops, including cabbages, broccoli, and radish (Beran et al. 2016).

The life cycle of *P. striolata* comprises four stages: egg, larva, pupa (underground), and adult (aboveground) (Chen et al. 2023). The infestation of *P. striolata* on Chinese flowering cabbage induces symptoms characterized by the emergence of small pores or tiny holes on the leaves, accompanied by necrosis. This beetle chewing of numerous tiny holes in leaves may damage seedlings or larger crop

plants, impair crop growth, render the crop unmarketable, or kill small plants outright (Capinera 2020). Adult beetles feed on leaves, reducing the plant's photosynthetic efficiency and the quality of vegetables (Brockman et al. 2020). Subsequently, they lay eggs in the nearby soil. These eggs soon hatch into larvae, which then damage the roots. The larvae feed plant roots, inhibiting the absorption and transport of nutrients through the roots, thereby impacting plant growth and ultimately causing plant death (Chen et al. 2022). The lifespan of larvae and adult beetles ranges from 26 to 33 days or 17 to 55 days, creating significantly overlapping generations (Nagalingam and Costamagna 2019). Adult *P. striolata* are black with two yellow stripes on their elytra and are about 1.5-2.5 mm long (Knodel 2017).

In Indonesia, there is a need for more information regarding the significance of *P. striolata* infestations in Chinese flowering cabbage cultivation. Therefore, research on the characteristics of the *P. striolata* beetle is essential, and one method is observing its various biological aspects (Price et al. 2011). Studying the biology and infestations of *P. striolata* on Chinese flowering cabbage is expected to provide valuable insights into this pest's characteristics. This information can be a foundation for establishing early detection techniques and recommending integrated pest management strategies.

MATERIALS AND METHODS

The research was conducted from March 2022 to March 2023. Insects and larvae were sampled in Cinangneng Village, Tenjolaya Sub-district, Bogor District, West Java, Indonesia. Pest infestation area and intensity were calculated in four sub-districts: Cisarua, Tenjolaya, Cibungbulang, and Ciomas in Bogor District. Insect rearing was performed at the Insect Biosystematics Laboratory, Department of Plant Protection, Faculty of Agriculture, Institut Pertanian Bogor, Bogor District.

Mass rearing of *P. striolata*

Adult *P. striolata* were obtained from Chinese flowering cabbage crops in Cinangneng Village, Bogor District. The propagation process was conducted in insect cages measuring 40×40×40 cm, with plastic and organza fabric walls. Inside the cages were two-week-old Chinese flowering cabbage plants planted in polybags. Host plants were placed inside the insect cages as a food source throughout the propagation process. Insects and host plants were regularly monitored and observed, and sample collection was carried out according to the research needs. This method allowed for acquiring a sufficient population of *P. striolata* for further research.

Biology of *P. striolata*

Observations of beetle biology were conducted in two distinct phases: observation during the pre-adult phase and observation during the adult phase. Biological aspects under scrutiny included the life cycle, the number of larval instars, stages of each developmental phase, adult lifespan,

and the preoviposition period. Additionally, morphological characteristics and behavior during each developmental stage were also observed. The length and width measurements at each developmental stage were conducted using a Leica M205C digital microscope paired with a Leica DFC 450 digital camera and LAS.V.4.4.0 (Build: 454) software connected to a computer. The measured parts were the longest and widest sections for eggs, pupae, and adults. In the case of larval body length, measurements were taken from the tip of the head to the end of the last abdominal segment.

Number of larval instars and developmental stages

This observation involved 5 pairs of *P. striolata* adults ready for mating. These 5 pairs were placed in transparent plastic cages with a diameter of 8 cm and a height of 23 cm, each within containers containing young Chinese flowering cabbage plants. The temperature and humidity were maintained within the 20-25°C range to support optimal conditions during the observation. Eggs found on Chinese flowering cabbage plants were collected and transferred to radish slices. Subsequently, the radish slices were placed in Petri dishes and covered with black polybags. Observations on the eggs were conducted every hour using a binocular microscope on the radish slices, aiming to monitor egg development until reaching the first instar larva stage. Radish served as a food source during the developmental phase, ensuring the creation of a suitable environment.

The life cycle, adult lifespan, and preoviposition period

Observations on the life cycle were conducted simultaneously with the observation of developmental stages. The observations started from the discovery of eggs on infested Chinese flowering cabbage until the emergence of adults laying eggs again. Therefore, to observe the adult lifespan beetles newly emerged from pupae and were collected and placed in transparent plastic cages. Each beetle was given several stems of fresh Chinese flowering cabbage, which were replaced daily, and observations continued until the beetles died. Preoviposition observations were conducted daily, concurrent with the observation of the adult lifespan. Subsequently, observations were carried out using a binocular microscope to determine the preoviposition period.

