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RESEARCH ARTICLE
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Evaluation of Cassava Clones for Yield Performance and Tolerance to Lace Bug (*Vatiga illudens*) in East Java, Indonesia

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ABSTRACT

Cassava (*Manihot esculenta* Crantz) is a major food and industrial crop in Indonesia, yet its productivity is threatened by insect pests. The cassava lace bug, *Vatiga illudens* (Hemiptera: Tingidae), was recently detected in the country. This study assessed its population density, damage intensity, and potential impact on yield across sixteen cassava clones. A randomized block design with three replications was implemented under screenhouse conditions in Malang and field conditions in Lumajang, East Java. In the screenhouse, adult densities ranged from 4.9 to 20.4 individuals per plant (mean 10.6), with damage intensities from 2.4% to 45.5%. Clone OMM 12-6-112 showed the lowest damage (2.4%), whereas UJ5 and OMM 1207-22 suffered the highest (45.5%). A significant positive correlation was found between adult density and damage intensity (R^2 = 0.727). No lace bug infestation was recorded in the field trial. Tuber yield varied significantly among clones, from 18.41 to 62.27t/ha. Clone OMM 1204-09 combined high yield (62.27t/ha) with relatively low damage (7.6%). These findings provide quantitative evidence of *V. illudens* impact under screenhouse conditions and highlight tolerant clones as promising genetic resources for cassava breeding and sustainable cultivation in infested regions.

Keywords: Clone evaluation, Host plant resistance, *Manihot esculenta*, Pest crop interaction, Screening trial.

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INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is the third most important source of carbohydrates in the tropics after rice and maize. In Indonesia, cassava plays a dual role as a staple food and a raw material for agro-industrial products such as starch, modified cassava flour (mocaf), animal feed, and bioethanol (Tonukari, 2004; Howeler et al., 2013; Khasanah et al., 2024). The roots contain an average starch content of about 31% of fresh weight, with variation ranging from 12% to 33% depending on genotype and growing environment (Anwar et al., 2023). Besides roots, cassava leaves are consumed as vegetables and livestock feed, further highlighting the crop's multifunctional value. In recent years, the expansion of small and medium scale starch industries and food diversification programs in Indonesia has further increased the strategic role of cassava as both a food security and industrial commodity (Puspitarini et al., 2025).

Indonesia ranks among the world's largest cassava producers, following Nigeria, Brazil, and Thailand. National production reached 16.7 million tons in 2023, with an average productivity of 24.65t/ha (Ardyani et al., 2022; Pusat Data dan Sistem Informasi Pertanian, 2024). Cassava is grown in almost all provinces, with Lampung, Central Java, East Java, and West Java as the main producing regions. East Java alone contributes nearly 10% of national cassava output, underlining its importance for food security and local agroindustry. However, productivity remains below the potential yield of improved varieties, largely because cultivation is dominated by smallholders who rely on low input systems and face recurrent biotic and abiotic constraints (Howeler, 2014).

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Despite its economic value, cassava is largely cultivated by smallholder farmers using traditional practices, often with minimal inputs and limited pest controls (Mawaddah et al., 2018; Ngongo et al., 2022). Consequently, cassava fields are vulnerable to pest outbreaks that significantly reduce productivity. In Indonesia, major insect pests include mites, mealybugs, hornworms, and scale insects (Saleh et al., 2013; Sidarlin et al., 2020; Puspitarini et al., 2024). Globally, insect pests such as whiteflies (*Bemisia tabaci*), mealybugs (*Phenacoccus manihoti*), and green mites (*Mononychellus tanajoa*) are well known for lowering photosynthetic efficiency and tuber yield (Calatayud & Le Rü, 2006; Bellotti et al., 2012; Supartha et al., 2022; Mkamilo et al., 2024; Anushka et al., 2025). Under tropical conditions, sap-sucking pests tend to proliferate rapidly because their development and reproduction are strongly favored by warm temperatures and continuous host availability (Deutsch et al., 2018).

Among these pests, lace bugs (*Vatiga* spp., Hemiptera: Tingidae) are recognized as serious constraints in Latin America, where severe infestations may result in considerable reductions in leaf photosynthetic capacity and root production. Historical and ecological evidence indicate that *Vatiga* species have long been recognized as economically important pests of cassava (Bellotti et al., 1999). Species of *V. illudens* is regarded as a major pest of cassava in its native regions, particularly in Brazil (Androcioli et al., 2022). The lace bug *Vatiga illudens* has recently been confirmed in Indonesia, first reported from East Java in 2021 (Puspitarini et al., 2021). This invasive species feeds on the abaxial leaf surface, causing chlorotic spotting, necrotic lesions, premature leaf drop, and in severe cases, substantial yield reduction. Studies in Brazil have demonstrated that feeding injury by *Vatiga* spp. reduces chlorophyll content, disrupts stomatal conductance, and suppresses photosynthetic rate, thereby leading to significant declines in biomass accumulation and marketable root yield (Fialho et al., 2009; Wengrat et al., 2020). These physiological impacts align with broader cassava ecophysiological principles described by El-Sharkawy (2004), reinforcing the biological plausibility of the damage symptoms now observed in Indonesia.

Recent local surveys in Banyumas and West Sumatra (2024–2025) reported high attack intensity and population density of *V. illudens*, with variations in attack levels between cassava accessions. The pest shows potential to cause significant losses, emphasizing the importance of integrated pest management (IPM) strategies, which rely on natural enemies, environmental factors, and plant varieties (Suroto et al., 2024; Suroto et al., 2025). Research indicates that V. illudens population size continues to increase during a single 30-day life cycle, and factors such as cassava accession, day length, temperature, and humidity influence population growth and spread. Compatibility varies among cassava varieties, with vegetable cassava from Gumelar District being more susceptible and variegated cassava from Sumbang District less so.

