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BIONOMICS OF THE LEAF FEEDER, *Pogonopygia nigralbata* Warren, DAMAGING *Illicium verum* TREES IN BAC KAN PROVINCE, VIETNAM

Nguyen Van Thanh[1], Le Van Binh[1], La Thi Bich Ngoc[2]

[1]Forest Protection Research Centre, Vietnamese Academy of Forest Sciences
[2]Northwestern University, Vietnam

ABSTRACT

Illicium verum is a non-timber forest product, which is widely cultivated in Vietnam. A leaf-feeder, *Pogonopygia nigralbata* Warren is a moth (Lepidoptera: Geometridae: Ennominae), has caused significant damage to plantations of this plant species in Bac Kan province. Field surveys in 2023 found *P. nigralbata* damage to *I. verum* in the districts of Cho Moi and Bach Thong, with a damage incidence (P%) ranging from 33.7% to 69.5% and an average damage index (DI) from 0.75 to 1.72. The life cycle spans 69 - 96 days, with overwintering occurring in the larval stage. Females lay 60 - 97 eggs during an oviposition period of 9 - 13 days. The larval and pupal stages last 32 - 46 days and 23 - 30 days, respectively. Adults survive for 12 - 23 days, with a longevity of 4 - 6 days. This pest should be researched in detail and included in future forest health monitoring programs in Bac Kan to determine its suitable mangement approaches.

Keywords: *Pogonopygia nigralbata*, *Illicium verum*, star anise, morphology, identification, pest, symptom, life cycle

MỘT SỐ ĐẶC ĐIỂM SINH HỌC CỦA LOÀI SÂU ĐO ĂN LÁ *Pogonopygia nigralbata* Warren (Lepidoptera: Geometridae: Ennominae) GÂY HẠI CÂY HỒI TẠI TỈNH BẮC KẠN

Nguyễn Văn Thành[1], Lê Văn Bình[1], Lã Thị Bích Ngọc[2]

[1]Trung tâm Nghiên cứu Bảo vệ rừng, Viện Khoa học Lâm nghiệp Việt Nam
[2]Trường Đại học Tây Bắc

TÓM TẮT

Cây Hồi (*Illicium verum*) là một loại lâm sản ngoài gỗ có giá trị kinh tế cao nên được gây trồng rộng rãi tại nhiều tỉnh của Việt Nam. Loài sâu đo hoa, *Pogonopygia nigralbata* Warren (Geometridae: Ennominae) được ghi nhận đã gây hại nghiêm trọng cho rừng trồng loài cây này tại tỉnh Bắc Kạn. Kết quả điều tra năm 2023 tại huyện Chợ Mới và Bạch Thông cho thấy tỷ lệ bị hại (P%) dao động từ 33,7% - 69,5% và chỉ số bị hại trung bình (DI) từ 0,75 - 1,72. Vòng đời của loài sâu ăn lá này từ 69 - 96 ngày, với giai đoạn qua đông xảy ra ở pha sâu non. Trưởng thành cái đẻ từ 60 - 97 trứng, trong khoảng thời gian từ 9 - 13 ngày. Giai đoạn sâu non và nhộng lần lượt kéo dài từ 32 - 46 ngày và từ 23 - 30 ngày. Sâu trưởng thành sống từ 12 - 23 ngày, với tuổi thọ từ 4 - 6 ngày. Loài sâu hại này cần được nghiên cứu đầy đủ và xem xét đưa vào các chương trình giám sát và đánh giá sức khỏe rừng trồng trong tương lai tại tỉnh Bắc Kạn để đề xuất các phương pháp quản lý phù hợp và hiệu quả.

Từ khóa: Cây Hồi, *Illicium verum*, Sâu đo hoa, *Pogonopygia nigralbata*, hình thái, giám định, triệu chứng, vòng đời

I. INTRODUCTION

The genus *Illicium* comprises 40 species originating from tropical regions, mainly Southeast Asia, the southeastern United States, the Caribbean, and parts of Mexico. Five species of *Illicium* are widely distributed globally, including *I. anisatum*, *I. arborescens*, *I. henryi*, *I. lanceolatum*, and *I. verum*. Most of these species thrive in high mountainous areas within the broadleaf forests of humid tropical rainforests. This genus provides substantial culinary, medicinal, ecological, ornamental, and economic benefits, making it a valuable group of plants with diverse applications. However, various species of insects and diseases have been reported to be serious pests of these *Illicium* species. Notable pests include *Dyscerus hylobioides* and *Andromeda stephanitis* in *I. anisatum* (Inoue *et al.*, 1997; Perley Spaulding, 1989; Williams & Wilkins, 2009), *Pseudodoniella* sp. in *I. verum*, *Aulacophora femoralis* in *I. arborescens* (Perley Spaulding, 1989), *Agrotis ipsilon* in *I. henryi* (Manuel, 2004), *Oides leucomelaena* and *Dilophodes elegans sincica* in *I. verum* (Manuel, 2004).