Population and infestation intensity of adult *P. striolata*

The *P. striolata* adult populations were collected using a sweep net on 5 plots within each field. Each plot was observed by performing 10 double sweeps. Subsequently, the count of *P. striolata* adult populations caught in the net was recorded. Population was collected on Chinese flowering cabbage plants two Weeks After Planting (WAP), 4 WAP, and 6 WAP. The assessment of infestation levels involved observation of the damage by *P. striolata* on Chinese flowering cabbage plants at 4 WAP in four districts in Bogor District. The observation method for infestation intensity included using the bio leaf foliar analysis application to analyze and monitor the plant leaf conditions. This application can estimate the percentage of leaf damage related to the total leaf area using images taken

through the camera or retrieved from the photo gallery. The scale values for assessing the intensity of the attack are based on the percentage of affected plants (Table 1). The measurement of damage intensity is calculated using the formula:

$$IS = \frac{\sum(n_i \times v_i)}{N \times Z} \times 100\%$$

Where:

IS : Pest attack intensity (%)

n_i : Number of leaves attacked by pests

v_i : Magnitude of the attack scale

Z : Highest scale value from the specified attack category

N : Number of observed plant leaves

Determination of plots and sample plants

Observations on the *P. striolata* adult population and infestation intensity were conducted in four districts: Cisarua, Tenjolaya, Cibungbulang, and Ciomas in Bogor District, West Java. Each district comprised two observed villages: Cinangneng (CNG), Tapos II (TPS), Sukamaju (SKJ), Cijujung (CJG), Laladon (LLD), Sukamakmur (SKM), Tugu Selatan (TGS), and Leuwimalang (LWM). In each village, one land plot was observed, measuring 8 x 10 m. A systematic sampling technique was employed for sample collection by determining 4 sample plots at the outermost points of the diagonal lines and one sample plot at the intersection of the diagonal lines. Each sample plot had dimensions of 1 m². Specifically for infestation intensity observation, in each sample plot, 25 plants were observed. Furthermore, 5 leaves were selected from each plant and examined to obtain data on infestation intensity.

Data analysis

Observational data on *P. striolata* biology are descriptive methods. Calculations were performed using Microsoft Excel 2019 software to analyze this biological data. The calculated results were then presented in tables and graphs, visually representing the population and infestation intensity of *P. striolata* in Chinese flowering cabbage crops.

RESULTS AND DISCUSSION

Pre-adult *P. striolata*

Pre-adult *P. striolata* undergoes a life cycle consisting of two phases: the pre-adult phase (egg-larva-pupa) and the

adult phase; the larvae and pupae develop within the Chinese flowering cabbage plants. The eggs of *P. striolata* have an average size of 0.41×0.20 mm, are yellow and oval, and transform into a cloudy white color (Figure 1.A). Mature eggs are ready to hatch (Figure 1.B) and exhibit a whitish-yellow hue with black spots indicating the development of eyes. Newly hatched instar one larvae have a C shape and actively move to break out of the eggshell. These scarab-shaped larvae are cylindrical and white and feature well-developed mandibles and three pairs of thoracic legs (Figure 2). The larval phase can damage Chinese flowering cabbage plant roots, leading to severe wilting and even plant death. Newly formed instar 1st larvae are transparent and fragile, turning shades from gray to dark brown. Additionally, instar 2nd larvae are white with dark brown heads. Before pupation, instar 3rd larvae cease feeding, becoming shorter and thicker. During the pupal phase, they exhibit a white color and an exarate type, showcasing visible antennae, mouthparts, wings, and legs (Figure 3). The tips of the mandibles are dark red, and the black eyes have a length ranging from 0.70 to 1.90 mm (Table 2).

