



The first report of the cassava lace bug (Hemiptera: Tingidae) and their impact on cassava plants on Sumatra Island, Indonesia

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Received: 14 March 2025 / Accepted: 29 September 2025
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Abstract

The cassava lace bug (Hemiptera: Tingidae), an invasive pest from South America, has significantly threatened cassava (*Manihot esculenta*) cultivation in Indonesia. The study aimed to identify lace bug species and assess their impact on cassava in Lima Puluh Kota Regency, West Sumatra, Indonesia. Systematic random sampling was conducted across 15 locations in five sub-districts of Lima Puluh Kota Regency, West Sumatra. Population density was assessed at three leaf positions (upper, middle, lower) using 50 to 90 plants per location. Damage severity was evaluated using a 0–5 scale, and morphological identification confirmed species identity. The study results indicate that morphological identification confirmed *Vatiga illudens* as the species infesting cassava plants in Limapuluh Kota District. Two-way ANOVA revealed highly significant effects of leaf position ($F_{2,45} = 53.576$, $p < 0.001$, $\eta_p^2 = 0.994$), location ($F_{4,30} = 82.31$, $p < 0.001$), and their interaction ($F_{8,30} = 30.19$, $p < 0.001$) on population density. Clear vertical stratification was observed: lower leaves (129.69 ± 5.18 individuals/leaf) > middle leaves (80.97 ± 2.01) > upper leaves (25.79 ± 1.25). Akabiluru district showed the highest infestation levels (82.32 ± 0.58 individuals/leaf) compared to other locations. Nymph populations dominated lower and middle leaf positions, while adults were more abundant on upper leaves. All sites exhibited 100% plant infestation with moderate damage intensity (38.11–47.57%). The entomopathogenic fungus *Lecanicillium lecanii* was identified infecting lace bugs. This first record confirms *V. illudens* establishment in Sumatra with significant ecological impact, emphasizing the urgent need for integrated pest management and surveillance programs.

Keywords Cassava pest · Lace bug · Population density · Tingidae

1 Introduction

The lace bugs (Hemiptera: Tingidae) is a recently identified pest affecting cassava (*Manihot esculenta*) crops in Indonesia. Lace bugs are included in the species of insect pests with a high level of host specificity so that they can only survive in places where their hosts are available (Souma and Kamitani 2020). Lace bugs are among the most significant pests of cassava plants, originating from South America. In 2002, this bug was not reported in Africa or Asia (Bellotti 2002). Lace bugs are key pests of cassava. This pest was first found outside its native area in November 2009 in Florida (Halbert 2010).

The lace bugs reported to attack cassava plants in Indonesia by several previous studies is *Vatiga illudens*. The lace bugs have been found in most East Java areas, such as Malang, Pasuruan, Blitar, Mojokerto, and Probolinggo (Puspitarini et al. 2021). This report is the first record of the discovery of lace bugs in Indonesia. These insects have also been found in Central Java, namely Banyumas (Suroto et al. 2023), and Bali, such as Denpasar, Tabanan, Karangasem, and Buleleng (Sudiarta et al. 2024). Based on the latest government regulation on the types of Quarantine Plant Pest Organisms (OPTK), namely Government Regulation No. 25 of 2020, these insects are not included in OPTK categories A1 or A2 (Ministry of Agriculture of the Republic of Indonesia 2020).

Lace bug *Vatiga* spp. can expand its current distribution into suitable areas and invade other regions where cassava is already cultivated (Montemayor et al. 2015). Fialho et al. (2009) stated that lace bugs can cause a reduction in cassava tuber yield of 48–55% and cause a reduction in cassava

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plant leaves of 48–50%. This pest raises concerns about its invasion and potential to become a new major pest of cassava plants, generally in West Sumatra and especially in Lima Pulu Kota Regency. Information on the level of lace bug attacks is essential as an initial step in taking control measures. This study aimed to identify lace bug species and assess their impact on cassava plants in Lima Pulu Kota Regency, West Sumatra, Indonesia. This study was conducted to address the critical knowledge gap regarding the recent invasion of lace bug species in West Sumatra's cassava-growing regions, where its ecological and economic impacts remain unquantified.

2 Material and methods

The research was conducted from May to August 2024. The study location was determined by a purposive sampling method, based on five sub-districts with the highest cassava plant production in Lima Pulu Kota Regency, namely Akabiluru, Luak, Situjuah Limo Nagari, Harau, and Guguak Sub-districts. In each sub-district, three cassava fields were determined with an area of $\pm 400 \text{ m}^2$, aged 5–6 months after planting, and attacked by lace bugs. Within each selected field, sample plants were determined using systematic random sampling, representing 10% of the total plant population per field (50–90 plants depending on field size). Plants were selected using a systematic grid pattern with random starting points to ensure representative coverage across each field. Sample leaves were determined by taking three parts of the plant leaves: the lower, middle, and upper leaves. The

variables observed were identifying lace bugs and their density, attacked and unattacked plants, the attack level, and natural enemies.

