BIODIVERSITAS
Volume 26, Number 10, October 2025
Pages: 5118-5124

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d261026

Helopeltis theivora dynamics and damage on cocoa clones under agronomic management in West Sumatra, Indonesia

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Manuscript received: 10 August 2025. Revision accepted: 12 October 2025.

Abstract. *Busniah M, Efendi S, Trizelia, Hermanda S. 2025.* Helopeltis theivora *dynamics and damage on cocoa clones under agronomic management in West Sumatra, Indonesia. Biodiversitas 26: 5118-5124.* This study analyzed the comparative resistance of cocoa clones to *Helopeltis theivora* in two types of cocoa plantations in West Sumatra, Indonesia. The comparison was made between plantations intensively managed by CV Scorpio and small plantations, focusing on two main clones, ICS 60 and TSH 858. The results showed that cocoa cultivation practices in intensive and smallholder cocoa plantations affected the abundance, percentage, and intensity of damage caused by *H. theivora*. The population and damage levels of *H. theivora* were higher in smallholder cocoa plantations than in intensive plantations. The type of clone cultivated also affects the abundance and damage level of *H. theivora* on cocoa plants. ICS 60 clone showed resistance to *H. theivora* compared to TSH 858 clone. Only the resistance of these clones to *H. theivora* was affected by cocoa cultivation practices. The resistance of these clones decreased in cocoa plantations that were not intensively managed. Secondary branches were the location of the highest damage intensity, and *H. theivora* showed a preference for attacking pods measuring 7-15 cm on ICS 60 and >15 cm on TSH 858. This study clearly shows that intensive cultivation practices play an important role in controlling the population of the pest *H. theivora*. The choice of cocoa clones is also a determining factor. The ICS 60 clone is more resistant to *H. theivora*. However, genetic resistance in cocoa clones is not absolute. Synergy between the selection of appropriate clones and good cultivation practices is the key to successful control of *H. theivora*.

Keywords: Integrated Pest Management (IPM), Miridae, monoculture, *Phytophthora palmivora, Sahlbergella singularis*

INTRODUCTION

West Sumatra has great potential to become the center of cocoa production in western Indonesia. Its strategic geographical position, supported by suitable agroclimatic conditions, makes it an ideal location for cocoa development. West Sumatra has also developed into a vital source of cocoa seeds, playing an important role in providing high-quality planting material for plantations in Sumatra. One of the seed sources is the CV Scorpio cocoa plantation. The plantation not only manages ordinary cocoa plantations but is also specifically designated as a source of seeds for superior cocoa clones, particularly ICS 60 and TSH 858. The clones are known to have good agronomic characteristics, such as high yield potential and resistance to pests or diseases. With the existence of source plantations, the supply of high-quality seeds can be maintained, which in turn will support the improvement of national cocoa productivity and quality, especially in western Indonesia. These efforts face several obstacles, one of which is disease and pest infestation.

Cocoa plants are susceptible to various pests and diseases that reduce yields and are one of the biggest concerns related to cocoa production (Kongor et al. 2024). *Distantiella theobroma* and *Sahlbergella singularis* are common pests in West African countries, while *Monalonion* spp. are common in the Americas. Cocoa shield bugs (*Bathycoelia thalassina*) are another economically significant pest in West Africa, while *Helopeltis* spp. are common in Southeast Asia, including Indonesia (Kongor et al. 2024). *Helopeltis* spp. consists of 40 species belonging to the Miridae family that cause damage to cocoa. Several species of *Helopeltis* spp. reported to attack cocoa are *Helopeltis theivora* and *H. bakeri* (Thube et al. 2022). *Helopeltis bakeri* (Hemiptera: Miridae) is the main insect pest of cocoa in the Philippines, especially in Luzon (Tavera et al. 2023). *Helopeltis theivora* and *H. bradyi* (Hemiptera: Miridae) are widely reported to infest cocoa plants in Indonesia (Buchory et al. 2024). Resulting in significant economic losses of 30% to 40% (Mahob et al. 2020).