Table 1. Scale values for each attack category

| Scale values | Percentage of leaf damage (%) | Damage category |
|--------------|-------------------------------|------------------|
| 0 | 0 | No damage |
| 1 | 0 < X ≤ 25 | Slight |
| 2 | 25 < X ≤ 50 | Moderate |
| 3 | 50 < X ≤ 75 | Severe |
| 4 | 75 < X ≤ 100 | Extremely severe |

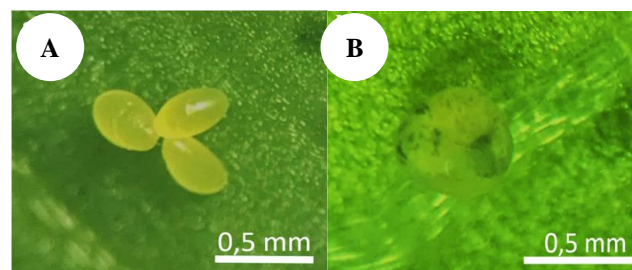


Figure 1. Eggs of *P. striolata*: A. Newly laid eggs; B. Eggs ready to hatch

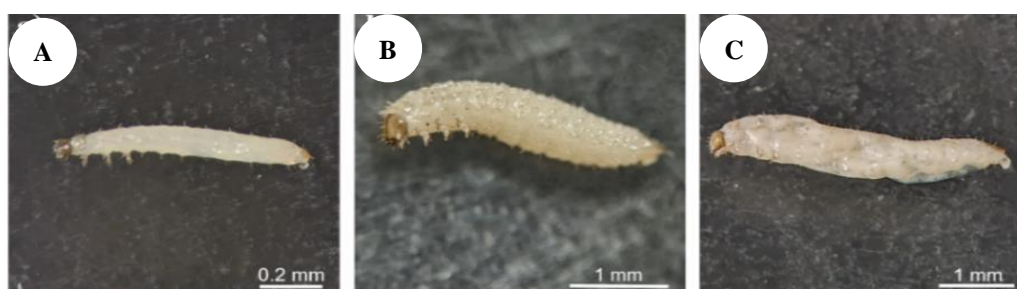


Figure 2. Larvae of *Phyllotreta striolata*: A. Instar 1 larva; B. Instar 2 larva; C. Instar 3 larva

Table 2. The average size of immature stages *P. striolata*

| Developmental stage | Stage (days) | Length (mm) | Width (mm) |
|---------------------|--------------|------------------|------------------|
| Eggs | 4.57 | 0.41 (0.39-0.42) | 0.20 (0.20-0.21) |
| First-instar larva | 5.00 | 1.05 (0.96-1.18) | 0.22 (0.20-0.30) |
| Second-instar larva | 3.40 | 2.10 (2.00-2.19) | 0.49 (0.46-0.54) |
| Third-instar larva | 4.57 | 3.75 (3.06-4.11) | 0.63 (0.60-0.69) |
| Pupae | 6.53 | 1.80 (0.70-1.90) | 0.81 (0.78-0.85) |

Notes: The numbers in parentheses are the minimum and maximum sizes

The pre-adult development period is relatively short compared to the lifespan of the adult. The laboratory's pre-adult stage of *P. striolata* lasts 27.15 days (Table 1). The development of the egg, from laying to the emergence of the first instar larva, takes between 3 to 6 days, with an average duration of 4.57 days. Next, the development of the larva from the first instar to becoming a pupa takes an average of 12.97 days. The pupal stage is the longest in the pre-adult developmental cycle of *P. striolata*, lasting an average of 6.53 days. Overall, the life cycle of *P. striolata*, from egg laying to the adult insect ready to lay eggs again, takes about 27.15 days.

Adult *P. striolata*

Adult males of *P. striolata* have an average length of 2.97 mm and a width of 1.59 mm, while the female averages 3.51 mm in length and 1.71 mm in width. The average lifespan of the adult is 119.10 days (Table 3). Observations indicate an average pre-oviposition period of 3.08 days. The antenna structure of *P. striolata* consists of 11 segments with the first three segments (1-2-3) prominently displaying a light brown color at the top. In contrast, a black color dominates segments 4 through 11. Significant morphological differences were observed between male and female imago, particularly in the antenna structure. The fifth antenna segment appears swollen in males, whereas, in females, it appears slenderer. The elytra of *P. striolata* are black with a yellow pattern forming longitudinal spots on each part, without reaching the tip or side of the elytra (Figure 4). The legs are overall brown, with dark brown femurs and light brown tibiae. The hind femur is enlarged, while the hind tibia is straight or slightly curved without spines at the tip. The aedeagus of *P. striolata* is approximately 0.80 mm long. Additionally, while observed from the top, the aedeagus has a pattern resembling a porous surface with a curved and pointed tip (Figure 5). This aligns with the description provided by Smith (1985).