2.1 Research location

Insect and plant sampling were conducted in five sub-districts with the highest cassava production in Lima Pulu Kota Regency. The altitude of the research location ranges from 523 to 668 m above mean sea level. The research location in the Luak Sub-district has the highest altitude, while the Harau Sub-district has the lowest altitude (Table 1).

2.2 Species identification

Identification was conducted to determine the lace bug species at the research site. The imago lace bug collected from the research site was brought to the laboratory and observed for morphological characters under a stereo microscope. The identification key used is the identification key of Froeschner (1993).

2.3 Population density assessment

Observations of lace bug abundance were made by counting directly in the field. Counting was done on the nymph and imago stadia on the sample leaves. Calculation of the population density of nymphs and imago was done by counting the number of each stadia on the sample leaves, and then calculating using the formula:

Table 1 Location of cassava plants used as research locations in 50 Kota Regency, West Sumatra, Indonesia

Sub-districts	Village	Location	Coordinate		Altitude (meters above mean sea level)
			Latitude	Longitude	
Akabiluru	Koto Tengah Batu Ampa	Seberang Parit 1	−0.273036°	100.582675°	600
		Seberang Parit 2	−0.270489°	100.581777°	
		Seberang Parit 3	−0.270532°	100.581998°	
Luak	Tanjung Haro Sikabu-kabu	Tanjung Haro 1	−0.254796°	100.659877°	668
		Tanjung Haro 2	−0.254822°	100.659815°	
		Tanjung haro 3	−0.26071°	100.657395°	
Harau	Sarilamak Gurun	Sarilamak	−0.118622°	100.650644°	523
		Gurun 1	−0.162467°	100.612466°	
		Gurun 2	−0.161473°	100.610931°	
Situjuah Limo Nagari	Situjuah Banda Dalam Situjuah Gadang	Banda Dalam,	−0.288638°	100.617423°	651
		Tanjung Simantuang 1	−0.28509°	100.64466°	
		Tanjung Simantuang 2	−0.28562°	100.644912°	
Guguak	Sungai Talang	Balubus 1	−0.191183°	100.551092°	554
		Balubus 2	−0.189642°	100.553183°	
		Balubus 3	−0.178605°	100.560458°	

$$\text{Population density} = \frac{\text{number of lace bug nymphs or imago}}{\text{number of leaves sampled}}$$

2.4 Percentage of affected plants

The percentage of affected plants is calculated based on the symptoms of lace bug attack in the form of yellowish-white chlorotic spots on the upper surface of the leaves. The percentage of affected plants can be calculated by comparing the number of affected plants with the total number of plants observed and expressed in percent (%) with the following formula:

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

P: Percentage of affected plants, a: number of affected plants, and b: number of plants observed.

2.5 Attack intensity

The level of plant damage caused by lace bug attacks can be calculated using the formula:

$$IS = \frac{\sum_i^n (ni \times vi)}{N \times Z} \times 100\%$$

IS: Intensity of attack, ni: number of plants with damage scale vi, vi: damage scale value, N: number of plants observed, Z: highest damage scale value.

Observations of attack intensity were made using a damage scale based on scoring the number of sample plants attacked by the lace bug. The scoring scale refers to Oliveira et al. (2001) (Table 2).

After calculating the intensity of the attack, the next step is to determine the severity of cassava plants based on the intensity of the attack, which can be seen in Table 3.

2.6 Natural enemy identification

Fungal pathogens infecting lace bugs were collected and cultured on Potato Dextrose Agar (PDA) medium for

Table 2 Scale of lace bug infestation on cassava leaves

Symptoms of an attack	Scale
No lace bug was found	0
There are some yellowish-white spots on the leaf veins	1
There are many yellowish-coloured spots around the leaf veins	2
There are many reddish-colored spots around the leaf veins	3
There are reddish spots on the entire leaf surface	4
Leaves become curled and dry and then defoliate or fall off	5

Table 3 Crop severity based on attack intensity

Attack intensity (%)	Description:
0–1	Healthy
> 1–25	Lightly damaged
> 25–50	Moderately damaged
> 50–75	Heavily damaged
> 75–100	Heavily damaged

morphological identification. Macroscopic characteristics (colony color, texture, growth pattern) and microscopic features (conidiophores, phialides, conidia) were compared with mycological references (Anggarawati et al. 2018; Muhtady and Fitri 2021).

2.7 Data analysis

All statistical analyses were performed using R software version 4.5.1. All data were checked for normality using the Shapiro–Wilk test and homogeneity of variance using Levene's test prior to analysis. A two-way ANOVA with Tukey's HSD post hoc test ($\alpha = 0.05$) was applied to identify significant density variations.