Helopeltis spp. infests cocoa pods at all stages, especially young pods (cherelles) and those approaching maturity (Bakar 2020). The stilet puncture causes necrotic lesions, the fruit becomes stunted, dries up, or even falls prematurely (Vanhove et al. 2019). If the fruit continues to develop, its skin can harden and crack, inhibiting the seeds' development (Ikhsan et al. 2024). In addition to cocoa pods, *Helopeltis* spp. also infests shoots and young twigs (Audrey et al. 2018). Infestation of these parts can cause shoot dieback and disrupt vegetative growth, which ultimately affects flower and pods formation in the following season (Vano et al. 2020). Punctures from *Helopeltis* spp. can provide entry points for other pathogens, such as the fungi *Phytophthora palmivora*, *Lasiodiplodia theobromae*, *Fusarium decemcellulare*, *Aspergillus*, and *Rhizoctonia*, which further exacerbate the damage. The level of damage depends on the cocoa variety and region. Insect pests have been identified as infesting various parts of the cocoa tree and its pods, resulting in economic losses (Oyenpemi et al. 2023).

The presence of *Helopeltis* spp. not only threatens the productivity of existing plantations, but it also has profound implications for efforts to procure high-quality seedlings. The existence of seed source gardens such as CV Scorpio in Lima Puluh Kota, West Sumatra, which are located close to other cocoa plantations, is highly relevant in this context. The cultivation practices applied in CV Scorpio's seed source garden are fundamentally different from those of smallholder plantations in the surrounding area. These differences include sanitation, pruning patterns, plant nutrition programs, and Integrated Pest Management (IPM) strategies that may be more intensive. The abundance and damage levels of *Helopeltis* spp. was not related to the cocoa cropping system, but mainly depended on farmers' cultivation practices (Mahob et al. 2020). Therefore, studying the population and infestation levels of *Helopeltis* spp. in both types of plantations is very important. However, information on the response of *Helopeltis* spp. to clones ICS 60 and TSH 858 has not been reported in cocoa plantations in West Sumatra or even in Indonesia. This study aimed to investigate the population and infestation of *H. theivora* on cocoa clones ICS 60 and TSH 858 in the seed source plantation of CV Scorpio and smallholder plantations. It also analyzed the factors affecting the population and infestation of *H. theivora.*

MATERIALS AND METHODS

Study area, determining the site and sample plants

Observations were conducted at the CV Scorpio cocoa plantation and smallholder cocoa plantations around the CV Scorpio cocoa plantation in Jorong Gando, Piobang, Payakumbuh Sub-district, Lima Puluh Kota District, West Sumatra, Indonesia (-0.212306, 100.572423). Each type of cocoa plantation consists of 6 plots. The area of each cocoa plantation plot was 1 hectare with 500 trees. Each clone consists of three plots of cocoa plantation. The age of cocoa plants in each clone was four years. At each location, 10% of the cocoa trees were selected as sample plants. Sample plants are determined systematically. Each sample plant was observed. The observation parameters were the percentage of infested plants, population density, percentage of infested fruit, and intensity of infestation. Observations were conducted over three months. The temperature at each location tends to be the same, namely 20-21°C, with humidity at 96-97%.

Observation of infested plants and pods

The percentage of infested plants was observed by counting all sample plants infested and not infested by *H. theivora* Infestation is characterized by symptoms of *H. theivora* on the pods. The percentage of pods infested is also differentiated based on pod location and size. The location of the pods is divided into four places, namely on the main stem, primary branches, secondary branches, and tertiary branches. The pods are classified into three sizes: <7, 7-15, and >15 cm.

Observation the intensity of *Helopeltis theivora* infestation

Cocoa pods infested with *H. theivora* are grouped into certain scales. The intensity of *H. theivora* infestation is then calculated using the following formula:

$$I = \frac{\sum(ni \times si)}{N \times S} \times 100\%$$

Where, I: Intensity of infestation, ni: Number of pods infested at a given infestation level, si: Scale of infestation, N: Total number of pods on sample plants, S: Highest scale value. Scale of infestation of *Helopeltis* spp. on cocoa pods can be seen in Table 1.

Data analysis

The average population, percentage of infestation, and intensity of infestation were analyzed using ANOVA in R Studio software version 4.4.2.