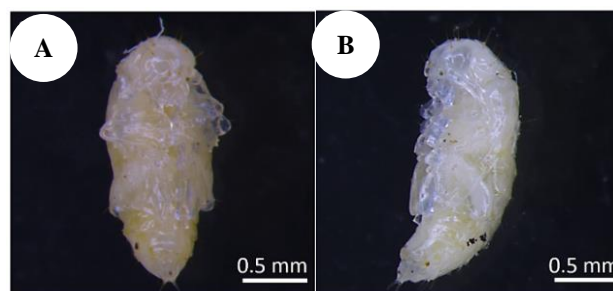
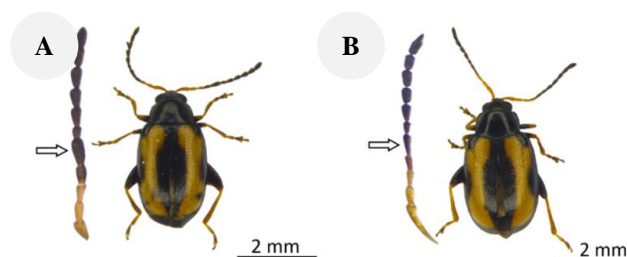
Population of adult *P. striolata*

The population of *P. striolata* on Chinese flowering cabbage declined during the study. Initially, Cinangneng had the highest population (45 insects at 2 WAP) but decreased to 11 at 6 WAP. Tapos II also experienced a decline, from 40 insects at 2 WAP to 14 insects at 6 WAP (Figure 6). This research indicates that the population of *P. striolata* tends to decrease with the aging of Chinese flowering cabbage. Presumably, these changes are caused by environmental shifts and variations in food sources at different growth stages.

Table 3. Average adult size, lifespan, and pre-oviposition period

| Observation | Male | Female |
|------------------------|------------------|------------------|
| Length (mm) | 2.97 (2.82-3.19) | 3.51 (3.32-3.70) |
| Width (mm) | 1.59 (1.54-1.66) | 1.71 (1.62-1.79) |
| Pre-oviposition (days) | | 3.08 |
| Lifespan (days) | 119.10 | |

Notes: The numbers in parentheses are the minimum and maximum sizes

**Figure 3.** Pupa of *Phyllotreta striolata*: A. Ventral view of the pupa; B. Lateral view of the pupa**Figure 4.** Adult of *Phyllotreta striolata*: A. Male; B. Female**Figure 5.** Male aedeagus

Symptoms and attack intensity

The observations of *P. striolata* attacks on Chinese flowering cabbage revealed the symptoms manifested include the presence of perforation or small holes on the leaf surface, accompanied by necrosis (Figure 7). This damage can lead to a complete harvest loss or permanently stunted plant growth, reducing overall yield. The intensity of *P. striolata* attacks on Chinese flowering cabbage varies across multiple observation locations (Table 4). The average data for attack intensity, expressed as a percentage, reveals differences among these locations. Leuwimalang has the lowest attack intensity at 23.56%, categorized as slight damage. Meanwhile, Laladon exhibits the highest attack intensity at 48.76%, classified as moderate damage. This indicates that Leuwimalang possesses properties or characteristics that make Chinese flowering cabbage more resistant to leaf pest attacks. The research suggests that the intensity of *P. striolata* attacks on Chinese flowering cabbage is related to the population density. It also indicates that differences in environmental characteristics at observation locations play a role in determining the vulnerability of Chinese flowering cabbage to leaf pest attacks. These differences are likely due to various environmental factors at each location, such as soil conditions, temperature, humidity, or farming practices.

Discussion

Morphological research on the leaf beetle *P. striolata* becomes crucial as it provides a deeper understanding of the morphological differences with similar insects found in observation locations. Smith (1985) asserted that *P. bipustulata* Fabricius 1801 is often misidentified as *P. striolata* due to substantial similarities in some physical characteristics, especially in the line patterns on the elytra and antenna morphology. The *P. striolata* has one line on the front wings that fades into a pale mark after the initial part and before the wing tip (Klimaszewski et al. 2020). However, in *P. bipustulata*, the pale mark on the front wings before the tip has a straight edge following the wing's margin, not bending inward at its wing tip, as seen in *P. striolata*. In addition to wing differences, there are also distinctions in the antennae. In *P. bipustulata*, the fifth segment on its antenna is simple and almost equal in length

to the sixth segment. In contrast, in *P. striolata*, in males, the fifth segment on its antenna is more significant and approximately twice as long as the sixth segment. The aedeagus in *P. striolata* has the closest resemblance to the aedeagus in other species, such as *P. decipiens* Horn 1889, *P. bipustulata*, *P. conjuncta* Gentner 1924, *P. dolichophalla* E. Smith 1985, *P. ramosa* Crotch 1874, and *P. ramosoides* (Smith 1985). Despite these similarities, the apex or tip of the aedeagus in *P. striolata* has specific differences that distinguish it from other species. The aedeagus is straight, with a pointed apex, strongly and ventrally curved, middle of the dorsal surface with short, transverse, and parallel grooves from the apex of the tectum to the apex of the basal piece (Anooj et al. 2020).