Yield losses of cassava due to *Vatiga* attack have been documented in several Latin American countries. Verified accounts summarized by Bellotti et al. (1999) demonstrated that *Vatiga* infestations can substantially reduce cassava productivity through chronic defoliation and impaired photosynthesis. Additional reports from Indonesia confirm new outbreaks in Asia, showing high infestation levels in East Java, Sumatra, and Bali (Sudiarta et al., 2024; Hamid et al., 2025; Suroto et al., 2025). Although no long-term yield-loss studies have yet been conducted in Indonesia, these international findings highlight the need for local assessments, especially given the rapid spread of *V. illudens* in several cassava-growing regions of East Java since its initial detection. Despite these reports, information on the population density and damage intensity of *V. illudens* in Indonesia remain scarce. Equally limited are studies linking cassava clone performance under lace bug infestation to tuber yield. Understanding such relationships is essential for resistance breeding and integrated pest management (IPM). Existing national reports mention the occurrence of leaf chlorosis and premature defoliation in multiple production centers, but quantitative data on infestation intensity, genetic variability in susceptibility, and potential yield penalties remain poorly documented (Puspitarini et al., 2025). Recent global reviews, such as Orek (2024), highlight similar knowledge gaps in sub-Saharan African and emphasize the need for integrated approaches combining host-plant resistance, ecological monitoring, and improved farmer awareness. This knowledge gap is particularly critical because farmers frequently attribute leaf yellowing to nutrient deficiency rather than insect damage, leading to delayed or inappropriate management actions.

The ecological behavior of *V. illudens* in its invaded range may also differ from its Latin American counterparts due to climatic differences and the diversity of cassava clones cultivated in Indonesia. Climatic suitability analyses conducted for related Tingidae species (Montemayor et al., 2015) and broader evidence on climate-driven pest expansion (Lehmann et al., 2020) indicate that Indonesia's warm-humid conditions likely facilitate establishment and sustained population growth of *V. illudens*. Year-round cassava cultivation further enables multiple overlapping generations, which could exacerbate its pest status if left unmanaged.

Moreover, global cassava improvement programs—particularly those coordinated by the Alliance of Bioversity International and CIAT—have generated germplasm with superior yield, disease resistance, and abiotic stress tolerance. However, breeding specifically for arthropod pest resistance, including lace bugs, has received comparatively little emphasis. Substantial advances in modern breeding tools have strengthened cassava genetic improvement, including the establishment of genomic selection pipelines (Wolfe et al., 2017) and genome-wide association analyses that clarified the genetic basis of major diseases such as cassava mosaic disease (Wolfe et al., 2016). In parallel, improvements in genotyping capacity, high-throughput phenotyping, and breeding operational frameworks have been documented by Rabbi et al. (2017), demonstrating that global cassava programs now possess robust genomic resources. Despite these developments, characterized sources of resistance to sap-sucking insects remain limited, and no dedicated breeding efforts have yet targeted lace bug resistance, restricting the availability of cultivars capable of withstanding *V. illudens* pressure. In Indonesia, studies on clone-specific resistance to sap-sucking insects have primarily focused on whiteflies and mites, leaving resistance to lace bugs largely unexplored.

Taken together, the recent emergence of *V. illudens* in Indonesia, coupled with limited local research on its biology, population dynamics, and impact on yield, underscores an urgent need for systematic evaluation. Smallholder farmers relying on cassava as a major food and income source remain vulnerable to this invasive pest. Therefore, this study was conducted to (i) evaluate the population density and damage intensity of *V. illudens* across sixteen cassava clones under screenhouse conditions, (ii) analyze the relationship between insect population and leaf damage, and (iii) assess yield performance of the tested clones under field conditions in East Java.

MATERIALS & METHODS

This study was conducted in two locations in East Java, Indonesia, during 2021. The screenhouse experiment was carried out in Malang Regency (latitude −8.0475, longitude 112.6250; 436m above sea level; temperature 30°C; humidity 80%) while the field experiment was conducted in Lumajang Regency (latitude −8.1829, longitude 113.0734; 100m above sea level; temperature 32°C; humidity 73-81%). Malang represents a cooler midland environment, whereas Lumajang represents a warmer lowland environment (Fig. 1).

Screenhouse Trial

The experiment evaluated 16 cassava genotypes, including 13 promising clones (OMM 1207-22, OMM 1207-57, OMM 1207-50, MLG 10311-25Gy-1, MLG 10311-50Gy-105, OMM 1201-63, OMM 1204-09, OMM 1204-36, OMM 1206-091, OMM 12-6-112, OMM 12-6-50, OMM 12-7-48, and Adira-4-10Gy-7) and three released cultivars used as checks (Adira-1, Adira-4, and UJ-5). A randomized block design with three replications was applied. Stem cuttings (25cm) were planted in 30cm diameter pots containing 5kg of soil, with one cutting per pot. Basal fertilization was applied at planting with 5–10g of NPK fertilizer per pot, and irrigation was provided as needed (Howeler et al., 2013).

Field Trial

The field experiment was conducted in Lumajang Regency during the 2021 rainy season using the same 16 cassava genotypes in a randomized block design with three replications. Stem cuttings (25cm) were planted vertically at 1m × 1m spacing in plots measuring 5m × 7m. Fertilizer was applied twice, at one and three months after planting, equivalent to 500kg Phonska and 100kg urea per hectare, following regional recommendations for cassava production (Howeler et al., 2013). Weeding and hilling were performed simultaneously with fertilization, while pruning was carried out at six weeks after planting by retaining two vigorous shoots. Other crop management practices, including pest and disease control, followed standard cassava cultivation recommendations (Howeler et al., 2013).

Data Collection

In the screenhouse experiment, leaves infested by lace bugs were collected and stored at 4°C for one hour to immobilize the insects, which were then examined under a Universal Serial Bus (USB) digital microscope. Adult populations were counted at two months after planting, when infestation first appeared, using a hand counter. Damage intensity was scored on a 0–4 scale following Bellotti et al. (1999):

- 0 = no symptoms (healthy leaves)
- 1 = ≤ 25% leaf area attacked
- 2 = 26–50% leaf area attacked
- 3 = 51–75% leaf area attacked
- 4 = 76–100% leaf area attacked

Damage intensity (I) was calculated using the formula:

$$I = \frac{\Sigma(n \times v)}{N \times V} \times 100\%$$

Where n = number of leaves in each score category, v = score value, N = total number of leaves observed, and V = maximum score.

Fig. 1: Locations of Malang (midland) and Lumajang (lowland) in East Java, Indonesia, representing contrasting environments in the present study.

In the field experiment, growth traits were measured as plant height at three and six months after planting, using three sample plants per plot. At harvest (10 months), yield components were recorded, including the number and weight of small and large tubers, and total fresh tuber yield.

Data Analysis

Data were subjected to analysis of variance (ANOVA) using Minitab 22.1 software. When significant differences were detected, mean comparisons were performed using the Least Significant Difference (LSD) test at the 5% probability level (Steel & Torrie, 1997). Additionally, cluster analysis was conducted to classify cassava genotypes based on their yield performance and tolerance to lace bug infestation (Mohammadi & Prasanna, 2003).