RESULTS AND DISCUSSION

Cultivation practices on CV Scorpio and smallholder cocoa plantations

Cocoa cultivation practices at CV Scorpio plantations differ from those at smallholder cocoa plantations (Table 2). Cocoa cultivation at CV Scorpio's cocoa plantation is carried out intensively, including pruning twice a year, NPK fertilization three times a year, burying infected plants, and regular harvesting. On the other hand, small cocoa plantations are cultivated traditionally. Farmers use a polyculture system, mixing cocoa with corn, coconut, and mango. Pruning was rarely done. Sanitary conditions were poor, with plant debris scattered everywhere. As a result of these cultivation practices, yields were low, at only 0.8 tons per hectare per year.

The population of *Helopeltis theivora* on CV Scorpio and smallholder cocoa plantations

The populations of nymphs and adults of *H. theivora* in small plantations were higher than in CV Scorpio plantations on both cultivated clones. The abundance of *H. theivora* nymphs in smallholder plantations on the TSH 858 clone was 1.143±0.46 individuals, significantly different from the abundance on ICS 60, which was 0.890±0.63 individuals (p: 0.0182) (Table 3). Similarly, the abundance of adult *H. theivora* was also higher in smallholder plantations on the TSH 858 clone, namely 2.053±0.57 individuals, which was significantly different from the abundance on ICS 60, namely 1.143±0.69 individuals (p: 0,0002). These findings indicate that plantation type and cocoa clones influence the abundance of *H. theivora*

The percentage of infested plants by *Helopeltis theivora* on CV Scorpio and smallholder cocoa plantations

Plantation type and clones influence the percentage of infestation by *H. theivora*. On CV Scorpio's cocoa plantation, the highest percentage of infestation was found on clone TSH 858, at 78.220±2.28% (p: 0.04). The percentage of infestation of *H. theivora* on TSH 858 clones was also higher in smallholder cocoa plantations, namely 87.987±0.72% (p: 0.003) (Table 4).

The percentage of infested pods by *Helopeltis theivora* on CV Scorpio and smallholder cocoa plantations

Clones influenced the percentage of pods infested in two types of cocoa plantations. The percentage of pods infested in CV Scorpio plantations was higher in the TSH 858 clone, at 43.670±5.01 (p: 0.0063) (Table 5). Conversely, in smallholder plantations, both clones experienced relatively high damage, with the highest damage found in the ICS clone at 54.693±12.23, significantly different from the TSH 858 clone at 51.033±11.71 (p: 0.0428). This indicates that cultivation patterns can influence the resistance of cocoa clones.

The percentage of infested pods by *Helopeltis theivora* base on pods location

Secondary branches were the location with the highest percentage of infested pods in both plantation types and both clones (Table 6). The percentage of pod infestation on secondary branches in smallholder plantations was 62.377±2.13% in clone ICS 60 (p: 0.000) and 63.083±1.09% in clone TSH 858 (p: 0.000). Meanwhile, the percentage of infestation on secondary branches in CV Scorpio cocoa plantations was lower, at 40.667±1.39% for ICS 60 (p: 0.000) and 51.300±1.30 for TSH 858 (p: 0.000).

The percentage of infested pods by *Helopeltis theivora* base on pods size

The size of cocoa pods affects the percentage of infestation by *H. theivora*. The highest infestation percentage in ICS 60 clones was found in pods measuring 7-15 cm in smallholder plantations, namely 60.833±1.46 (p: 0.0003), while in CV Scorpio plantations, the infestation was lower, namely 34.753±1.30 (p: 0.0012). Unlike TSH 858 clones, the highest percentage of infestation was found in pods measuring >15 cm, with a percentage of infestation in smallholder plantations of 58.467±0.51 (p: 0.0000) and CV Scorpio plantations of 52.467±0.51 (p: 0.0000) (Table 7). This shows that TSH pods are more susceptible to *H. theivora* infestation, even though cocoa cultivation has been carried out intensively.