Table 4. Average adult size, lifespan, and pre-oviposition period

| Districts | Villages | Attack intensity (%) |
|--------------|--------------|----------------------|
| Cibungbulang | Sukamaju | 31.60 |
| | Cijujung | 32.60 |
| Tenjolaya | Cinangneng | 29.36 |
| | Tapos II | 27.08 |
| Ciomas | Laladon | 48.76 |
| | Sukamakmur | 47.08 |
| Cisarua | Tugu Selatan | 24.36 |
| | Leuwimalang | 23.56 |

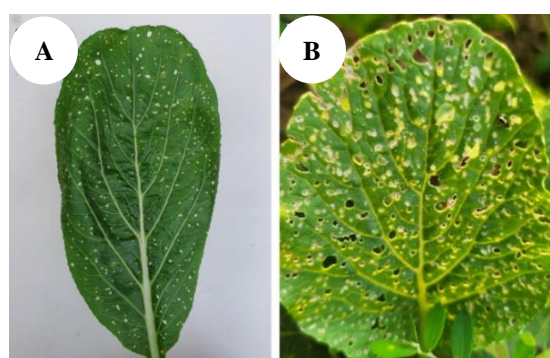


Figure 7. Symptoms of *P. striolata* attack on Chinese flowering cabbage leaves: A. Attack intensity 13.50%; B. Attack intensity 80.10%

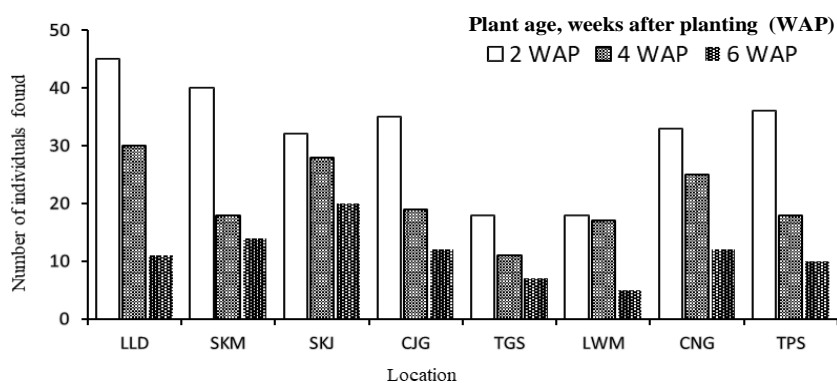


Figure 6. The population of *Phyllotreta striolata* in each village in Bogor District, West Java, Indonesia. Notes: LLD: Laladon; SKM: Sukamakmur; SKJ: Sukamaju; CIG: Cijujung; TGS: Tugu Selatan; LWM: Leuwimalang; CNG: Cinangneng; TPS: Tapos II

A more profound understanding of the life cycle of *P. striolata* and the influencing factors holds crucial implications in pest management. Knowing that the life cycle of *P. striolata* has an average duration of 27.15 days ensures that these insects can undergo several generations during a single mustard plant growth period; this directly impacts the harvest yield and the quality of Chinese flowering cabbage. Research by Rather et al. (2017) notes that *P. striolata* exhibits a multivoltine life cycle in the Kashmir region, where generations emerging after winter appear during the last two weeks of March and remain active until the end of October. This beetle can achieve one to two generations annually in North America (Olfert et al. 2018). In-depth knowledge of the biology and life cycle of *P. striolata* would significantly aid in designing the most effective control strategies and determining the optimal timing for pest control measures. Timely information regarding the developmental stage of invasive species across their range can inform pest management decisions, including early detection, eradication, and suppression efforts, or management to slow the spread of a species (Crimmins et al. 2020).

Research describing the population dynamics of *P. striolata* on Chinese flowering cabbage provides a clear picture of how this insect population changes with the development of the plants. Data analysis indicates a decrease in the number of insects from the beginning to the end of the study. This decline is presumed to be influenced by environmental changes and shifts in food sources at various stages of growth. Environmental factors such as stem hardening and specific nutrient requirements like Nitrogen (N) are also believed to impact the insect population. Plant volatile compounds have a crucial role in the coevolution between plants and herbivorous insects (Pérez-Hedo et al. 2021; Sun et al. 2022). Herbivorous insects have evolved with sophisticated adaptations triggered by plant volatile compounds to support their nutritional functions and reproduction (Clavijo et al. 2014). The environmental conditions and the availability of food resources changes become vital factors to consider in understanding the dynamics of insect populations in Chinese flowering cabbage.