RESULTS

Screenhouse Trial

Insect Identification

Observations using a USB digital microscope revealed lace bug adults and nymphs at various instar stages on the abaxial leaf surface of cassava (Fig. 2). Adults were greyish brown in colour and measured around 3 mm in length, while nymphs were pale white with darker antennae in older stages (Fig. 3). All specimens collected in this study were morphologically identified as *Vatiga illudens*.

Fig. 2: Adult and nymph stages of lace bug (*V. illudens*) on cassava leaves under a USB digital microscope.

Symptoms of Lace Bug Attack on Cassava

Affected leaves initially displayed chlorotic spots along the veins, which developed into reddish-brown necrotic lesions. In advanced stages, leaves turned yellow and frequently abscised prematurely (Fig. 4). Lace bugs typically move by walking rather than flying when disturbed.

Population and Plant Damage

Lace bugs infested all cassava clones tested, but population density and damage intensity varied (Table 1). The mean adult population was 10.6 individuals per plant, ranging from 4.9 (OMM 12-6-112) to 20.4 (UJ5). Damage intensity ranged from 2.4% (OMM 12-6-112 and Adira 4) to 45.5% (UJ5 and OMM 1207-22). Regression analysis revealed a strong positive correlation between adult population density and plant damage (r = 0.853, R^2 = 0.727; Fig. 5).

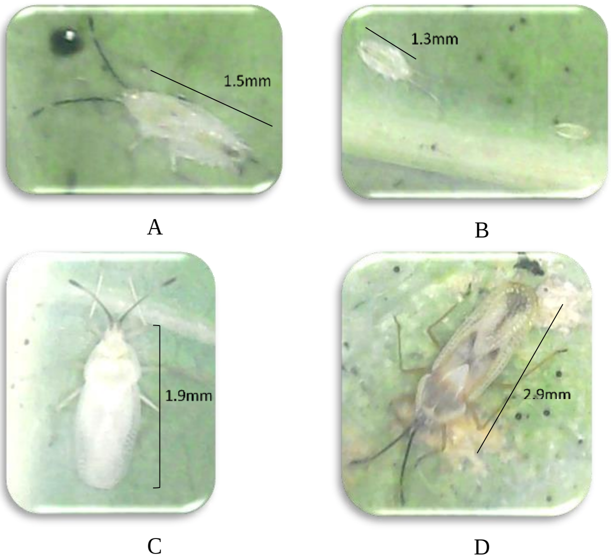

Fig. 3: Nymphal instars (A–C) and adult (D) of lace bug observed under magnification.

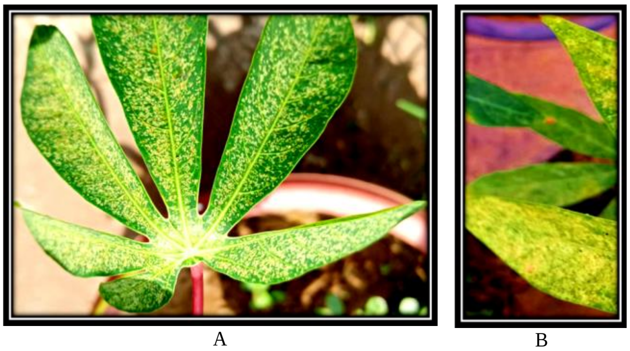

Fig. 4: Symptoms of cassava lace bug attack: (A) early chlorotic spots; (B) advanced necrotic lesions and leaf abscission.

Table 1: Adult population density and damage intensity of lace bug (*V. Illudens*) on 16 cassava clones at two months after planting under screenhouse conditions.

Cassava clones	Adult and nymph population density	Damage intensity (%)
UJ5	20.4a	45.5a
OMM 1207-22	17.5ab	45.5a
OMM 1207-57	10.0cde	9.0bc
OMM 1207-50	13.1bcd	12.8b
MLG 10311-25Gy-1	10.4cde	12.9b
MLG 10311 50Gy-105	10.3cde	12.2b
OMM 1201-63	9.4de	8.5bc
OMM 1204-09	7.9de	7.6bc
OMM 1204-36	6.1e	4.7bc
OMM 1206-091	10.5cde	9.4bc
OMM 12-6-112	4.9e	2.4c
OMM 12-6-50	9.2de	5.3bc
OMM 12-7-48	9.5de	7.6bc
Adira-1	5.2e	2.9c
Adira-4-10Gy-7	16.4abc	11.2bc
Adira 4	9.4de	2.4c
Mean	10.6	12.5
LSD 5%	5.9	7.6
CV (%)	23.1	26.7

Note: Values followed by different letters within a column differ significantly according to the Least Significant Difference (LSD) test at P<0.05.

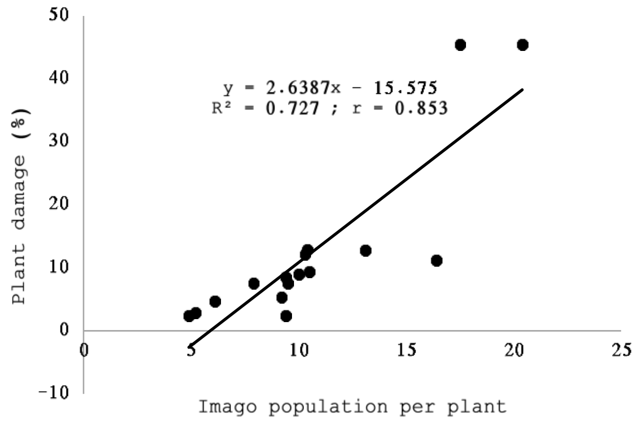

Fig. 5: Relationship between lace bug (adult+nymph) population (X) and cassava leaf damage intensity (Y).

Field Trial

Significant differences were observed among cassava clones for most yield parameters, except the number of small and large tubers (Table 2). Large tuber weight per plant ranged from 2.278 to 6.167kg, while small tuber weight varied between 0.233 and 0.800kg. Fresh tuber yield per hectare ranged from 18.41 to 62.27t/ha, with an overall mean of 47.85t/ha. Nine clones surpassed the mean yield, including OMM 1207-22, OMM 1207-57, MLG 10311-25Gy-1, MLG 10311-50Gy-105, OMM 1204-09, OMM 1204-36, OMM 1206-091, OMM 12-6-112, and OMM 12-6-50. Field observations indicated that no lace bug or red mite infestations were recorded in Lumajang field plots during the trial period.