Table 1. Scale of infestation of *Helopeltis* spp. on cocoa pods

Scale	Criteria of infested fruit	Category
0	No damage	Undamaged
1	There are puncture marks caused by *Helopeltis* spp. covering less than 10% of the total surface area of the pods.	light infestation
2	There are puncture marks caused by *Helopeltis* spp. covering 11% to 25% of the total surface area of the pods.	Moderate infestation
3	There are puncture marks caused by *Helopeltis* spp. covering 26% to 50% of the surface of the pods.	Heavy infestation
4	There are puncture marks from *Helopeltis* spp. covering >50% of the surface of the pods.	Massive infestation

Table 2. Cultivation practices on CV Scorpio and smallholder cocoa plantations in Jorong Gando, Piobang, Payakumbuh Sub-district, Lima Puluh Kota District, West Sumatra, Indonesia

Cultivation practices	Cocoa plantations			
	CV Scorpio		Near by	
Clone	ICS 60 and TSH 858	ICS 60 and TSH 858	ICS 60 and TSH 858	ICS 60 and TSH 858
Age	8 years	8 years	8 years	8 years
Planting distance	3x3 meter	3x3 meter	3x3 meter	3x3 meter
Cropping system	Monoculture	Monoculture	Policulture (corn, coconut, mangosteen)	Policulture (corn, coconut, mangosteen)
Pruning	Regularly (twice a year)	Regularly (twice a year)	Rarely pruned	Rarely pruned
Sanitation	Diseased plants are burrowed	Diseased plants are burrowed	Plant remains scattered around	Plant remains scattered around
Fertilization	Giving NPK three times a year, 75 grams NPK per plant	Giving NPK three times a year, 75 grams NPK per plant	Rarely fertilized	Rarely fertilized
Pest management	Bury affected plants Harvest frequently	Bury affected plants Harvest frequently	Rare immersion of plant residues and irregular harvest	Rare immersion of plant residues and irregular harvest
Harvest	1.8 ton/ha/year Harvest frequently Every week during the harvest season	1.8 ton/ha/year Harvest frequently Every week during the harvest season	0.8 ton/ha/year Irregular harvest	0.8 ton/ha/year Irregular harvest

Intensity of pods attacked by *Helopeltis theivora* on CV Scorpio and smallholder cocoa plantations

Cultivated cocoa clones influence the intensity of *H. theivora* infestation in two types of cocoa plantations. The intensity of *H. theivora* infestation on TSH 858 clones was higher in CV Scorpio cocoa plantations, namely 23.133±0.96 (p: 0.0042). In contrast, cocoa clones did not affect the intensity of infestation in smallholder cocoa plantations (p: 0.1270) (Table 8).

Table 3. The population of *H. theivora* on CV Scorpio and smallholder cocoa plantations in West Sumatra, Indonesia

Plantation	Clone	Population of *H. theivora* (ind./pods) (mean±SD)	
		Nympha	Adults
CV Scorpio	TSH 858	0.743±0.89a	1.243±0.56a
	ICS 60	0.430±0.62b	0.710±0.39b
Smallholder plantations	TSH 858	1.143±0.46a	2.053±0.57a
	ICS 60	0.890±0.63a	1.143±0.69b

Table 4. The percentage of infested plants by *H. theivora* on CV Scorpio and smallholder cocoa plantations in West Sumatra, Indonesia

Plantation	Clone	Infested plants (%) (mean±SD)
CV Scorpio	TSH 858	78.220±2.28a
	ICS 60	66.863±4.91b
Smallholder plantations	TSH 858	87.987±0.72a
	ICS 60	77.587±0.97b

Table 5. The percentage of infested pods by *H. theivora* on CV Scorpio and smallholder cocoa plantations in West Sumatra, Indonesia

Plantation	Infested pods by *H. theivora* (%) (mean±SD)	
	ICS 60	TSH 858
CV Scorpio	31.133±15.96b	43.670±5.01a
Smallholder plantations	54.693±12.23a	51.033±11.71b

Table 6. The percentage of infested pods by *H. theivora* base on pods location

Clon	Infested pods by *H. theivora* base on pods location (%) (mean±SD)		
	Location	Plantation	
		Smallholder plantations	CV Scorpio
ICS 60	Stem	41.887±1.09b	25.667±1.37b
	Primer branch	43.133±1.39b	28.883±1.35b
	Secondary branch	62.377±2.13a	40.667±1.39a
	Tertiary branch	41.900±1.33b	18.883±1.07c
TSH 858	Stem	50.467±1.79b	32.187±1.01d
	Primer branch	41.500±0.51c	44.450±0.51b
	Secondary branch	63.083±1.09a	51.300±1.30a
	Tertiary branch	40.55±0.58c	36.933±0.52c

Intensity of pods attacked by *Helopeltis theivora* base on place of pods on cocoa plantation CV Scorpio and smallholder cocoa plantations

Secondary branches on cocoa plants were the site of the highest intensity of *H. theivora* infestation on both clones in both types of plantations. In clone ICS 60, the intensity of pod damage on secondary branches reached 33.033±1.10% in smallholder plantations and 20.853±1.05% at CV Scorpio (Table 9). The intensity of pod infestation on secondary branches was also high in clone TSH 858, at 27.217±0.25% in smallholder plantations and 26.900±1.06a% in CV Scorpio plantations.