3 Results

3.1 Species of lace bugs on cassava plants

The results of identifying lace bugs on cassava plants from all sampling locations are *Vatiga illudens*. The specific characteristics of *V. illudens* are having a pair of tubercles (small spines) at the anterior of the head near the antenna (sometimes only having one tubercle, but its position is not in the middle). The first antenna segment (scape) is shorter than the head. The dorsum part looks like lace. Hemelytra has a costa section divided by the areola from the base to the tip of the wing. The specific characteristics of *V. illudens* can be seen in Fig. 1.

Male and female imago of lace bug have a brownish-yellow color. The difference between male and female imago can be seen from the ventral abdomen. The male imago has a distinctive claw-like part on the apical abdomen (Fig. 2a). The female imago has one groove along the midline of the ventral side of the apical abdomen (Fig. 2b).

3.2 Population density of lace bug

Two-way ANOVA revealed highly significant effects of location ($F_{4,30} = 82.31$, $p < 0.001$, $\eta_p^2 = 0.003$), leaf position ($F_{2,45} = 53.576$, $p < 0.001$, $\eta_p^2 = 0.994$), and their interaction ($F_{8,30} = 30.19$, $p < 0.001$, $\eta_p^2 = 0.002$) on population

density. Post hoc analysis (Tukey's HSD test) revealed that the lace bug population density in Akabiluru (82.32 ± 56.12 individuals/leaf) was significantly highest among all other locations ($p < 0.001$). Leaf position emerged as the dominant factor determining population density with an effect size of $\eta^2 = 0.994$. The density at the lower position (129.69 ± 5.58 individuals/leaf) was significantly higher than middle (80.97 ± 2.01) and upper leaves (25.79 ± 0.97) (all pairwise $p < 0.001$). The significant interaction effect indicated that while the general pattern of vertical gradient (lower > middle > upper) was consistent across all study locations, the magnitude of differences varied among

locations, particularly at the lower position, where Akabiluru (138.37 ± 0.91) differed significantly from other locations. In contrast, at upper and middle positions, all locations showed non-significant density differences (Table 4).

The imago stage is more common in the upper leaves than the nymph stage. The imago population averages 13.65 individuals/leaf, while the average nymph population is 11.50 individuals/leaf. The imago stage is less common in the middle leaves than in the nymph stage. The imago population averages 40.31 individuals/leaf, while the average nymph population is 41.57 individuals/leaf. The imago stage is less common in the lower leaves than the nymph stage. The

Fig. 1 Specific characteristics of *V. illudens*: a pair of tubercles on the head (a), scape shorter than the head (b), scape, and hemelytra with costal parts divided by areola from the base to the tip of the wings (c) (magnification 40x)

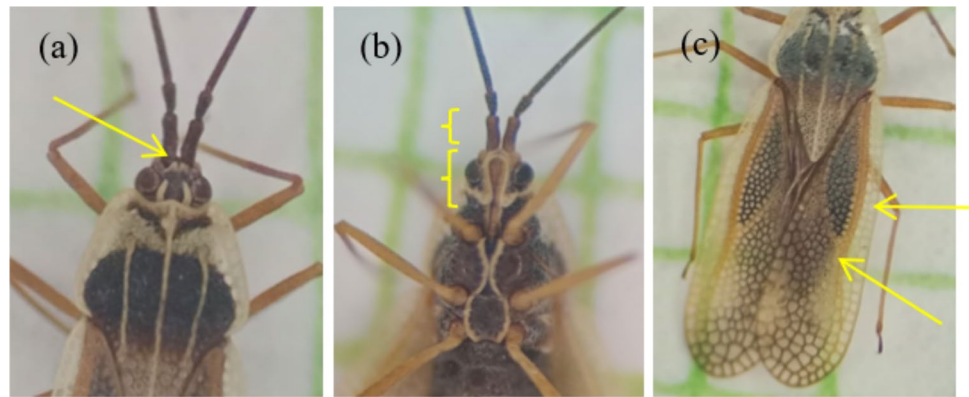


Fig. 2 Male (a) and female (b) imago of lace bug seen from the dorsal view (magnification 40x)

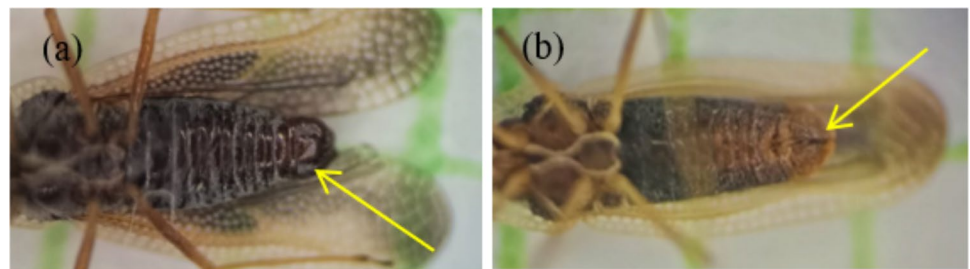


Table 4 Population density of lace bug based on leaf position on plants at various observation locations

