J. Trop. Plant Pests Dis.
Vol. 26, No. 2, September 2026
Pages: 363–378

ISSN: 1411-7525
E-ISSN: 2461-0399
DOI : 10.23960/j.hptt.226363-378

REVIEW

Overview of infestation status and management of the rice leaffolder, *Cnaphalocrocis medinalis* (Guenée) (Lepidoptera: Pyralidae), in Malaysian paddy areas

Nor Aida Shafina Mustapar[1], Nur Athiqah Md Yusof[1], Salmah Mohamed[1], & Marina Roseli[2]

Manuscript received: 21 October 2025. Revision accepted: 30 December 2025. Available online: 26 June 2026

ABSTRACT

The rice leaffolder, *Cnaphalocrocis medinalis* (Guenée) (Lepidoptera: Pyralidae), is a major foliar pest of rice (*Oryza sativa* L.) across Asia, including Malaysia, where recent outbreaks have re-established it as a significant constraint to rice productivity. This review synthesizes current knowledge on its biology, life cycle, feeding behavior, and ecological interactions within Malaysian rice agroecosystems. Available evidence indicates that pest outbreaks are closely associated with environmental factors, particularly high humidity and dense crop canopies, while natural enemies—including parasitoids and predators—play a critical role in regulating field populations. Habitat management practices, such as the introduction of flowering plants along rice bunds, may enhance natural enemy activity and contribute to the suppression of rice leaffolder populations. In addition, augmentative biological control using *Trichogramma* spp. represents a promising strategy for early-stage suppression of the pest. Integrating these ecological and biological approaches within an Integrated Pest Management (IPM) framework offers a viable pathway to reduce reliance on chemical inputs while improving system resilience. This review also identifies key research gaps and provides directions for developing locally adapted, sustainable management strategies for *C. medinalis* in Malaysia.

Keywords: Rice leafolder, paddy, recent occurrence, sustainable management

INTRODUCTION

Rice (*Oryza sativa* L.) serves as the primary staple food for more than half of the global population and plays a pivotal role in food security across Asia. In Malaysia, rice cultivation is of strategic economic and social importance, particularly within the eight designated granary areas that collectively cover approximately 673,745 ha of paddy fields, of which 412,949 ha are managed under gazetted schemes such as MADA, KADA, and IADA (Dorairaj & Govender, 2023; Kamaruddin & Rashid, 2025). Despite continuous government efforts to achieve a 75% rice self-sufficiency level by 2025, this target remains unmet due to multiple constraints, including land conversion, soil degradation, irrigation limitations, and persistent pest and disease pressures (Choy, 2023; Mondal et al., 2017; Annuar & Hisham, 2025). This indicates that biotic stressors, particularly insect pests, remain a critical bottleneck in sustaining national rice productivity.

Among these constraints, lepidopteran pests represent a major threat, with rice leaffolders causing significant yield losses through defoliation and disruption of photosynthetic capacity during critical growth stages (Yaakop et al., 2020; Md Yusof et al., 2021). Two leaffolders species have been reported in Malaysia rice ecosystems, namely *Cnaphalocrocis medinalis* (Guenée) and *Marasmia patnalis* Bradley (Md Yusof et al., 2015). Of these, *C. medinalis* has emerged as the dominant and most destructive species, with recurrent outbreaks reported in major rice-growing regions. Severe infestations can damage 50–70% of leaf area and lead to yield losses of up to 46% (Padmavathi et al., 2013; Bilal et al., 2019). Such damage levels highlight the pest's capacity to shift from a secondary to a primary pest under favorable ecological and agronomic conditions.

Ecological interactions within rice agroecosystems also influence the population dynamics of rice insect pests. Studies in Southeast Asia have demonstrated that ecological engineering practices, including the establishment of flowering plants around rice fields, can enhance the abundance of predators and parasitoids and strengthen natural biological control in paddy ecosystems (Usyati et al., 2020).

Corresponding author:
Nur Athiqah Md Yusof (athiqahmdyusof@unisza.edu.my)

[1]Faculty of Bioresources and Food Industry, University Sultan Zainal Abidin, Besut Campus, Terengganu, Malaysia 22200
[2]Faculty of Agriculture, University Putra Malaysia, UPM Serdang, Selangor, Malaysia 43400

Likewise, studies on parasitoid diversity associated with rice pests have shown that egg parasitoids such as *Trichogramma japonicum*, *Telenomus rowani*, and *Tetrastichus schoenobii* are important natural enemies in rice agroecosystems and may contribute to the suppression of rice leaffolder and other rice pest populations under field conditions (Wilyus et al., 2012). The importance of biological control in rice ecosystems has also been emphasized through studies involving entomopathogenic fungi and nematodes as environmentally friendly alternatives to chemical insecticides (Chaerani & Nurbaeti, 2007; Ponijan et al., 2023). These findings collectively support the increasing relevance of sustainable and ecologically based pest management strategies for rice production systems.