Observations of *P. striolata* attacks on Chinese flowering cabbage depict symptoms that are pretty serious and detrimental. These beetles target all plant stages and extend their impact up to harvest. In severe infestations, leaves may develop holes or yellow spots that subsequently dry up. The damage to plants by this beetle can escalate rapidly and result in the total loss of crops if not promptly controlled (Sekulic and Rempel 2016). Control tactics are often needed to prevent economic damage from these pests (Mason et al. 2020). Chemical pesticides are often used to control *P. striolata*, but certain population groups have shown decreased sensitivity to common insecticides, such as neonicotinoids (Shen et al. 2021). Therefore, limited knowledge of the resistance mechanisms in *P. striolata* can lead to decreased pesticide effectiveness and increased reliance on chemicals. Therefore, Tengfei et al. (2022) recommend using seed coating containing Spinetoram to control pests on Chinese flowering cabbage. Chen et al.

(2023) have successfully demonstrated that seed coating with *Metarhizium anisopliae* (Metschn.) Sorokin conidia effectively controls larvae and protects Chinese flowering cabbage seedlings. Therefore, obtaining genetic information regarding important insecticide targets for *P. striolata* would be highly beneficial. Using phenological models for timing control actions to coincide with the peak susceptibility of the target organism optimizes effectiveness by taking advantage of susceptible life stages, reducing chemical use, saving time and money, and minimizing effects on non-target species (Murray 2020). Gultom et al. (2014) emphasize the importance of a strong understanding of pest population dynamics, their natural enemies, and their connection to plant phenology for effective pest control. Various strategies can be considered to control the population of *P. striolata* and its impact on Chinese flowering cabbage; companion planting to control *P. striolata* infestations is one approach. Another strategy is implementing a crop rotation system, where other plants replace Chinese flowering cabbage in the planting cycle, which can disrupt the insect's life cycle and reduce pest populations. Strategies to prevent damage by *P. striolata* can be implemented by scheduling seed planting during periods of low pest activity. In managing *P. striolata* control, the primary approach involves early monitoring of damage and implementing measures such as row covers, trap crops, and mulch. The use of insecticide sprays based on economic thresholds also led to the possibility of using alternative spray biopesticides, such as nematodes or entomopathogenic fungi, to control *Phyllotreta* pests (Reddy et al. 2014; Antwi and Reddy 2016; Briar et al. 2018). Monitoring and managing weeds and potential host plants around Chinese flowering cabbage fields can also effectively reduce resources and shelter for *P. striolata*.

REFERENCES

- Anooj SS, Raghavendra KV, Shashank PR, Nithya C, Sardana HR, Vaibhav V. 2020. An emerging pest of radish, striped flea beetle *Phyllotreta striolata* (Fabricius), from Northern India: Incidence, diagnosis and molecular analysis. *Phytoparasitica* 48 (5): 743-753. DOI: 10.1007/s12600-020-00825-4.
- Antwi FB, Reddy GVP. 2016. Efficacy of entomopathogenic nematodes and sprayable polymer gel against crucifer flea beetle (Coleoptera: Chrysomelidae) on Canola. *J Econ Entomol* 109 (4): 1706-1712. DOI: 10.1093/jee/tow140.
- Atirach N, Sirirut M, Lewis EE. 2021. Biological control potential of entomopathogenic nematodes against the striped flea beetle, *Phyllotreta sinuata* Stephens (Coleoptera: Chrysomelidae) *Crop Prot* 141 (1): 105448. DOI: 10.1016/j.cropro.2020.105448.
- Badan Pusat Statistik (BPS). 2019. Luas Panen Tanaman Sayuran Menurut Kabupaten/Kota (Hektar). Central Bureau of Statistics. <https://jabar.bps.go.id/site/resultTab>. [Indonesian]
- Beran F, Alemán JHG, Lin MY, Hsu YC, Mewis I, Srinivasan R, Ulrichs C, Boland W, Hansson BS, Reinecke A. 2016. The aggregation pheromone of *Phyllotreta striolata* (Coleoptera: Chrysomelidae) revisited. *J Chem Ecol* 42 (8): 748-755. DOI: 10.1007/s10886-016-0743-6.
- Briar SS, Antwi F, Shrestha G, Sharma A, Reddy GVP. 2018. Potential biopesticides for managing crucifer flea beetle, *Phyllotreta cruciferae* (Coleoptera: Chrysomelidae) under dryland canola production in Montana. *Phytoparasitica* 46 (2): 247-254. DOI: 10.1007/s12600-018-0645-y.
- Brockman R, Kuesel R, Archer K, O'Hearn K, Wilson N, Scott D, Williams M, Bessin R, Gonthier D. 2020. The impact of plant