Illicium verum is an aromatic evergreen tree native to Southeast Asia. Its fruits, known as star anise, are widely used in Chinese and Vietnamese dishes (Wang *et al.*, 2011). Apart from its culinary applications, star anise is valued for its medicinal properties in traditional herbal remedies across various countries, including China, Japan, Indonesia, Malaysia, Mexico, Cuba, and the United States. It is believed to alleviate symptoms such as vomiting, stomach aches, insomnia, skin inflammation, and rheumatic pain (Wang *et al.*, 2011). Additionally, the essential oil extracted from star anise is traditionally employed to treat rheumatism (Freire *et al.*, 2011). Many principal constituents of star anise have been isolated and tested for fumigant toxicity and repellency against insect pests and diseases (Zhou *et al.*, 2016; Matos *et al.*, 2020), promising potential application to the field of plant protection.

Due to the rapid and widespread expansion of *I. verum* plantation areas in China and Vietnam, this tree species has been facing significant damage from insect pests and disease infestations. For example, *Pseudodoniella* sp. feeds on fruits and branch tips of its host, resulting in the premature drop of flowers and fruits as well as wilting branches (Yuelan *et al.*, 2004). Additionally, Zhao (2009) identified 10 insect pests and diseases infesting *I. verum* trees in China. Because of high commercial values, the Vietnamese government has encouraged planting of these two tree species in economic afforestation in Northern provinces of Vietnam, including Bac Kan. The total estimated area of *I. verum* plantations in the province in 2021 was 3,576 hectares. A previous study has reported a list of 43 species of insect pests on *I. verum* trees in Bac Kan province (Quang *et al.*, 2022). *Pogonopygia nigralbata* was considered among the most dangerous pests and their widespread is a concern to producers (Quang *et al.*, 2022).

I. verum plantations in Bac Kan province have been attacked heavily by the *Pogonopygia nigralbata* leaf-feeders in recent years. However, little is known about its morphological identification and biological characteristics. The primary objectives of this study were to (i) provide the morphological description of developmental phases, (ii) quantify the extent of the damage, and (iii) determine its life cycle. This information is expected to assist local households and government authorities in pest surveillance and

in suitable management plan development for this serious pest.

II. MATERIALS AND METHODS

2.1. Study sites and insect collection

Field observations were conducted in 2023 and 2024 in *I. verum* plantations of 14 - 25 - year - old trees exhibiting *Pogonopygia nigralbata* foliage damage in Cho Moi and Bac Thong districts of Bac Kan province. Laboratory studies of larvae were carried out at the Forest Protection Research Centre (FPRC) of the Vietnamese Academy of Forest Sciences in Hanoi, Vietnam.

The infested *I. verum* plantations ranged from 15 to 35 hectares, with typical tree densities of 1,800 trees per hectare. Two age groups of trees were selected for the study of foliage damage across 10 plots in each district. Each plot, measuring 500 m^2, was randomly located within the plantations. Foliage damage caused by *P. nigralbata* larvae was recorded on 90 trees per plot, with tree heights ranging from 120 to 150 cm. The last instar larvae of *P. nigralbata* were reared on their host leaves until adults emerged. Samples of *P. nigralbata* leaf-feeders obtained as pupae from infested *I. verum* trees were separated into petri dishes (9 × 1.5 cm) and taken to the FPRC's laboratory, where they were maintained at 25°C (± 2°C) temperature, 65% (± 5%) relative humidity, and a 12-hour photoperiod until adult emergence.

2.2. Morphological characterization

The species were initially identified based on the external morphological characteristics of 35 adult specimens (17 males and 18 females) using the keys provided by Warren (1894). Measurements of the immature stages (102 eggs, 67 larvae, and 91 pupae) were conducted with a Leica M165C stereozoom microscope (Leica Microsystem, Wetzlar, Germany) equipped with a micrometric scale. The head capsule width of larvae was measured as the largest distance between the genae, while the body length was measured from the frons to the last abdominal segment. For pupal width, the maximum width of the fourth abdominal segment was used. Means and standard errors were calculated for the measurements of these specimens. Adult voucher specimens were placed in the insect collection of the FPRC.