Sub-districts	Population density (individuals/leaf) ¹			Location mean ² ± SD	
	Top Leaf	Middle Leaf	Bottom Leaf		
Akabiluru	26.13 ± 0.81 A	82.46 ± 0.07 A	138.37 ± 0.91 A	82.32 ± 0.58	a
Guguak	26.95 ± 0.91 A	83.26 ± 1.57 A	129.91 ± 0.43 B	80.04 ± 0.68	b
Harau	25.95 ± 0.66 A	81.34 ± 0.21 A	130.42 ± 0.47 B	79.24 ± 0.13	b
Luak	25.62 ± 0.78 A	78.83 ± 0.50 A	125.91 ± 0.49 B	76.79 ± 0.12	c
Situjuah Limo Nagari	24.29 ± 1.88 A	78.98 ± 0.89 A	123.87 ± 0.52 B	75.70 ± 1.09	c
Leaf position mean ³ ± SD	25.79 ± 1.25 c	80.97 ± 1.99 b	129.69 ± 5.18 a		

¹Simple effect notation (Interaction): means with uppercase different letters in each cell are significantly different (Tukey's HSD test, $p < 0.001$)

²Location main effect notation: means with lowercase different letters in the location mean column are significantly different (Tukey's HSD test, $p < 0.001$)

³Leaf position main effect notation: means with lowercase different letters in the location mean row are significantly different (Tukey's HSD test, $p < 0.001$)

Table 5 Population density of lace bug based on leaf position on the plant and the stage found

Sub-districts	Population density (individuals/leaf)					
	Top		Middle		Bottom	
	Imago	Nymph	Imago	Nymph	Imago	Nymph
Akabiluru	13.40 ± 0.27	12.74 ± 0.54	40.26 ± 0.16	42.20 ± 0.13	52.22 ± 0.26	86.15 ± 0.89
Luak	14.31 ± 0.16	10.82 ± 0.64	38.90 ± 0.28	39.93 ± 0.23	47.05 ± 0.32	78.86 ± 0.33
Harau	13.80 ± 0.23	11.31 ± 0.54	39.50 ± 0.05	41.85 ± 0.19	48.77 ± 0.41	81.65 ± 0.26
Situjuah Limo Nagari	13.31 ± 1.04	10.99 ± 0.88	39.08 ± 0.27	39.90 ± 0.63	45.85 ± 0.32	78.02 ± 0.82
Guguak	16.13 ± 0.12	10.82 ± 1.01	41.32 ± 0.60	41.94 ± 1.01	47.90 ± 0.89	82.01 ± 0.47
Mean ± SD	14.19 ± 1.15	11.60 ± 0.98	39.81 ± 0.96	41.16 ± 1.16	48.36 ± 2.27	81.34 ± 3.01

Table 6 Percentage of plants attacked by lace bug in five sub-districts in 50 Kota Regency

Sub-districts	Percentage of plants attacked (%)		
	Field 1	Field 2	Field 3
Akabiluru	100	100	100
Luak	100	100	100
Situjuah limo nagari	100	100	100
Harau	100	100	100
Guguak	100	100	100

imago population averages 47.19 individuals/leaf, while the average nymph population is 81.77 individuals/leaf. In the lower leaves, the nymph stage is more dominant than the imago stage. The population of lace bugs based on the stages found can be seen in Table 5.

3.3 Percentage of plants attacked

The observation results showed that the percentage of plants attacked by lace bug in each observation location reached 100%. The percentage of plants attacked can be seen in Table 6.

3.4 The intensity of lace bug attacks

The highest intensity of lace bug attacks in five sub-districts in Lima Pulu Kota Regency occurred in Guguak Sub-district at 47.57%, while the lowest attack intensity occurred in Situjuah Limo Nagari Sub-district at 38.11%. The overall condition of the observed plants was included in the moderately damaged category. The intensity of lace bug attacks can be seen in Table 7.

3.5 Fungi found on lace bugs

Fungal pathogens infecting lace bugs (Fig. 3) were morphologically identified as *Lecanicillium lecanii*. The macroscopic morphology of the *L. lecanii* colony is white from

Table 7 The intensity of lace bug attacks in five sub-districts of 50 Kota Regency, West Sumatra

Sub-districts	The intensity of attack (%) (Mean ± SD)	Description
Guguak	47.57 ± 0.24	Moderate damage
Akabiluru	46.13 ± 0.19	Moderate damage
Harau	44.02 ± 0.44	Moderate damage
Luak	39.69 ± 0.20	Moderate damage
Situjuah Limo Nagari	38.11 ± 0.13	Moderate damage

above and pale yellow from below. The fungal colony has a smooth, dense, and relatively thick texture. The colony is irregularly round and does not have a concentric circle distribution. Microscopically, the *L. lecanii* has short, slender, upright conidiophores formed from hyphal cells, hyaline in color, with no septa, and branches with phialids. Conidia are hyaline and have a cylindrical to oval shape with varying sizes. The macroscopic and microscopic morphology of *L. lecanii* can be seen in Fig. 4.