- essential oils and fine mesh row covers on flea beetle (Chrysomelidae) management in brassicaceous greens production. *Insects* 11 (10): 1-16. DOI: 10.3390/insects11100714.
- Cao LJ, Wang ZH, Gong YJ, Zhu L, Hoffmann AA, Wei SJ. 2017. Low genetic diversity but strong population structure reflects multiple introductions of western flower thrips (Thysanoptera: Thripidae) into China followed by human-mediated spread. *Evol Appl* 10 (4): 391-401. DOI: 10.1111/eva.12461.
- Capinera JL. 2020. Handbook of Vegetable Pests, 2nd ed. Academic Press, San Diego.
- Chen D, Yan R, Xu Z, Qian J, Yu Y, Zhu S, Wu H, Zhu G, Chen M. 2022. Silencing of *dre4* contributes to mortality of *Phyllotreta striolata*. *Insects* 13 (11): 1072. DOI: 10.3390/insects13111072.
- Chen W, Yuan W, He R, Pu X, Hu Q, Weng Q. 2023. Screening of fungal strains and formulations of *Metarhizium anisopliae* to control *Phyllotreta striolata* in Chinese Flowering Cabbage. *Insects* 14 (6): 567. DOI: 10.3390/insects14060567.
- Clavijo MA, Gershenson J, Unsicker SB. 2014. Little peaks with big effects: establishing the role of minor plant volatiles in plant-insect interactions. *Plant Cell Environ* 37 (8): 1836-1844. DOI: 10.1111/pce.12357.
- Crimmins TM, Gerst KL, Huerta DG, Marsh RL, Posthumus EE, Rosemartin AH, Switzer J, Weltzin JF, Coop L, Dietschler N, Herms DA, Limbu S, Trotter RT, Whitmore M, Macaluso K. 2020. Short-term forecasts of insect phenology inform pest management. *Ann Entomol Soc Am* 113 (2): 139-148. DOI: 10.1093/aesa/saz026.
- Gikonyo MW, Biondi M, Beran F. 2019. Adaptation of flea beetles to brassicaceae: host plant associations and geographic distribution of *Psylliodes Latreille* and *Phyllotreta Chevrolat* (Coleoptera, Chrysomelidae). *Zookeys* 2019 (856): 51-73. DOI: 10.3897/zookeys.856.33724.
- Gultom RM, Pangestiningih Y, Lubis L. 2014. Pengaruh beberapa insektisida terhadap hama *Lamprosema indicata* F. dan *Spodoptera litura* F. pada tanaman kedelai (*Glycine max* (L) MERRIL Jurnal Agroekoteknologi Universitas Sumatera Utara 2 (3): 100087. DOI: 10.32734/jaet.v2i3.7505. [Indonesian]
- Klimaszewski J, Hoebeke ER, Langor DW, Douglas HB, Borowiec L, Hammond HEJ, Davies A, Bourdon C, Savard K. 2020. Synopsis of adventive species of *Coleoptera* (Insecta) recorded from Canada. Part 5: Chrysomeloidea (Cerambycidae, Chrysomelidae, and Megalopodidae). Pensoft, Moscow. DOI: 10.3897/ab.e50613.
- Knodel JJ. 2017. Flea beetles (*Phyllotreta* spp.) and their management. In: Reddy GVP (eds). Integrated Management of Insect Pests on Canola and Other Brassica Oilseed Crops. CABI International, North Dakota.
- Mason J, Michael Alford A, Patrick Kuhar T, Munyaneza J. 2020. Flea beetle (Coleoptera: Chrysomelidae) populations, effects of feeding injury, and efficacy of insecticide treatments on eggplant and cabbage in Southwest Virginia. *J Econ Entomol* 113 (2): 887-895. DOI: 10.1093/jee/toz355.
- Murray MS. 2020. Using Degree Days to Time Treatments for Insect Pests. <https://extension.usu.edu/pests/research/degree-days>.
- Nagalingam T, Costamagna AC. 2019. Two methods for rearing the striped flea beetle *Phyllotreta striolata* (Coleoptera: Chrysomelidae) under laboratory conditions. *Can Entomol* 151 (5): 677-683. DOI: 10.4039/tce.2019.44.