Intensity of pods attacked by *Helopeltis theivora* base on place of pods on CV Scorpio and smallholder cocoa plantations

The infestation intensity was higher in all pod size categories in smallholder plantations than in CV Scorpio plantations. In clone ICS 60, pods measuring 7-15 cm showed the highest infestation intensity in both types of plantations, namely 31.533±1.13 in smallholder plantations and 19.900±1.06 in CV Scorpio plantations (Table 10). Pods measuring >15 cm showed the highest infestation intensity, reaching 25.833±0.24 in TSH 858 clones in smallholder plantations and 25.583±1.17 in CV Scorpio plantations.

Discussion

Cultivation practices are the key factor influencing production disparities between the intensively managed CV Scorpio and neighboring smallholder plantations, even though both grow the same cocoa clones (ICS 60 and TSH 858). CV Scorpio's cocoa plantation implements intensive cultivation practices, including monoculture planting patterns and regular pruning. Pruning affects light absorption, leaf growth, the number of flowers, and the number of pods that develop, wither, and are ready for harvest (Tosto et al. 2022). Pruning and shade trees reduces capsid infestations and fruit wilt (Asitoakor et al. 2022). NPK fertilization is optimally carried out three times a year. Potassium application increased stomatal conductance, leaf greenness and hence yield (Adet et al. 2024). There was a clear positive effect of fertiliser on cocoa yields in the smallholder fields in Nigeria, Ghana, Cameroon and Côte d'Ivoire (Vasquez-Zambrano et al. 2025). Bury infected plants and harvest frequently. Periodic removal of diseased pods has been proven to control certain pests and diseases (Armengot et al. 2020). Intensively managed cocoa production reaches 1.8 tons/ha/year. The average cocoa production in Nigeria and Ghana was 400 kg/ha. Côte d'Ivoire and Ghana are the largest producers, followed by Nigeria and Cameroon worldwide (Wessel dan Quist-Wessel 2015).

Cocoa cultivation practices on two of the head of the plantation type affect the abundance of *H. theivora*. The abundance of nymphs and adults of *H. theivora* was higher in smallholder plantations than in intensive cocoa plantations. This difference proves that optimal cocoa plantation management can significantly reduce the number of pests (Dewi et al. 2025). Regular pruning, sanitation, and routine harvesting have been proven to suppress the population of *H. theivora*. In contrast, the population of *H. theivora* in smallholder plantations is relatively high. Pruning was rarely done, resulting in dense canopies that were susceptible to pests, including *H. theivora*. Increases in the number and height of shade trees have a negative impact on cocoa yield and growth through changes in cocoa tree morphology (Ariza-Salamanca et al. 2024).

Table 7. The percentage of infested pods by *H. theivora* base on pods size

Clone	Size of pods	Plantation (%) (mean±SD)	
		Smallholder plantations	CV Scorpio
ICS 60	<7 cm	48.900±1.37b	25.653±1.31b
	7-15 cm	60.833±1.46a	34.753±1.30a
	>15 cm	51.733±1.28b	31.267±1.29b
TSH 858	<7 cm	39.717±0.35c	37.167±0.55b
	7-15 cm	47.450±1.03b	37.853±1.05b
	>15 cm	58.467±0.51a	52.467±0.51a

Table 8. Intensity of pods attacked by *H. theivora* on CV Scorpio and smallholder cocoa plantations in West Sumatra, Indonesia

Plantation	Intensity of pods attacked (%) (mean±SD)	
	ICS 60	TSH 858
Smallholder plantations	28.467±1.04a	26.750±0.72a
CV Scorpio	16.783±1.18b	23.133±0.96a

Table 9. Intensity of pods attacked by *H. theivora* base on place of pods on CV Scorpio and smallholder cocoa plantations in West Sumatra, Indonesia