4 Discussion

The morphological identification of *Vatiga illudens* in Lima Pulu Kota Regency represents a significant westward expansion of this Neotropical invasive species in Indonesia. The diagnostic characters observed in this study, particularly the paired cephalic tubercles and distinctive hemelytra structure with costal areolae, are consistent with previous descriptions based on the similarity of characters from Froeschner's (1993) identification key and the characteristics of *V. illudens* proposed by Puspitarini et al. (2021) and Sudiarta et al. (2024). Species of the genus *Vatiga* originate from the Neotropical region and show a clear preference for plants from the genus *Manihot*, especially *Manihot esculenta* Crantz, which is commonly known as cassava and one of the most important plants in Africa, Central and South America, and Asia (Guidoti et al. 2015). This confirmation extends

Fig. 3 Lace bug infested with fungus. a. fungus-infested imago, b. fungus-infested nymphs

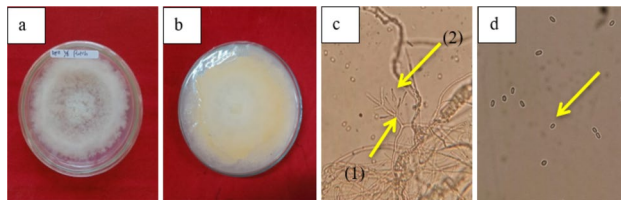
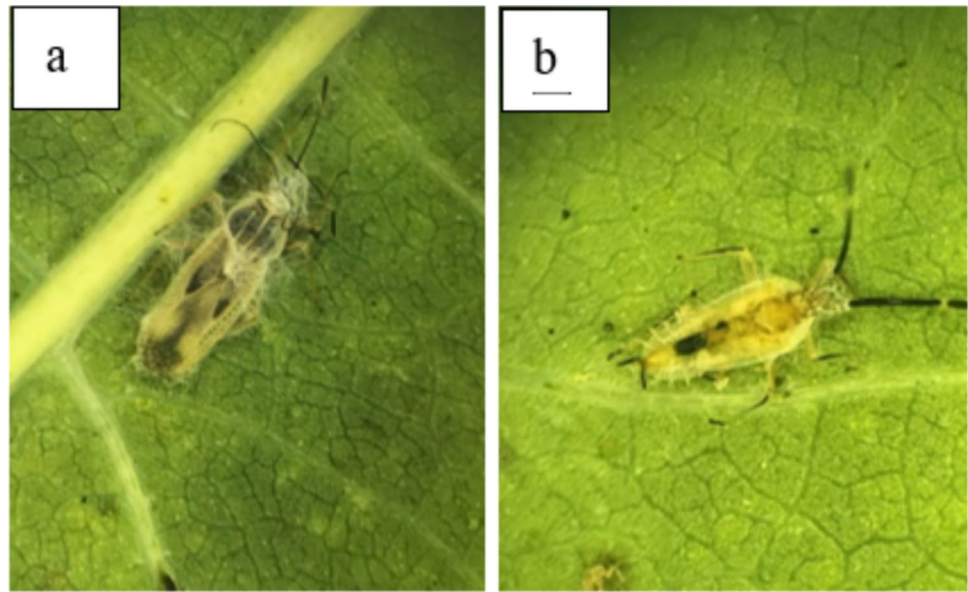


Fig. 4 Macroscopic and microscopic morphology of *Lecanicillium lecanii*. a. top view of colony, b. bottom view of the colony, c. conidiophores with phialid branches, d. conidia, 1. conidiophores, 2. phialids (lens magnification 400x)

the known distribution of *V. illudens* to Sumatra, indicating successful establishment across major Indonesian islands within approximately two decades since its first detection in East Java. The rapid geographic expansion of *V. illudens* across Indonesia parallels invasion patterns observed in other regions. Similar to its spread in Florida following the 2009 introduction (Halbert 2010), the species demonstrates remarkable dispersal capacity and environmental adaptability. The presence of established populations across all surveyed locations suggests that initial introduction to West Sumatra likely occurred several years prior to this study, allowing sufficient time for population establishment and local adaptation.

The observations of the population density of lace bug show that the average highest population density is found on the lower leaves, while the lowest population density is found on the upper leaves. It was found in all research locations. The same thing was found in research by Puspitarini et al. (2021), which found that lace bugs preferred the lower and middle leaves, while the lace bugs observed on the upper leaves were relatively low. Pietrowski et al. (2024) further

stated that these insects were found on the underside of leaves, especially in the middle to lower third of the cassava plant. The high population of lace bugs on the plant's lower leaves is thought to be due to cyanogenic compounds in the plant leaves. Santos et al. (2019) stated that the higher the cyanogenic compound content in cassava plants, the lower the population of lace bugs, both nymphs and imagos. Puspitarini et al. (2025) also stated that the leaf nutritional profile (proximate content), as well as phenol and hydrogen cyanide (HCN) content, were analyzed as potential factors affecting the biological parameters of *V. illudens*. Ospina et al. (2024) further suggested that cyanogenic compound concentrations are higher in leaves from young cassava plants and decrease with increasing physiological age. Therefore, the cyanogenic content in old cassava leaves is less than that of young leaves.