Despite its economic significance, information on the current status of *C. medinalis* in Malaysia remains fragmented and lacks comprehensive synthesis. This review aims to consolidate existing knowledge on the pest within Malaysian rice agroecosystems, including its biology, ecology, distribution, and interactions with natural enemies. By integrating historical records with recent findings, this study provides an updated perspective on its population dynamics and outbreak patterns. Furthermore, this review identifies critical research gaps and discusses their implications for the development of sustainable management strategies, particularly within the framework of integrated pest management (IPM). Such synthesis is essential to support evidence-based decision-making and to enhance the resilience of rice production systems under evolving agroecological conditions.

GEOGRAPHIC DISTRIBUTION AND OCCURRENCE

Cnaphalocrocis medinalis is one of the most widely distributed lepidopteran pest of rice across Asia, including Malaysia (Figure 1). In, Malaysia this species has been associated with recurrent outbreaks for several decades, indicating its strong adaptation to irrigated rice agroecosystems. Historical observations from Sekinchan reported severe infestations during the 1980s, resulting in yield losses ranging from 30% to 80% in heavily affected fields (Ooi & Yazid, 1982).

Subsequent studies have confirmed the persistence of the pest across different ecological zones. For instance, field observations in Semanggol demonstrated continuous foliar damage from the tillering stage to crop maturity, with significantly higher larval densities during the main cropping season compared to the off-season. This pattern was closely associated with increased relative humidity, suggesting that microclimatic conditions play a key role in regulating population buildup (Roseli et al., 2021). This seasonal amplification implies that climatic variability may act as a trigger for localized population outbreaks.

More recent reports (2024–2025), indicate that infestations remain widespread, affecting major rice-growing regions such as Kelantan, Perlis, and Perak. In Perlis, infestations impacted more than 700 hectares of paddy fields and affected 352 farmers, with estimated yield losses exceeding 40% (Jamil et al., 2021; Sharif, 2024) (Figure 2). In Tumpat, economic losses were estimated at approximately RM1 million, while in Bagan Serai, infestations covered about 1100 ha with yield reductions approaching 50% in severely affected plots (Wahid, 2024; Pauzi, 2025). These reports collectively indicate that *C. medinalis* has transitioned from a sporadic pest to a consistently damaging constraint in Malaysian rice production systems.

Over the past decades, research in Malaysia has contributed valuable insights into the population dynamics of *C. medinalis*, particularly the influence of abiotic factors such as relative humidity (Roseli et al., 2021). However, the ecological drivers underlying its

Figure 1. Geographical distribution of *C. medinalis* as a major rice pest across Asia, highlighting regions with reported infestations.

recurrent outbreaks remain insufficiently understood. Specifically, the interactive effects of agronomic practices, landscape complexity, and insecticide regimes on pest resurgence have not been systematically evaluated. Emerging evidence of insecticide resistance, including reduced susceptibility to fipronil in certain populations, further complicates management efforts and raises concerns regarding the long-term efficacy of chemical control strategies (Subhagan et al., 2025).

Despite these concerns, studies examining the relationship between pesticide use patterns and leaffolder population dynamics in Malaysia remain limited. This gap highlights the need for integrative research that links pest ecology with management practices, particularly within the framework of Integrated Pest Management (IPM). Such an approach is essential for reducing reliance on chemical inputs, mitigating resistance development, and enhancing the ecological resilience of rice agroecosystems.

MORPHOLOGY, BIOLOGY AND LIFE CYCLE

Cnaphalocrocis medinalis (Lepidoptera: Pyralidae) undergoes complete metamorphosis consisting of four developmental stages: egg, larva, pupa, and adult. The eggs are typically laid in small batches of 10–12, arranged in longitudinal rows on the leaf surface. They are flat, oval, and initially white in color (Figure 3), with oviposition occurring more frequently on the upper leaf surface than on the lower surface. This oviposition preference likely provides a favorable microclimate that enhances egg survival and accelerates early population establishment. The incubation period is relatively short, lasting approximately 6–7 days (Hao, 2013).

Upon hatching, neonate larvae migrate to the base of the youngest unopened leaves and begin feeding. From the second instar onward, larvae move to older leaves, where they construct characteristic tubular feeding chambers by folding the leaf blade (Figure 4). Typically, a single larva occupies one folded leaf. This shelter-feeding behavior protects the larvae from natural enemies and reduces exposure to foliar insecticides, thereby increasing survival and feeding efficiency. Larvae feed by scraping the mesophyll tissue, and a single individual may damage three to four leaves during its development.

Morphologically, mature larvae are yellowish-green with a dark brown head capsule and can be identified by a pair of subdorsal spots on the mesonotum and a straight anterior margin of the pronotum (Figure 5) (Reissig et al., 1986; Md Yusof et al., 2015). Larval development consists of five to seven instars and spans approximately 15–25 days, depending on

Figure 2. Characteristic leaf damage caused by rice leaf folder on rice leaves (Photo source: NPPC, 2025).