Table 2: Yield and yield components of 16 cassava clones at Lumajang, East Java, Indonesia

Cassava clones	Number of tubers per plants		Tuber weight per plant (kg)		Tuber yield (t/ha)
	Large	Small	Large	Small	
OMM 1207-22	9.667	4.000	6.167a	0.722a	49.85abc
OMM 1207-57	7.556	2.333	5.111a	0.511ab	55.16ab
OMM 1207-50	6.667	2.333	4.394ab	0.239b	46.99bc
MLG 10311-25Gy-1	7.444	3.333	4.939a	0.428ab	52.60ab
MLG 10311-50Gy-105	7.667	3.778	5.417a	0.533ab	53.66ab
OMM 1201-63	7.667	3.000	4.644a	0.339ab	37.55c
OMM 1204-09	5.333	2.556	5.744a	0.539ab	62.27a
OMM 1204-36	6.111	1.889	4.250ab	0.261b	47.98abc
OMM 1206-091	8.111	3.556	4.100ab	0.361ab	52.66ab
OMM 12-6-112	6.667	3.000	4.306ab	0.344ab	51.34abc
OMM 12-6-50	8.111	3.333	5.167a	0.489ab	52.65ab
OMM 12-7-48	6.667	4.667	3.994ab	0.522ab	43.58bc
Adira 1	7.889	2.778	2.278b	0.233b	18.41d
Adira 4-10Gy-7	7.556	3.667	4.972a	0.478ab	40.93bc
UJ 5	7.111	3.000	4.839a	0.372ab	54.15ab
Adira 4	8.222	4.333	5.078a	0.489ab	53.76ab
Mean	7.42	3.22	4.704	0.429	48.30
F test	ns	ns	*	*	*
LSD 5%	2.82	1.98	1.28	0.25	7.89
CV (%)	22.81	36.83	16.36	34.49	9.79

Note: Values followed by different letters within a column differ significantly according to the Least Significant Difference (LSD) test at P<0.05.

Cluster analysis grouped the cassava clones into three clusters (Fig. 6). Cluster 1 included OMM 1207-22 and Adira 4. Cluster 2 contained most clones with moderate-to-high yield and relatively lower lace bug damage. Cluster 3 consisted solely of Adira 1, which showed the lowest yield performance.

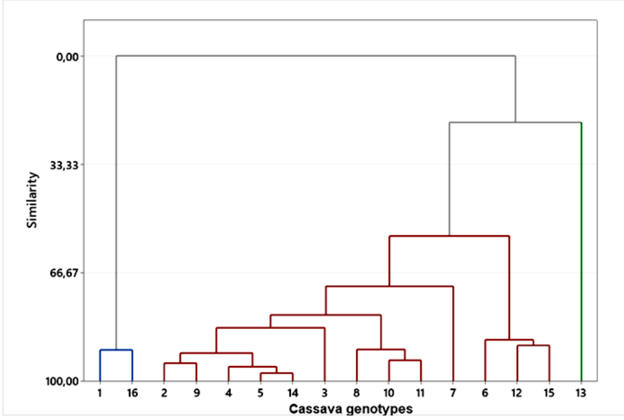

Fig. 6: Cluster analysis of cassava clones based on tuber yield, yield components, and lace bug damage intensity.

DISCUSSION

The morphological traits observed under the USB digital microscope, including body color, antennal banding, and nymphal instar progression, were consistent with diagnostic descriptions of *Vatiga illudens* (Froeschner, 1993; Bellon et al., 2012; Wengrat et al., 2020). This morphological agreement supports the species identification made in the present study.

The detection of only *V. illudens* is in line with earlier studies, although in Latin America overlapping occurrences with *V. manihotae* have been reported (Bellotti et al., 1999; Bellon et al., 2012). Feeding behavior and associated symptoms recorded here, including the progression from chlorotic spots to necrosis and eventual leaf abscission, were also similar to previous observations (Alves and Ster, 2004; Nabity et al., 2009). In severe infestations, total defoliation has been documented (Androcioli et al., 2022).

Significant variation in lace bug population density and the extent of plant damage was observed among the evaluated cassava clones. Clones OMM 12-6-112 and the released cultivar Adira 1 maintained the lowest insect populations and exhibited only minimal injury, indicating the presence of resistance-related traits. Such resistance may be associated with morphological barriers or biochemical defence mechanisms. Supporting this, Vieira et al. (2011) found that cassava roots with higher cyanogenic potential experienced reduced lace bug infestations, which may help explain the lower pest pressure observed in certain clones in the present study.

Piercing-sucking herbivores, including lace bugs and mites, have evolved behavioural and physiological strategies that allow them to avoid or tolerate defensive metabolites, thereby reducing the activation of cyanogenesis (Boter and Diaz, 2023; Martinez and Diaz, 2024). Nonetheless, plant cyanogenic responses can influence pest performance. Arnaiz et al. (2022) demonstrated that *Arabidopsis thaliana* increases its HCN content when attacked by *Tetranychus urticae*, resulting in reduced leaf damage and lower mite fecundity. Similarly, *T. urticae* was reported to preferentially feed on cassava cultivars with low HCN levels (Wu et al., 2025a), while its development and reproduction were shown to be inhibited by cyanogenic glycosides (Wu et al., 2025b). Additional studies have also documented the negative effects of HCN and other cyanogenic glucosides on insect biological performance (Nguyen, 2022; Boter & Diaz, 2023; Yadav et al., 2023; Martinez & Diaz, 2024). These compounds are typically more abundant in young leaves (Boter and Diaz, 2023; Yadav et al., 2023; Krasuska et al., 2024).

High cyanogenic content in cassava is known to contribute to plant resistance and is advantageous for the starch production; however, its bitter taste limits its suitability for fresh consumption (Moses et al., 2025). In contrast to the resistant clones, UJ5 and OMM 1207-22 supported higher lace bug populations and sustained greater damage, suggesting that these clones provide more favourable conditions for oviposition and development. Adequate nutritional quality of the host plant is essential for female fecundity and longevity (Panizzi & Parra, 2012; Wengrat et al., 2020). Resistant cassava clones have been shown to prolong nymphal duration, decrease fecundity, and shorten adult lifespan, thereby limiting population growth (Awmack & Leather, 2002).