- Olfert O, Weiss RM, Soroka JJ, Elliott RH. 2018. Bioclimatic approach to assessing factors influencing shifts in geographic distribution and relative abundance of two flea beetle species (Coleoptera: Chrysomelidae) in North America. *Can Entomol* 150 (1): 66-79. DOI: 10.4039/tce.2017.51.
- Pérez-Hedo M, Alonso-Valiente M, Vacas S, Gallego C, Rambla JL, Navarro-Llopis V, Granell A, Urbaneja A. 2021. Eliciting tomato plant defenses by exposure to herbivore induced plant volatiles. *Entomol Gen* 41 (3): 209-218. DOI: 10.1127/entomologia/2021/1196.
- Pipithsangchan S, Sritungnan S, Choto S. 2001. On-farm comparisons between Bio-insecticides and Synthetic Insecticides in Vegetable Production Hat Yai, Thailand. ACIAR, Canberra.
- Price PW, Denno RF, Eubanks MD, Finke DL, Kaplan I. 2011. *Insect Ecology*. Cambridge University, New York. DOI: 10.1017/CBO9780511975387.
- Ragunandan NV, Anooj SS, Prathapan KD. 2023. The striped flea beetle *Phyllotreta striolata* (Illiger) (Coleoptera: Chrysomelidae) invades South India. *Indian J Entomol* 13 (1): 1-2. DOI: 10.55446/ije.2023.1584.
- Rather BA, Hussain B, Mir GM. 2017. Seasonal incidence and biodiversity of flea beetles (Coleoptera, Alticinae) in a Brassicaceous vegetable agro-ecosystem of Kashmir Valley. *Am Entomol Soc* 127 (3): 252-268. DOI: 10.3157/021.127.0308.
- Reddy GVP, Tangtrakulwanich K, Wu S, Miller JH, Ophus VL, Prewett J. 2014. Sustainable management tactics for control of *Phyllotreta cruciferae* (Coleoptera: Chrysomelidae) on canola in Montana. *Crop Prot* 66: 8-13. DOI: 10.1016/j.cropro.2014.08.013.
- Sekulic G, Rempel CB. 2016. Evaluating the role of seed treatments in canola/oilseed rape production: Integrated pest management, pollinator health, and biodiversity. *Plants* 5 (3): 1570-1578. DOI: 10.3390/plants5030032.
- Shen GM, Ou SY, He C, Liu J, He L. 2021. Full length sequencing reveals novel transcripts of detoxification genes along with related alternative splicing events and lncRNAs in *Phyllotreta striolata*. *PLoS One* 16 (3): 1-17. DOI: 10.1371/journal.pone.0248749.
- Smith EH. 1985. Revision of the genus *Phyllotreta* Chevrolat of America North of Mexico Part I. The Maculate Species (Coleoptera: Chrysomelidae, Alticinae). Field Museum of Natural History, Atlanta. DOI: 10.5962/bhl.title.3408.
- Soroka J, Grenkow L, Otani J, Gavloski J, Olfert O. 2018. Flea beetle (Coleoptera: Chrysomelidae) species in canola (Brassicaceae) on the northern great plains of North America. *Can Entomol* 150 (1): 100-115. DOI: 10.4039/tce.2017.60.
- Sun X, Sun Y, Ma L, Liu Z, Zhang C, Huang W, Siemann E, Ding J. 2022. Linking aboveground and belowground interactions via herbivore-induced plant volatiles. *Entomol Gen* 42 (3): 421-429. DOI: 10.1127/entomologia/2022/1344.
- Telaumbanua M, Purwantana B, Sutiarsa L, Falah MAF. 2016. Studi pola pertumbuhan tanaman sawi (*Brassica rapa* var. *parachinensis* L.) hidroponik di dalam greenhouse terkontrol. *Agritech* 36 (1): 104-105. DOI: 10.22146/agritech.10690. [Indonesian]
- Tengfei X, Nanda S, Fengliang J, Qingsheng L, Xia F. 2022. Control efficiency and mechanism of spinetoram seed-pelleting against the striped flea beetle *Phyllotreta striolata*. *Sci Rep* 12 (1): 1-13. DOI: 10.1038/s41598-022-13325-8.
- Wang G, Peng M, Wang Y, Chen Z, Zhu S. 2022. Preharvest hydrogen peroxide treatment delays leaf senescence of chinese flowering cabbage during storage by reducing water loss and activating antioxidant defense system. *Front Plant Sci* 13 (2): 2-5. DOI: 10.3389/fpls.2022.856646.