The significantly higher population density observed in Akabiluru than other locations may be attributed to several factors, including altitude, local microclimate conditions, cassava cultivar preferences, or agricultural management practices. The altitude range of study sites (523–668 m a.s.l.) falls within the optimal elevation range for cassava cultivation in tropical regions. Akinwumiju et al. (2020) stated that the optimal elevation range for cassava cultivation in tropical regions is generally between 105 and 1500 m. Cassava thrives in low-lying areas, while some cultivars can perform well at higher altitudes, indicating a wide adaptability. It suggests that *V. illudens* has successfully adapted to highland conditions in West Sumatra. This adaptability expands the potential geographic range for invasion beyond lowland areas and indicates that mountainous cassava-growing regions throughout Indonesia may be vulnerable to infestation. Microclimate is another factor that can influence

the population density of *V. illudens*. Research has shown that temperature variations significantly affect *V. illudens* population dynamics, with maximum, mean, and minimum temperatures being key determinants of nymph development (Bellon et al. 2018; Santos et al. 2019). Several local agricultural practices, including planting density, intercropping systems, and pesticide application history, likely contribute to the observed location-specific variations. The continuous cultivation of cassava reported in the study area creates ideal conditions for pest population buildup, as noted by Montemayor et al. (2015), who emphasized the role of year-round host availability in supporting invasive lace bug populations.

Based on the stage, the population density of the nymph stage lace bug is higher than the imago stage on the leaves in the middle and lower parts of the plant, while for the upper leaves, the imago stage has a higher density. It is likely due to nutritional requirements. Lower leaves tend to have more limited nutrient content due to higher densities, so imago tend to move to the upper leaves of the plant in order to mate and lay eggs. By laying eggs on the upper leaves, the survival of the offspring can be maintained because the offspring get enough nutrients. Clissold and Simpson (2015) stated that the population dynamics of herbivorous insects are strongly influenced by temperature and host plant quality.

V. illudens is an important pest of cassava plants, and it is currently starting to get much attention because the impact of the damage caused is quite significant, ranging from leaf fall to decreased quality and weight of tubers. Sudiarta et al. (2024) stated that attack symptoms on the upper leaf surface are small yellow spots with brownish variations. If the attack is heavy, the spots spread across the plant leaves. Symptoms of curling in a brownish-yellow color indicate a severe attack on the young shoots of cassava plants. The percentage of plants attacked by lace bug at all observation locations reached 100%. Lace bugs can be found on all plants observed. It is thought to be because lace bugs have invasive properties. Because the lace bug is not a native pest in Indonesia, it is feared that it will become an invasive species, such as *Phenacoccus manihoti* (Sudiarta et al. 2024). The spread of lace bugs is also supported by planting distances that are too tight, making it easier for them to move from one plant to another. In addition, the continuous planting of cassava on the same land for a long time is also a factor in the rapid spread of the lace bug. Montemayor et al. (2015) stated that food availability strongly influences the development of lace bugs. Simultaneously, planting cassava throughout the year will significantly support the development of the lace bug population.

The density of the lace bug population on the plants influenced the high intensity of lace bug attacks. Adults and nymphs feed on the undersurfaces of the lower plant leaves (Bellotti et al. 1994). Both can cause damage to cassava leaves, so the photosynthesis process on the leaf surface is

hampered. In addition, this pest can also cause leaves to fall off early, until no leaves remain if a severe attack occurs (Bellon et al. 2012). The higher the density of the pest population, the more severe the damage it causes. The severity of crop damage is also influenced by the destructive ability of a pest (Pathania et al. 2020).

Based on identifying the fungus that attacks lace bug in the field, it is identified as *Lecanicillium lecanii*. *L. lecanii* is an insect-pathogenic fungus that can live in various places (cosmopolitan) and is easily found in tropical and subtropical areas. This fungus can produce toxic secondary metabolites, namely bassionolide and dipicolinic acid (Błaszczuk et al. 2021). The toxic properties of this fungus are thought to be one of the causes of death in lace bug nymphs and imago in the field. *L. lecanii* is an insect-pathogenic fungus often used for pest control and has many hosts. The *L. lecanii* can infect several host insects, including the Order Orthoptera, Hemiptera, Lepidoptera, Thysanoptera, and Coleoptera (Hadi et al. 2020). The broad host range of this fungus is expected to be an alternative to lace ladybird control, so that the population increase of lace bug can be controlled.