The strong positive correlation between insect density and damage (r = 0.853) underlines the direct role of population buildup in yield loss. According to Bellotti & Schoonhoven (1978), lace bug populations typically rise rapidly during the first three months of cassava growth, a period when plants are most vulnerable. This emphasizes the need for early monitoring and prompt pest management practices.

High yield performance was achieved by some clones, such as OMM 1204-09 (62.27t/ha) and OMM 12-6-112 (51.34t/ha), which also showed low damage in screenhouse tests. These clones represent strong candidates for future release, as they combine resistance with productivity. Such cases are valuable for breeding programs, since trade-offs between resistance and yield are commonly observed. For example, Adira 1 was resistant but relatively low yielding, whereas UJ5 was susceptible but moderately productive. Identifying clones like OMM 12-6-112, which overcome this trade-off, is critical for cassava improvement in Indonesia. Resistance in cassava to insect pests is usually polygenic and horizontal, making it difficult to inherit in breeding programs (Vendramim & Nishikawa, 2001). Cyanogenic compounds are believed to contribute to resistance, since higher hydrocyanic acid concentrations are correlated with lower infestation (Cosenza et al., 1981; Vieira et al., 2011).

Cluster analysis further highlighted differences among clones in terms of resistance and yield potential (Stam & McDonald, 2018). These findings reinforce the importance of integrating pest resistance into selection criteria to ensure both productivity and stability in future cassava cultivars. Interestingly, no lace bug infestation was detected in field trials conducted in Lumajang. This finding aligns with Puspitarini et al. (2021), who stated that the occurrence of lace bug was confirmed in Malang, Pasuruan, Blitar, Mojokerto, and Probolingo. However, the introduction pathway of the lace bug to East Java is still unknown. Based on the results of this initial survey, lace bug has not yet spread to the westernmost (Ngawi) and easternmost (Jember, Bondowoso, and Banyuwangi) regions of East Java. This absence may be attributed to environmental conditions, particularly the timing of planting during the rainy season, when lace bug populations are typically suppressed. Previous studies have reported that lace bug outbreaks are more frequent and severe during dry periods, with higher temperatures and lower humidity favouring population buildup (Halbert, 2016; Bellon et al., 2017; dos Santos et al., 2019). Such seasonal effects could have masked pest pressure in the field and explain the contrast with screenhouse results. These findings suggest that although several cassava clones demonstrated promising tolerance under controlled infestation, their performance under natural field conditions requires further validation across multiple environments and planting seasons to ensure stable resistance expression. The absence of nearby infested cassava fields or natural reservoirs of lace bugs could have prevented migration or introduction into the trial site. This is particularly relevant for *Vatiga illudens,* which is native to certain regions and may not have been present in the area where the trial was conducted.

Globally, *V. illudens* exhibits high adaptability, enabling rapid establishment in new regions, including Southeast Asia. Comparative studies from Latin America, Africa, and Asia highlight differences in biological traits, behaviour, and damage levels. In Latin America, as the native range, population densities are largely controlled by natural enemies such as parasitoids, predators, and entomopathogenic pathogens, allowing relatively stable ecosystem dynamics. Recent studies have also emphasized biological control strategies, including the application of *Beauveria bassiana* to suppress populations (Loureiro et al., 2023). In Africa, *V. illudens* is emerging as an invasive pest with limited but increasing spread, due to suitable climates and lack of established natural enemies, as predicted by potential invasion models (Montemayor et al., 2015). In Asia, particularly Indonesia, *V. illudens* is a newly introduced exotic pest with high infestation levels, reflecting both rapid adaptation to warm-humid conditions and minimal natural enemy pressure (Puspitarini et al., 2021; Suroto et al., 2024; Sudiarta et al., 2024; Hamid et al., 2025). Climate change further amplifies its potential by extending suitable habitats and altering generational overlap (Lehmann et al., 2020; Orek, 2024).

Environmental drivers, such as temperature, humidity, altitude and planting season, significantly influence *V. illudens* development and population dynamics. Screenhouse trials demonstrated consistent infestation, whereas field trials in Lumajang showed no infestation, highlighting environmental suppression of pest activity. Soil fertility and cassava nutritional status further modulate pest density and damage. This underscores the importance of understanding local environmental effects for predicting infestation risk and tailoring management strategies. Although this study was conducted at a single location and season, the differential responses of clones under screenhouse and field conditions indicate potential environment-related variation in resistance expression. Clone responses differed across conditions, with OMM 12-

6-112 and Adira 4 showing low infestation and damage, whereas UJ5 remained highly susceptible. These interactions emphasize the need to consider G×E in breeding programs, aiming to develop clones with stable resistance across environments. However, formal genotype × environment analysis requires multi-location and multi-season testing. Therefore, the present findings should be interpreted as preliminary indications of environmental influence rather than confirmed G×E interactions. The implications for sustainable agriculture are substantial. Resistant cultivars help stabilize yields, reduce pesticide dependence, preserve biodiversity, and maintain ecosystem services. Combining resistant varieties with cultural practices, environmental monitoring, and biological control forms the basis of effective integrated pest management (IPM) strategies. This approach aligns with the principles of ecologically and economically sustainable agriculture. Taken together, the results highlight the importance of considering environmental factors, resistance traits, and local pest ecology when selecting cassava clones for areas threatened by *V. illudens*. These insights provide a foundation for refining future research directions and improving pest mitigation strategies.

Conclusion

The cassava lace bug (*Vatiga illudens*) was detected in Malang Regency, East Java, with infestation intensity ranging from 2.4% to 45.5% under screenhouse conditions. Significant variation in tolerance was observed among the 16 cassava clones tested. Clone OMM 1204-09 exhibited the highest tuber yield (62.67t/ha) with relatively low damage (7.6%), while OMM 12-6-112 combined the lowest damage intensity (2.4%) with high yield potential (51.34t/ha). In contrast, no lace bug incidence was recorded in the Lumajang field trial during the study period. These findings highlight the availability of tolerant and high-yielding cassava clones that may serve as promising candidates for cultivation and genetic improvement in areas exposed to *V. illudens*.