2.3. Damage assessment

Two field surveys for damage assessment were conducted in Cho Moi and Bach Thong during the specimen collection period. Thirty infested *I. verum* trees were used to describe the damage diagnostics. Five temporary plots, each measuring 1,000 m² (25 × 40 m), were established at each site. The canopies of 30 randomly selected host trees in each plot were assessed using binoculars. Damage was classified into five levels: 0 = no damage; 1 = leaf area loss < 25%; 2 = leaf area loss 25 to < 50%; 3 = leaf area loss 50 to < 75%; 4 = leaf area loss ≥ 75%.

From the damage assessment results, the damage incidence (P%) was calculated using equation 1 (McMaugh, 2005):

$$P\% = (n/N) \times 100 \quad (1)$$

Where: n is the number of trees defoliated by *P. nigralbata*; N is the total number of trees evaluated.

The average damage index (DI) in each plot was calculated using equation 2 (Nguyen and Dao, 2004):

$$DI = (\Sigma n_i \times v_i)/N \quad (2)$$

Where: n_i is the number of defoliated trees at damage index i;

v_i is the damage index at level i;

N is the total number of trees evaluated.

The damage severity level was categorized based on the average damage index as follows: DI = 0, no damage; 0 < DI ≤ 1, slight damage; 1

< DI ≤ 2, medium damage; 2 < DI ≤ 3, severe damage; 3 < DI ≤ 4, very severe damage.

Data analysis was carried out using Microsoft Office Excel software.

2.4. Observation of life cycle

In the laboratory, once *P. nigralbata* male and female adults emerged from the pupae, they were maintained in small, screened net cages of standard size (60 × 40 × 40 cm). Newly emerged adults were kept in these rearing cages for 1 - 2 days, with honeybee solution provided as food. After mating and oviposition, eggs were collected on tissue paper and transferred to petri dishes (9 × 1.5 cm) kept in acclimatized chambers at 25^{o}C (± 2^{o}C) and 65% (± 5%) humidity. Newly hatched larvae were then reared individually in the laboratory using fresh leaves of *Illicium verum* trees, and maintained until they reached the adult stage again. The branches with leaves were placed in a 0.5 L glass bottle filled with water and changed weekly to prevent the leaves from drying out. Biological observations were made on the duration of each developmental stage from egg to adult, including the total lifespan in the laboratory, as well as seasonally in the field.

III. RESULTS

3.1. Identification and characterization

Based on the external morphological description of adults, eggs, larvae and pupae, *Pogonopygia nigralbata* Warren (1894) infesting *Illicium verum* trees in Cho Moi and Bac Thong districts, Bac Kan provinces included the following characteristics:

Adults (Fig. 1): Grayish white, prominently marked with numerous black spots on the wings; body length 22.5 ± 0.1 mm, forewing length 63.4 ± 0.2 mm, hindwing length is 45.8 ± 0.3 mm. Antennae are thread-like, compound eyes are yellow brown. Thorax features many black spots, surrounded by yellow-orange hair. Abdomens have parallel rows of black spots, with the rest of body being grayish white. Forewings have evenly distributed black spots, with a higher concentration along the outer edges, while hindwings have black spots concentrated at the edges and white near the base, legs grayish white.

Eggs (Fig. 1): Grayish brown, oval; Eggs are laid on the underside of leaves, not in clusters but scattered; Each female lays 60 - 70 eggs.

Larvae (Fig. 1): Blackish gray; Head yellow-brown and thorax is covered with numerous black spots; Body has 5 pairs of legs, with the first 3 pairs being yellow-brown and the last 2 pairs being grayish brown; Body length ranges from 6.5 - 28.6 mm, and width ranges from 1.8 - 6.7 mm. The larvae of *P. nigralbata* passed through five instars:

1st larval instar ranges from 6.5 - 14.7 mm in length and 1.8 mm - 2.4 mm in width.

2nd larval instar ranges from 14.5 - 20.8 mm in length and 2.5 - 3.4 mm in width.

3rd larval instar ranges from 21.2 - 24.9 mm in length and 3.3 - 4.8 mm in width.

4th larval instar ranges from 24.8 - 27.2 mm in length and 4.6 - 5.4 mm in width.