5 Conclusion

This study confirms the establishment of *Vatiga illudens* in Sumatra, representing the region's first record of this invasive cassava pest. The species exhibits complete infestation across all surveyed areas with significant population densities and moderate damage levels, indicating successful adaptation to local conditions and potential for rapid geographic expansion. The vertical distribution pattern of lace bug populations and the presence of the entomopathogenic fungus *Lecanicillium lecanii* provide important insights for developing targeted integrated pest management strategies. These findings emphasize the urgent need for surveillance programs to monitor the spread and implementation of biological control measures to mitigate economic impacts on cassava production systems. Immediate action is required to prevent further invasion of this destructive pest into other cassava-growing regions of Indonesia. Future research should prioritize developing *L. lecanii*-based biocontrol programs and assessing economic losses to inform evidence-based management decisions.

Acknowledgements Acknowledgments to the Faculty of Agriculture, Universitas Andalas, which has provided research funding assistance following Research Contract Number: 01/PL/SPK/PNP/FAPERTA-Unand/2024 for Fiscal Year 2024

Authors' contributions **Hasmiandy Hamid**: Conceptualization, Methodology, Formal analysis, Resource, Writing—Original Draft, Writing—Review & Editing, Supervision. **Silvani Anjelina**: Investigation, Writing—Original Draft. **Refinaldon**: Conceptualization,

Methodology. Yunisman: Visualization. Eka Candra Lina: Writing—Original Draft.

Funding The Faculty of Agriculture, Universitas Andalas, which has provided research funding assistance following Research Contract Number: 01/PL/SPK/PPN/FAPERTA-Unand/2024.

Data availability The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interest The authors declare that they have no known competing for financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

- Akinwumiju AS, Adelodun AA, Orimoogunje OI (2020) Agro-climato-edaphic zonation of Nigeria for a cassava cultivar using GIS-based analysis of data from 1961 to 2017. *Sci Rep* 10:1–15. <https://doi.org/10.1038/s41598-020-58280-4>
- Anggarawati SH, Santoso T, Anwar R (2018) The use of entomopathogenic fungi *Beauveria bassiana* (Balsamo) Vuillemin and *Lecanicillium lecanii* (Zimm) Zare & Gams for controlling *Helopeltis antonii* Sign (Hemiptera: Miridae). *J Trop Silv* 8: 197–202. <https://doi.org/10.29244/j-siltrop.8.3.197-202>
- Bellon PP, Oliveira HN. de, Loureiro E de S, Santana DRS, Osubo AA, Mota TA (2018) Populational fluctuation of lace bug in cassava. *Arq Inst Biol (Sao. Paulo)* 84: 1–6. <https://doi.org/10.1590/1808-1657000602015>
- Bellon PP, Wengrat APGS, Kassab SO, Pietrowski V, Loureiro ES (2012) Occurrence of lace bug *Vatiga illudens* and *Vatiga manihotae* (Hemiptera: Tingidae) in Mato Grosso do Sul, midwestern Brazil. *An Acad Bras Cienc* 84:703–705. <https://doi.org/10.1590/S0001-37652012000300012>
- Bellotti AC (2002) Arthropod pests, in: Hillocks RJ, Thresh JM, Bellotti AC (Eds.) *Cassava: Biology, production and utilization*. CAB Publishing, pp. 209–235. <https://doi.org/10.1079/9781845938154.0183>
- Bellotti AC, Braun AR, Arias B, Castillo JA, Guerrero JM (1994) Origin and management of Neotropical cassava arthropod pests. *Afr Crop Sci J* 2:407–417
- Błaszczak L, Waśkiewicz A, Gromadzka K, Mikołajczak K, Chełkowski J (2021) *Sarocladium* and *Lecanicillium* associated with maize seeds and their potential to form selected secondary metabolites. *Biomolecules* 11:1–11. <https://doi.org/10.3390/biom11010098>
- Clissold FJ, Simpson SJ (2015) Temperature, food quality and life history traits of herbivorous insects. *Curr Opin Insect Sci* 11:63–70. <https://doi.org/10.1016/j.cois.2015.10.011>
- Fialho J de F, Vieira EA, Paula-Moraes SV De, Silva MS, Junqueira NTV (2009) Danos causados por percevejo-de-renda na produção de parte aérea e raízes de mandioca. Economic damage caused by lacebug upon cassava root and foliage yield. *Sci Agrar* 10: 151–155
- Froeschner RC (1993) The neotropical lace bugs of the genus *Vatiga* (Hemiptera : Tingidae), pests of cassava : new synonymies and key to species. *Proc Entomol Soc Wash* 95:457–462
- Guidoti M, Montemayor SI, Guilbert É (2015) Lace bugs (Tingidae), in: Panizzi AR, Grazia J (Eds.), *True bugs (Heteroptera) of the Neotropics*. Springer Dordrecht, New York and London, pp. 395–422. https://doi.org/10.1007/978-94-017-9861-7_6
- Hadi MS, Taufiqurrahman AF, Choliq FA, Istiqomah I, Karindah S (2020) Pathogenicity of entomopathogenic fungi *Lecanicillium lecanii* against predator insect *Menochilus sexmaculatus*. *Planta Trop J Agrosains (Journal Agro Sci)* 8: 63–68. <https://doi.org/10.18196/pt.2020.115.63-68>
- Halbert S (2010) The cassava lace bug, *Vatiga illudens* (Drake) (Hemiptera : Tingidae), A new exotic lace bug in Florida. Florida. Ministry of Agriculture of the Republic of Indonesia (2020) Peraturan Menteri Pertanian No. 25 Tahun 2020 tentang jenis organisme pengganggu tumbuhan Karantina. Jakarta.
- Montemayor SI, Dellapé PM, Melo MC (2015) Predicting the potential invasion suitability of regions to cassava lacebug pests (Hemiptera: Tingidae: *Vatiga* spp.). *Bull Entomol Res* 105:173–181. <https://doi.org/10.1017/S0007485314000856>
- Muhtady MC, Fitri I (2021) Exploration and identification of entomopathogen *Lecanicillium* sp. with baiting insect method. *J Mat Sains* 1:99–106
- Oliveira MAS, Fialho J de F, Alves RT, Oliveira JNS, Gomes AC (2001) Dinâmica populacional do percevejo-de-renda (*Vatiga illudens*) na cultura da mandioca no Distrito Federal. *EMBRAPA, Bol Pesqui e Desenvol*. 15
- Ospina MA, Tran T, Pizarro M, Luna J, Salazar S, Londoño L, Ceballos H, Becerra Lopez-Lavalle LA, Dufour D (2024) Content and distribution of cyanogenic compounds in cassava roots and leaves in association with physiological age. *J Sci Food Agric* 104(8):4851–4859. <https://doi.org/10.1002/jsfa.13123>
- Pathania M, Verma A, Singh M, Arora PK, Kaur N (2020) Influence of abiotic factors on the infestation dynamics of whitefly, *Bemisia tabaci* (Gennadius 1889) in cotton and its management strategies in North-Western India. *Int J Trop Insect Sci* 40:969–981. <https://doi.org/10.1007/s42690-020-00155-2>
- Pietrowski V, Wengrat APG da S, Barilli DR, Carvalho LC, Guerreiro JC, Souza-Filho MF de, Ringenberg R (2024) Insetos pragas da cultivo da Mandioca na Região Centro-Sul do Brasil, Embrapa Agropecuaria Oeste; IAC: Campinas; Embrapa Mandioca e Fruticultura. Edunioeste, Cascavel
- Puspitarini RD, Fernando I, Setiawan Y, Anggraini D, Rizqi HA (2021) First record of the cassava lace bug *Vatiga illudens* (Drake, 1922) (Hemiptera: Heteroptera: Tingidae) from East Java, Indonesia. *Biodiversitas* 22: 2870–2876. <https://doi.org/10.13057/biodiv/d220738>
- Puspitarini RD, Simbolon AM, Putri C, Ardianto HDB, Rudiantoyo VER, Saputri WP, Muhammad FN, Fernando I (2025) Resistance of ten Indonesian cassava cultivars to the cassava lacebug, *Vatiga illudens* (Drake) (Hemiptera: Tingidae), a newly invasive exotic