DECLARATIONS

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REFERENCES

Alves, R.T., & Ster, J.P. (2004). Biology and damage of *Vatiga spp.* in cassava. *Pesquisa Agropecuária Brasileira*, 39(9), 871–878. https://doi.org/10.1590/S0100-204X2004000900004

Androcioli, H.G., Hoshino, A.T., Gisloti, L.J., Kawashima, A.B., Oliveira, L.M., Ventura, M.U., Guide, B.A., Hata, F.T., & Menezes Jr., A.D. (2022). Occurrence and distribution of lace bug, whitefly, and shoot fly pest species on cassava (Manihot esculenta) crops according to region in Paraná State, Brazil. *Semina: Ciências Agrárias,* 43(1), 311–330. https://doi.org/10.5433/1679-0359.2022v43n1p311

Anushka, S.R., Santhoshkumar, T., Harish, E.R., & Narayana, R. (2025). Management of sucking pests of tapioca. *International Journal of Advanced Biochemistry Research*, 9(10), 489–493. https://www.doi.org/10.33545/26174693.2025.v9.i10g.6088

Anwar, S., Santosa, E., & Purwono, (2023). Cassava growth and yield on ultisol of different soil organic carbon content and NPK fertilizer levels. *Journal Agronomi Indonesia,* 51(3), 312-323. https://doi.org/10.24831/jai.v51i3.47806

Ardyani, N.P., Gunawan, B., & Harahap, J. (2022). Ekologi politik budidaya singkong di Kecamatan Arjasari Kabupaten Bandung Provinsi Jawa Barat. *Aceh Anthropological Journal*, 6(2), 137. https://doi.org/10.29103/aaj.v6i2.8040

Arnaiz, A., Santamaria, M.E., Rosa-Diaz, I., Garcia, I., Dixit, S., Vallejos, S., Gotor, C., Martinez, M., Grbic, V., & Diaz, I. (2022). Hydroxynitrile lyase defends Arabidopsis against *Tetranychus urticae*. *Plant Physiology*, 189(4), 2244–2258. https://doi.org/10.1093/plphys/kiac170

Awmack, C.S., & Leather, S.R. (2002). Host plant quality and fecundity in herbivorous insects. *Annual Review of Entomology*, 47, 817–844. https://doi.org/10.1146/annurev.ento.47.091201.145300

Bellon, P.P., da Silva Wengrat, A.P.G., Kassab, S.O., Pietrowski, V., & Loureiro, E.S. (2012). Occurrence of lace bug *Vatiga illudens* and *Vatiga manihotae* (Hemiptera: Tingidae) in Mato Grosso do Sul, Midwestern Brazil. *Anais da Academia Brasileira de Ciências* 84(3): 703–705. https://doi.org/10.1590/S0001-37652012000300012

Bellon, P.P., da Silva Wengrat, A.P.G., Kassab, S.O., Pietrowski, V., & Loureiro, E.S. (2017). Populational fluctuation of lace bug in cassava. *Arquivos do Instituto Biológico*, 84, e0602015. https://doi.org/10.1590/1808-1657-0000602015

Bellotti, A.C., Arias, B.V., Vargas, O.H., Reyes, J.A., & Guerrero, J.M. (2012). Insects and mites that attack cassava and their control. In B. Ospina & H. Ceballos (Eds.), *Cassava in the third millennium: modern production, processing, use and marketing systems* (pp. 213–250). https://hdl.handle.net/10568/54610

Bellotti, A.C., & Schoonhoven, A.V. (1978). Mite and insect pests of cassava. *Annual Review of Entomology*, 23, 39–67. https://doi.org/10.1146/annurev.en.23.010178.000351

Bellotti, A.C., Smith, L., & Lapointe, S.L. (1999). Recent advances in cassava pest management. *Annual Review of Entomology,* 44(1), 343-370. https://doi.org/10.1146/annurev.ento.44.1.343

Boter, M., & Diaz, I. (2023). Cyanogenesis, a plant defence strategy against herbivores. *International Journal of Molecular Sciences*, 24(8), 6982. https://doi.org/10.3390/ijms24086982

Calatayud, P.A., & Le Rü, B. (2006). *Cassava–mealybug interactions* (eds.). IRD Éditions / CIRAD. (See chapter on cassava plant and pest interactions). Available: https://books.openedition.org/irdeditions/9872

Cosenza, G.W., Bellotti, A.C., & Lozano, J.C. (1981). Relationships between hydrocyanic acid potential and resistance of cassava to *Phenacoccus manihoti* and *Mononychellus tanajoa*. *Journal of Economic Entomology*, 74(6), 784–787. https://doi.org/10.1093/jee/74.6.784

Deutsch, C., Tewksbury, J.J., Tigchelaar, M., Battisti, D., Merrill, S.C., & Naylor, R.L. (2018). Increase in crop losses to insect pests in a warming climate. *Science,* 361(6405), 916-919. https://doi.org/10.1126/science.aat3466

dos Santos, J.K.B., dos Santos, T.T., Chargas, A.B., dos Santos, E., de Sauza Silva, A.V., da Silva, D.J., da Silva Araujo, A. Pinheiro, R.A., Barbosa, J.P.F., das Neves, J.D.S., da Silva Wengrat, A.P.G., & de Barros, R.P. (2019). Correlation of climatic elements with phases of the lace bug *Vatiga illudens* (Hemiptera: Tringidae) in two cassava cultivars (*Manihot esculenta* Crantz, Euphorbiaceae). *African Journal of Agricultural Research*, 14(9), 559-564.

El-Sharkawy, M.A. (2004). Cassava biology and physiology. *Plant Molecular Biology,* 56, 481-501. https://doi.org/10.1007/s11103-005-2270-7

Fialho, J.F., Vieira, E.A., Paula-Moraes, S.V.P., Silva, M.S., & Junqueira, N.T.V. (2009). Danos causados por percevejo-de-renda na produção de parte aérea e raízes de mandioca. *Scientia Agraria Paranaensis*, 10, 151–155.