5th larval instar ranges from 26.8 - 29.6 mm in length and 5.4 - 6.2 mm in width.

Pre-pupae (Fig. 1): Light gray; 22.4 - 25.2 mm in length, and 4.3 - 5.1 mm in width, with distinct segmentation.

Pupae (Fig. 1): Brown, 21.3 - 23.4 mm in length, 4.5 - 5.0 mm in width; Head is larger, and abdomen tapers gradually to the tail; Abdomen consists of 5 segments, and the tail has a spine.

Figure 1. Morphological characteristics of *Pogonopygia nigralbata*:
1. Adult; 2. Egg; 3. 1st larva; 4. 2nd larva; 5. 3rd larva; 6. 4th larva; 7. 5th larva; 8. Pre-pupa; 9. Pupa

3.2. *Pogonopygia nigralbata* damage in *Illicium verum* plantations

Pogonopygia nigralbata was found exclusively on *I. verum* trees in plantation forests (Fig. 4). The larvae of *P. nigralbata* consume the entire leaf blade, starting from the edges and moving toward the central vein, and from the leaf apex down to the petiole. Severe infestations sometime caused complete defoliation, and consequently host trees died.

Figure 2. Damage symptoms of *Pogonopygia nigralbata* in *Illicium verum* foliage in Bac Kan province

The damage incidence (P%) and damage index (DI) of *P. nigralbata* infestation in *I. verum* plantations in Cho Moi and Bach Thong ranged from 44.2% to 57.5% and 1.68% to 2.15%, respectively. The greatest P% and DI were observed in Cho Moi (57.5% and 2.15) were higher than those observed in Bach Thong (Table 1).

Table 1. Damage incidence and average damage index of *Pogonopygia nigralbata* in *Illicium verum* plantations in Bac Kan province

District	14 - 19-year-old plantations		20 - 25-year-old plantations	
	P%	DI	P%	DI
Cho Moi	51.1 ± 1.23	2.03 ± 0.05	57.5 ± 1.08	2.15 ± 0.46
Bach Thong	44.2 ± 1.12	1.68 ± 0.14	46.2 ± 1.22	1.72 ± 0.22

Note: P% is damage incidence (%), DI is mean damage index. Values are mean ± SE (n = 3)

3.3. Biological Characteristics

The life cycle of *P. nigralbata* spans 69 - 96 days, with overwintering occurring during the larval stage in stem crevices of infested *I. verum* trees and under soil or shrubs. Females lay 60 - 97 eggs during an oviposition period of 9 - 13 days. It takes 10 - 14 days for eggs to hatch (mean 11.85 ± 0.37 days). The larval and pupal periods take 32 - 46 days (mean 38.60 ± 0.80 days) and 23 - 30 days (23.42 ± 0.42 days), respectively. Adult longevity under laboratory conditions is 4 - 6 days (mean 4.98 ± 0.33 days) (Table 2).

Adult moths begin laying eggs once mated 12 - 24 hours after emergence from the pupa. Eggs are deposited singly on the crevies of bark of the *I. verum* trees. Newly hatched larvae mainly feed on the young leaves of host trees.

Table 2. Life stages of *Pogonopygia nigralbata* in *Illicium verum* under laboratory conditions at temperature of 25°C ± 2°C and relative humidity of 65 ± 5%

Developmental stage	Time (day)	Average (day)
Adult	4 - 6	4.98 ± 0.33
Egg	10 - 14	11.85 ± 0.37
Larva	32 - 46	38.60 ± 0.80
Pupa	23 - 30	23.42 ± 0.42
Total	**69 - 96**	**78.85**

The developmental timetable of *P. nigralbata* over a period of 5 months (from January 2023 to May 2023) initially recorded the appearance of 2 generations per year. The first generation started from the end of February to the beginning of March, and the second generation started from the beginning of April to the end of April 2023. Based on the life cycle characteristics of *P. nigralbata* and the number of generations per year, the investigation schedules of each generation were determined to be carried out four times, one time at each stage: egg, larva, pupa, and adult. As the main activities of the pest are concentrated from January to May, this period was used in the integrated pest management.