- species in Asia. *Crop Prot* 193:107208. <https://doi.org/10.1016/j.cropro.2025.107208>
- Santos JKB dos, Santos TT dos, Chagas AB, Santos E dos, Silva DJ da, Araujo A da S, Pinheiro RA, Barbosa JPF, Neves JDS das, Wengrat APG da S, Barros RP de (2019) Correlation of climatic elements with phases of the lace bug *Vatiga illudens* (Hemiptera: Tingidae) in two cassava cultivars (*Manihot esculenta* Crantz, Euphorbiaceae). *African J Agric Res* 14: 582–587. <https://doi.org/10.5897/ajar2018.13780>
- Souma J, Kamitani S (2020) Taxonomic review of the lace bug genus *Omolax* (Hemiptera: Heteroptera: Tingidae) endemic to “Oriental Galapagos” (The Ogasawara Islands, Japan) with the description of its new allied genus and species. *Entomol Sci* 24:3–11. <https://doi.org/10.1111/ens.12445>
- Sudiarta IP, Dinarkaya SM, Devi KS, Ariyanta IPB, Wirya GNAS, Sugiarta D, Selangga DGW, Gargita IWD, Wiguna PPK, Yulidhi KA, Devi PS (2024) Occurrence of cassava lace bug *Vatiga illudens* (Drake, 1922) (Hemiptera: Heteroptera: Tingidae) in Bali, Indonesia. *J Trop Biodivers Biotechnol* 9: 1–7. <https://doi.org/10.22146/jtbb.87438>
- Suroto A, Tarjoko T, Oktaviani E, Fauziah JN (2023) Uji paksa serangan *Vatiga illudens* (Drake, 1992) (Hemiptera: Tingidae) pada tanaman singkong varigata (*Manihot esculenta* var. Variegata) di Screenhouse Fakultas Pertanian UNSOED, in: *Proceedings Series on Physical & Formal Sciences*. UMP Press, pp. 260–264. <https://doi.org/10.30595/pspfs.v5i.731>

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