Froeschner, R.C. (1993). Lace bug genera of the world, I: Introduction, a review of the New World genera (Hemiptera: Tingidae). *Smithsonian Contributions to Zoology*, 461, 1–29. http://dx.doi.org/10.5479/si.00810282.574

Halbert, S. (2016). *Pest Alert: The Cassava Lace Bug, Vatiga illudens (Drake) (Hemiptera: Tingidae)*. Florida Department of Agriculture and Consumer Services (FDACS). Retrieved from https://www.fdacs.gov/content/download/66881/file/Pest_Alert_-_Vatiga_illudens%2C_The_Cassava_Lace_Bug.pdf

Hamid, H., Anjelina, S., Reflinaldon, R., Yuniswan, Y., & Lina, E.C. (2025). The first report of the cassava lace bug (Hemiptera: Tingidae) and their impact on cassava plants on Sumatra Island, Indonesia. *Journal of the Saudi Society of Agricultural Sciences,* 24, 57. https://doi.org/10.1007/s44447-025-00065-0

Howeler, R.H. (2014). Sustainable soil and crop management of cassawa in Asia: a reference manual. https://cgspace.cgiar.org/bitstream/10568/51590/4/Sustainable_soil_crop_management_cassava_asia_2014.pdf

Howeler, R.H., Lutaladio, N., & Thomas, G. (2013). *Save and grow: Cassava. A guide to sustainable production intensification.* Food and Agriculture Organization of the United Nations (FAO), Rome. Available: https://www.fao.org/3/i3278e/i3278e.pdf

Khasanah, Y., Indrianingsih, A.W., Triwitono, P., & Murdiati, A. (2024). Production, biological activities and functional food of modified cassava flour (mocaf). *Canrea Journal: Food Technology, Nutrition, and Culinary Journal,* 7(2), 213–229. https://doi.org/10.20956/canrea.v7i2.1280

Krasuska, U., Ciacka, K., Staszek, P., Tyminski, M., Wal, A., & Gniazdowska, A. (2024). Hormetic action of cyanide: Plant gasotransmitter and poison. *Phytochemistry Reviews,* 23(3), 705–719. https://doi.org/10.1007/s11101-023-09904-w

Loureiro, E.S., Cruz, P.M.D., Pessoa, L.G.A., Ribeiro, M.D.P., Carnevale, A.B., & Machado, A.C. (2023). Flutuação populacional e controle de *Vatiga illudens* com *Beauveria bassiana. Revista em Agronegócio e Meio Ambiente (RAMA), 16*(1), e11248. https://doi.org/10.17765/2176-9168.2023v16n1e11248

Lehmann, P., Ammunet, T., Barton, M., Battisti, A., Eigenbrode, S.D., Jepsen, J.U., Kalinkat, G., Neuvonen, S., Niemela, P., Terblanche, J.S., Okland, B., & Bjorkman, C. (2020). Complex responses of global insect pests to climate warming. *Frontiers in Ecology and the Environment, 18*(3), 141-150. https://doi.org/10.1002/fee.2160

Martinez, M., & Diaz, I. (2024). Plant cyanogenic-derived metabolites and herbivore counter-defences. *Plants,* 13(9), 1239. https://doi.org/10.3390/plants13091239

Mawaddah, R., Aupeno, B., & Haryanto, H. (2018). Keragaman serangga predator hama kutu putih (*Phenacoccus manihoti*) pada tanaman ubi kayu (*Manihot esculenta* Crantz) di Lombok Utara. *Journal Crop & Agroecology, 1*(2), 1-17.

Mkamilo, G., Kimata, B., Masinde, E.A., Masisila, F.F., Menya, R.O., Matondo, D., & Maruthi, M.N. (2024). Impact of viral diseases and whiteflies on the yield and quality of cassava. *Journal of Plant Diseases and Protection,* 131, 959–970. https://doi.org/10.1007/s41348-024-00903-3

Mohammadi, S.A., & Prasanna, B.M. (2003). Analysis of genetic diversity in crop plants—salient statistical tools and considerations. *Crop Science*, 43(4), 1235–1248. https://doi.org/10.2135/cropsci2003.1235

Montemayor, S.I., Dellape, P.M., & Melo, M.C. (2015). Predicting the potential invasion suitability of regions to cassava lacebug pests (Heteroptera: Tingidae: *Vatiga* spp.). *Bulletin of Entomological Research,* 105(2), 173-181. https://doi.org/10.1017/S0007485314000856

Moses, R.J., Edo, G.I., Jikah, A.N., Emakpor, O.L., & Agbo, J.J. (2025). Cassava consumption and the risk from cyanide poisoning. *Vegetos.* 38, 1713–1724. https://doi.org/10.1007/s42535-024-01121-w

Nabity, P.D., Zavala, J.A., & DeLucia, E.H. (2009). Indirect suppression of photosynthesis on individual leaves by arthropod herbivory. *Annals of Botany*, 103(4), 655–663. https://doi.org/10.1093/aob/mcn127

Ngongo, Y., Sumarno, Y., Nugroho, K., Winarto, E.I., & Koesoemaningtyas, D.R.E. (2022). The roles of cassava in marginal semi-arid farming in East Nusa Tenggara, Indonesia. *Sustainability,* 14(9), 5439. https://doi.org/10.3390/su14095439

Nguyen, T.D. (2022). Plant and pest: The art of (cyanide) war. *Plant Physiology*, 189(4), 1896–1897. https://doi.org/10.1093/plphys/kiac243

Orek, C. (2024). A review of management of major arthopod pests affecting cassava production in sub-Saharan African. *Crop Protection, 175,* 106465. https://doi.org/10.1016/j.cropro.2023.106465

Panizzi, A.R., & Parra, J.R.P. (2012). Insect Bioecology and Nutrition for Integrated Pest Management (1st ed.). CRC Press. https://doi.org/10.1201/b11713

Puspitarini, R.D., Fernando, I., Setiawan, Y., Anggraini, D., & Rizqi, H.A. (2021). First record of the cassava lace bug *Vatiga illudens* (Drake, 1922) (Hemiptera: Tingidae) from East Java, Indonesia. *Biodiversitas,* 22(7), 2870-2876. https://doi.org/10.13057/biodiv/d220738

Puspitarini, R.D., Purwantoro, A., Pradifta, V.D.A., Muhammad, F.N., & Fernando, I. (2024). Abundance of arthropod pests and their natural enemies on cassava fields implementing different agroecosystem management. *Biodiversitas*, 25(9), 2901–2907. https://doi.org/10.13057/biodiv/d250909

Puspitarini, R.D., Simbolon, A.M., Putri, C., Ardianto, H.D.B., Rudiantoyo, V.E.R., Saputri, W.P., Muhammad, F.N., & 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 Protection*, 193, 107208. https://doi.org/10.1016/j.cropro.2025.107208

Pusat Data dan Sistem Informasi Pertanian (2024). *Statistik Pertanian 2024.* Kementerian Pertanian. ISBN: 979-8958-65-9. https://repository.pertanian.go.id/handle/123456789/24656

Rabbi, I.Y., Udoh, L.I., Wolfe, M., Parkes, E.Y., Gedil, M.A., Dixon, A., Ramu, P., Jannink, J.L., & Kulakow, P. (2017). Genome-wide association mapping of correlated traits in cassava: dry matter and total carotenoid content. *The Plant Genome, 10*(3), plantgenome2016.09.0094. https://doi.org/10.3835/plantgenome2016.09.0094

Saleh, N., Rahayu, M., Indiati, S.W., & Radjit, B.S., Wahyuningsih, S. (2013). Hama, penyakit dan gulma pada tanaman ubikayu. Badan Penelitian dan Pengembangan Pertanian, Kementerian Pertanian, Jakarta. IAARD Press.