Clone	Location	Plantation (%) (mean±SD)	
		Smallholder plantations	CV Scorpio
ICS 60	Stem	21.450±1.03bc	9.417±0.94c
	Primer branch	24.467±1.04b	13.900±1.06b
	Secondary branch	33.033±1.10a	20.853±1.05a
	Tertiary branch	21.033±1.10c	9.477±1.04c
TSH 858	Stem	23.900±1.06b	4.600±0.57c
	Primer branch	26.033±1.10ab	14.350±1.14b
	Secondary branch	27.217±0.25a	26.900±1.06a
	Tertiary branch	17.477±1.04c	6.453±1.07c

Table 10. Intensity of pods attacked by *H. theivora* base on place of pods on CV Scorpio and smallholder cocoa plantations in West Sumatra, Indonesia

Clone	Size of pods	Plantation (%) (mean±SD)	
		Smallholder plantations	CV Scorpio
ICS 60	<7 cm	23.033±1.10b	13.367±1.12b
	7-15 cm	31.533±1.13a	19.900±1.06a
	>15 cm	19.967±1.08b	9.183±0.87c
TSH 858	<7 cm	16.450±1.06b	6.033±1.10c
	7-15 cm	24.700±1.11a	13.467±1.04b
	>15 cm	25.833±0.24a	25.583±1.17a

The variation in pest abundance between shaded and unshaded plantations may reflect microclimatic differences that influence the behavior and survival of *H. theivora*. Shaded conditions tend to maintain higher humidity and lower temperature fluctuations, which can suppress adult activity and oviposition frequency, whereas unshaded environments favor greater host visibility and higher feeding rates due to increased exposure and plant stress.

The cultivated clone also influenced the abundance of nymphs and adults of *H. theivora*. The highest abundance of nymphs and adults of *H. theivora* was found in clone TSH 858 in smallholder plantations and intensive cocoa plantations. This indicates that the TSH 858 clone is more susceptible to infestation by *H. theivora.* Even on intensively cultivated plantations, the population abundance of *H. theivora* remained high on this clone. Even though TSH 858 clones have been reported to be tolerant to pests and diseases (Ediwirman 2022). In addition to cocoa plants, other host plants of *Helopeltis* spp. have been reported to show resistance. Cultivar is one of the most important factors, while the unique physical properties (e.g., color and tenderness) and chemical components (e.g., primary and secondary metabolites) of different tea shoots can mediate the probing attempts and feeding decisions of *H. theivora* (Bordoloi et al. 2023; Borthakur and Bora 2023). Antibiosis is related to toxins or growth inhibitors in cocoa plants. Some cocoa plants may produce compounds that act as natural pesticides, inhibiting the growth of fungal pathogens or deterring insect pests (N'Guessan et al. 2008). In contrast, ICS 60 clones showed resistance to *Helopeltis* spp. even when cultivated on smallholder plantations. However, there is no information reporting the resistance mechanism of ICS 60 clones to *H. theivora*.

The percentage of cocoa plants infested is also influenced by cultivation patterns. Cocoa plants on smallholder plantations suffer more damage than those on intensive cocoa plantations. The difference in the percentage of plants infested by *H. theivora* in CV Scorpio's plantation and smallholder plantations is related to the cultivation practices applied in each plantation. The feeding behavior of tea mosquito bugs (*Helopeltis* spp.) on plants can be influenced by various abiotic and biotic factors (Yao et al. 2025). Regular pruning at CV Scorpio's plantation creates a more open canopy, allowing optimal air circulation and light penetration. Effective canopy management, such as pruning to optimize light (Adet et al. 2024). These conditions are naturally unfavorable for *H. theivora*, which seek shade and humidity. *Helopeltis theivora* like lush plants because they tend to be dark. Higher temperatures and humidity create ideal environmental conditions for the survival and reproduction of *H. theivora* (Yao et al. 2025). In addition, a positive relationship between humidity (i.e., rainfall) and tea leafhopper infestation has been reported in several tea-growing regions in India (Chakraborty and Chakraborty 2005). *Helopeltis theivora* preferred nocturnal feeding over diurnal feeding, with the number of feeding punctures during the night time being much greater than those during the daytime (Radhakrishnan 2022). Changes in temperature, rainfall intensity, photoperiod variation, and the use of intercropping and cover crops can affect the growth and development of tender shoots, which in turn influences the feeding preferences of *H. theivora* (Babu et al. 2022). In contrast, smallholder cocoa plantations that rarely prune create a dense and humid canopy, providing an ideal habitat for *Helopeltis* spp. Shade conditions could influence the feeding damage caused by *H. theivora*, with tea plantations in the higher shade more susceptible to such damage (Yao et al. 2025).