Table 3. Life cycles and emergence times of *Pogonopygia nigralbata* in study sites in Vietnam

Generation	Month																																			
	1			2			3			4			5			6			7			8			9			10			11			12		
I	P	P	P	P	P	P	P	P																												
							A	A	A																											
								E	E	E	E																									
										L	L	L	L	L																						
II													P	P	P	0																				
															A	A	A	A																		
																		E	E	E	E															
																				L	L	L	L	L												
III (next year)																								P	P	P	P									
																										A	A	L								
																												P	P	P	P	E	E	E	E	
																																A	A	L	L	L

Note: L, larva; P, pupa; A, adult; E, egg

IV. DISCUSSION

In this study, the herbivorous insect causing defoliating of *Illicium verum* plantations in Vietnam was identified as *Pogonopygia nigralbata*. This marks the first morphological description of *P. nigralbata* in Bac Kan province. Previous records include sightings in Myanmar (Spitsyn *et al.*, 2017), Malaysia (Aris *et al.*, 2017; Khen, 2010; Lödl, 1993), Japan (Inoue, 1963; Sibatanp, 1954), Taiwan (TFRI, 2012), and China (https://www.funet.fi/).

Research on the biological characteristics of *P. nigralbata*, which affects agricultural and forestry trees, is still ongoing. This study is the first to document the life cycle of this pest on *I. verum* trees and plantations in Vietnam. Typically, larvae consume the entire leaf blade, starting at the edges and moving toward the central vein, progressing from the leaf apex to the petiole. This feeding behavior can result in complete defoliation and subsequent mortality of the host trees. The larvae create silk cocoons and pupate in the soil or under trunk hollows. Immature leaves are more vulnerable to these leaf-feeders than mature leaves. *P. nigralbata* moths lay their eggs on the underside of leaves, and the young larvae then move around the tree to find suitable leaves for feeding. Our study revealed that *P. nigralbata* requires 69 - 96 days to complete a life cycle on *I. verum* trees and produces two generations per year in Northern Vietnam.

In the past few decades, *I. verum* trees were found in natural forests in the northern mountains of Vietnam in general and specifically in Bac Kan province, where local people freely accessed the natural forests to collect *I. verum* fruits. Recently, as the fruits of this plant species have become more popular due to high sale prices, this plant species has been grown in economic plantations in Bac Kan and has become one of the main multi-purpose trees for improving the livelihood of rural and local communities. The presence of *P. nigralbata* across two districts of the province poses a significant risk to people's livelihoods. The first symptoms of *P. nigralbata* damage were observed in Bac Kan in 2020, and since then, the pest has become a serious problem for

commercial plantations. It is unclear whether it is an exotic pest or *P. nigralbata* spread into nearby plantations from wild populations. Further studies are needed to determine the dispersal origin of this leaf-feeder epidemic in Bac Kan. The provincial government of Bac Kan has encouraged the development of large-scale plantations of *I. verum* for a long period. It is possible that this expansion plan increases the likelihood of this pest outbreak. If damage from *P. nigralbata* poses a risk to reforestation, it is essential to study the management of this pest to mitigate damage for growers. However, there have been no studies on the control of *P. nigralbata* pest in Vietnam or other countries. Future research is needed to develop effective and appropriate management solutions for *P. nigralbata*.

In summary, this is the first report on the bionomics of *P. nigralbata* caterpillars feeding on *I. verum* trees in plantations in Bac Kan province. Given the commercial importance of this non-timber forest product in Vietnam, this species should now be included in national monitoring programs for forest pests to determine its pest status.

Climate change and global warming are often cited as key factors behind the widespread outbreaks of numerous forest insect pests globally, including in Vietnam. However, in this study, we did not observe any significant impact of weather variables on the damage level caused by these pests on *I. verum* trees. This indicates a need for further research to fully understand this phenomenon. Interestingly, the relationship between host tree ages and damage incidence has been documented in several forest insect pests in Vietnam. For instance, *Orientozeuzera rhabdota* affects *Manglietia conifera* and *Michelia mediocris* (Chi *et al.*, 2023), *Cryptophlebia ombrodelta* impacts *Erythrophleum fordii* (*Chi et al.*, 2023), and *Zeuzera multistrigata* targets *Eucalyptus* hybrids (Chi *et al.*, 2022), *Bacchisa medioviolacea* in *Docynia indica* (Quang *et al.*, 2022). These studies highlight a significant variation in pest damage across different tree ages, with young plantations suffering more severe damage than older ones. Contrary to these findings, our study did not observe this age-related trend in *I. verum* plantations. This suggests that multiple age plantations of *I. verum* in Bac Kan and other star anise-growing provinces in Vietnam might experience similar pest damage levels, regardless of tree age.

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Email tác giả liên hệ: nguyenthanhvfu52@gmail.com
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