Sidarlin, I.G., Swibawa, I.G., Hariri, A.M., & Susilo, F.X. (2020). Populasi dan tingkat serangan hama kutu putih pada ubi kayu (Manihot esculenta Crantz) pada beberapa lokasi penanaman di Lampung. *Jurnal Agrotek Tropika*, 8(2), 375–381. https://doi.org/10.23960/jat.v8i2.3912

Stam, P., & McDonald, B.A. (2018). When resistance gene pyramids are not durable—The role of pathogen diversity. *Molecular Plant Pathology*, 19(3), 521–524. https://doi.org/10.1111/mpp.12636

Steel, R.G.D., & Torrie, J.H. (1997). *Principles and procedures of statistics: A biometrical approach* (3rd ed.). McGraw-Hill, New York.

Sudiarta, P., Dinarkaya, S.M., Devi, K.S., Ariyanta, P.B., Wirya, G.N.A.S., Sugiarta, D., Selangga, D.G.W., Gargita, W.D., Wiguna, P.P.K., Yuliadhi, K.A., & Devi, P.S. (2024). Occurrence of cassava lace bug *Vatiga illudens* (Drake, 1922) in Bali, Indonesia. *Journal of Tropical Biodiversity and Biotechnology*, *9*(1), 1–7. https://doi.org/10.22146/jtbb.87438

Supartha, I.W., Widaningsih, D., Susila, I.W., Yudha, I.K.W., Utama, I.W.E.K., & Wiradana, P.A. (2022). Range of host plants, spatial distribution, and insect predator of *Phenacoccus manihoti* (Hemiptera: Pseudococcidae) as an emerging pest of cassava plants in Bali. *Biodiversitas,* 23(6), 3022–3030. https://doi.org/10.13057/biodiv/d230629

Suroto, A., Tarjoko, T., Oktaviani, E., & Khairunnisa, A. (2024). Exploration and description of potential natural enemies of Vatiga illudens in Banyumas, Central Java. *Gontor Agrotech Science Journal*, *10*(1), 11–24. https://doi.org/10.21111/agrotech.v10i1.10841

Suroto, A., Tini, E.W., Fauziah, J.N., & Oktaviani, E. (2025). Study of cassava lace bug (Vatiga illudens Drake 1922) life table on cassava accessions collected from Banyumas Regency, Central Java Province. *Gontor Agrotech Science Journal*, *11*(1), 80–96.

Tonukari, N.J. (2004). Cassava and the future of starch. *Electronic Journal of Biotechnology, 7*(1), 5–8.

Vendramim, J.D., & Nishikawa, M.A.N. (2001). Melhoramento para resistência a insetos. In L. L. Nass, A. C. C. Valois, I. S. Melo & M. C. Valadares-Inglis (Eds.), *Recursos genéticos e melhoramento - plantas* (pp. 737–781). Fundação MT, Rondonópolis. https://repositorio.usp.br/item/001188749

Vieira, E.A., Fialho, J.F., Faleiro, F.G., Bellon, G., da Fonseca, K.G., Carvalho, L.J.C.B., Silva, M.S., de Paula-Moraes, S.V., de Oliveira, C.M., & Denke, M.L. (2011). Characterization of sweet cassava accessions based on molecular, quantitative and qualitative data. *Crop Breeding and Applied Biotechnology,* 11(3)*,* 232-240. https://doi.org/10.1590/S1984-70332011000300005

Wengrat, A.P.G.S., Barilli, D.R., Uemura-Lima, D.H., Gazola, D., Guimaraes, A.T.B., & Pietrowski, V. (2020). Resistance of cassava genotypes to *Vatiga manihote* (Drake 1922) (Hemiptera: Tingidae). *Revista Brasileira de Entomologia,* 64(3), e20200017. https://doi.org/10.1590/1806-9665-RBENT-2020-0017

Wolfe, M.D., del Carpio, D.P., Alabi, O., Ezenwaka, L.C., Ikeogu, U.N. Kayondo, I.S., Lozano, R., Okeke, U.G., Ozimati, A.A., Williams, E., Egesi, C., Kawuki, R.S., Kulakow, P., Rabbi, I.Y., & Jannink, J.L. (2017). Prospects for genomic selection in cassava breeding. *The Plant Genome,* *10*(3), 15. https://doi.org/10.3835/plantgenome2017.03.0015

Wolfe, M.D., Rabbi, I.Y., Egesi, C., Hamblin, M., Kawuki, R., Kulakow, P., Lozano, R., del Carpio, D.P., Ramu, P., & Jannink, J.L. (2016). Genome-wide association and prediction reveal genetic architecture of cassava mosaic disease resistance and prospects for rapid genetic improvement. *The Plant Genome,* *9*(2), 118. https://doi.org/10.3835/plantgenome2015.11.0118

Wu, M., Chen, Q., Liu, Y., Wu, C., An, X., Zhao, Z., Hao, G., Gregory, I.O., Wang, Y., Li, Z., & Liang, X. (2025a). High hydrogen cyanide release in cassava leaf shapes the cultivar resistance against the two-spotted spider mite, *Tetranychus urticae. Authorea,* https://doi.org/10.22541/au.173607912.22589954/v1

Wu, M., Liang, X., Liu, Y., Wu, C., An, X., Zhao, Z., Hao, G., Gregory, I.O., Li, Z., & Chen, Q. (2025b). Mechanisms underlying the effects of cyanogenesis on development and reproduction of *Tetranychus urticae*: Insights from enzyme activity and gene expression aspects. *Ecotoxicology and Environmental Safety,* 290, 117523. https://doi.org/10.1016/j.ecoenv.2024.117523

Yadav, M., Singh, I.K., & Singh, A. (2023). Dhurrin: A naturally occurring phytochemical as a weapon against insect herbivores. *Phytochemistry*, 205, 113483. https://doi.org/10.1016/j.phytochem.2022.113483