There is a direct correlation between the abundance of *Helopeltis* spp. and the percentage of cocoa plants infested, and the quality of cultivation practices influences both factors. CV Scorpio's cocoa plantation, which implements intensive cultivation management and a series of optimal agronomic practices, can directly reduce the abundance of *Helopeltis* spp. to a lower level. Although the population of *Helopeltis* spp. was low, it can cause high damage in the cocoa plantation of CV Scorpio. Lower pest abundance should reduce the chances of infestation. The higher abundance of *Helopeltis* spp. in smallholder cocoa plantations, this directly resulted in a high percentage of infested plants. Four third instar nymphs of *H. theivora* cause maximum damage to plant leaves (Yao et al. 2025). Female adults and the fifth instar nymph are the most destructive stages during the life history (Yao et al. 2025). These results are consistent with previous investigations showing that fifth instar nymphs are the most voracious feeders throughout their life cycle (Bhuyan and Bhattacharyya 2006). Additionally, the population of natural enemies in tea plantations, particularly some species in the two important predators, Reduviidae and Oxyopidae, for *H. theivora*, could also influence the extent of feeding damage caused by this pest (Srikumar et al. 2017).

The percentage of pod damage was lower in clone ICS 60 than in TSH 858 in the CV Scorpion cocoa plantation. The ICS 60 clone is known for its slightly rough or bumpy pod skin, but under good management conditions, the pod skin appears to provide adequate protection. In contrast, TSH clone 858, which also has rough/wavy skin and an elongated shape, showed slightly higher susceptibility. This difference indicates that the pod characteristics of TSH 858 clones may be more preferred or susceptible to *Helopeltis* than ICS 60. In smallholder cocoa plantations, this pattern was still evident but with much more severe damage to both clones, indicating that plantation management factors were much more influential than differences in pod characteristics between clones. ICS 60 clones in smallholder plantations suffered damage higher than in CV Scorpio cocoa plantations. TSH 858 clones in smallholder plantations also suffered high damage. Differences in the levels of several volatile and non-volatile metabolites between cultivars may be crucial components that influence the susceptibility or resistance of these cultivars to *H. theivora* (Yao et al. 2025). These metabolites can influence the habitat orientation and the feeding efforts and choices of *H. theivora* on tea plants (Hu et al. 2024).

The infested pods are mostly found on secondary branches. The most preferred feeding site was at the second leaf position, accounting for 70.94±3.68% of daily feeding spots (Yao et al. 2025). This may also be related to the oviposition behavior of *Helopeltis* spp. on soft parts of the plant. *Helopeltis theivora* eggs were mainly deposited below the epidermic of tender stem (Yao et al. 2025). The feeding position of *H. theivora* on tea shoots includes buds, first, second, and third leaves, indicating a preference for feeding on soft parts (Yao et al. 2025). The pod size most frequently infested by *Helopeltis* spp. on ICS 60 clones was 7-15 cm, while on TSH 858 clones it was more than 15 cm (>15 cm). *Helopeltis* spp. began attacking pods at a young age, and the majority of the pods were infested when they reached 8 cm in length (Bakar 2020). Larger pods provide more opportunities for nymphs and adults of *H. theivora* to pierce and suck. This piercing-sucking insect pest typically feeds on the tender tissues of host plants (Sankarganesh et al. 2023). *Helopeltis theivora* preferred feeding on the large-leaf tea cultivar (Yao et al. 2025). *Helopeltis* spp. first insert their labial stylets into the epidermis of fresh buds, young stems, and leaves and then inject toxic saliva containing several digestive-related enzymes and finally suck the cell sap that has been digested (Roy et al. 2015). This indicates that at this size, the physical or chemical characteristics of ICS 60 pods may be most attractive or susceptible to pests.

ACKNOWLEDGEMENTS

The authors would like to thank the Research and Community Service, Universitas Andalas (LPPM), Indonesia, for funding the article processing charge (APC) for this article.

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