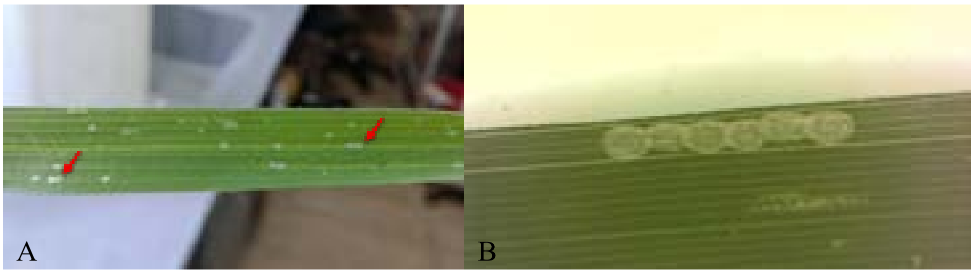

Figure 3. Egg morphology and oviposition pattern of the rice leaffolder (*C. medinalis*). A. Freshly laid eggs (indicated by red arrows) appearing flat on the surface of a rice leaf; B. Magnified view of *C. medinalis* eggs, illustrating their typical arrangement in longitudinal rows and characteristic oval, flattened morphology.

environmental conditions such as temperature and humidity (Hao, 2013). This relatively extended feeding period represents a critical window during which substantial foliar damage can accumulate.

Pupation occurs within loosely woven silken structures on leaf blades or rice stubble (Pathak & Khan, 1994). The pupa transitions in color from bright yellow to brown as development progresses (Figure 6). Under tropical conditions, the pupal stage lasts approximately 6–8 days (Hao, 2013), contributing to the rapid turnover of generations.

Adult moths have a wingspan of 18–22 mm and are characterized by yellowish-brown forewings with distinct darker transverse bands, including prominent inner and outer lines and a less defined middle band. The hindwings are whitish with brown margins. When at rest, adults adopt a triangular posture. Sexual dimorphism is evident, with females generally larger and darker, displaying well-defined transverse wing markings, while males are slightly smaller, paler with a greenish tinge, and possess a tuft of dense black hairs along the mid-costa (Figure 7) (Wilson, 1997).

Adults exhibit strong flight capability, facilitating dispersal across rice-growing landscapes. This high dispersal ability, combined with efficient mate-finding behavior, enhances reinfestation potential even after local population suppression. Under tropical conditions, *C. medinalis* can complete its life cycle within 25–35 days and produce six to seven overlapping generations annually (CABI, 2021; Hao, 2013). Such rapid and continuous generation turnover significantly increases the risk of population outbreaks, particularly in intensive rice cultivation systems with asynchronous planting schedules (Figure 8).

FEEDING DAMAGE AND YIELD IMPACT

Table 1 summarizes the feeding damage caused by *C. medinalis* larvae different rice growth stages, highlighting the associated symptoms and their implications for crop performance.

Larvae of *C. medinalis* characteristically fold rice leaves longitudinally by stitching the leaf margins and feed internally by scraping the green mesophyll tissue within the folded structure. This feeding behavior creates a concealed microhabitat that protects larvae from natural enemies and reduces exposure to foliar insecticides (Adhikari et al., 2022). As a result, feeding damage initially appears as linear, pale white streaks that later develop into membranous patches. Under severe infestations, these lesions coalesce, producing extensive translucent areas on the leaf surface (Figure 9). Such structural damage leads to a substantial reduction in functional leaf area, directly impairing photosynthetic capacity and limiting carbohydrate accumulation required for optimal grain filling (Han

Figure 4. Characteristic leaf damage caused by the rice leaffolder (*C. medinalis*). Larvae fold and stitch leaf margins with silk to form tubular shelters and feed on the inner mesophyll tissue, producing white, papery patches that significantly reduce photosynthetic capacity and plant vigor.

Figure 5. Larva of the rice leaffolder (*C. medinalis*), showing its characteristic yellowish-green body and dark brown head capsule.

Figure 6. Pupa of the rice leaffolder (*C. medinalis*), showing the typical coloration change from yellow to brown during development.

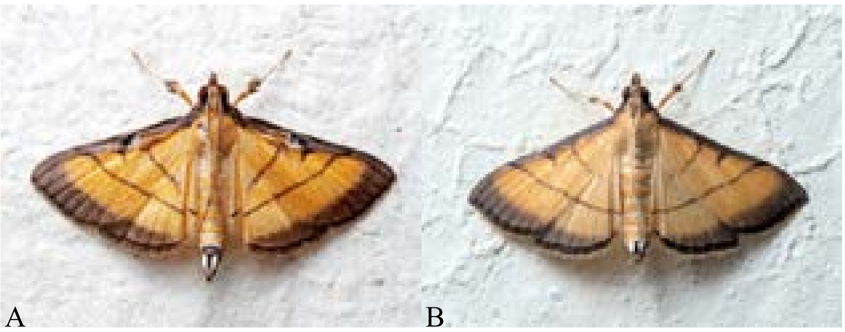

Figure 7. Adult morphology of the rice leaffolder (*C. medinalis*), showing sexual dimorphism. A. Male with a tuft of dense black hairs along the mid-costa of the forewing; B. Female with more uniform wing coloration.

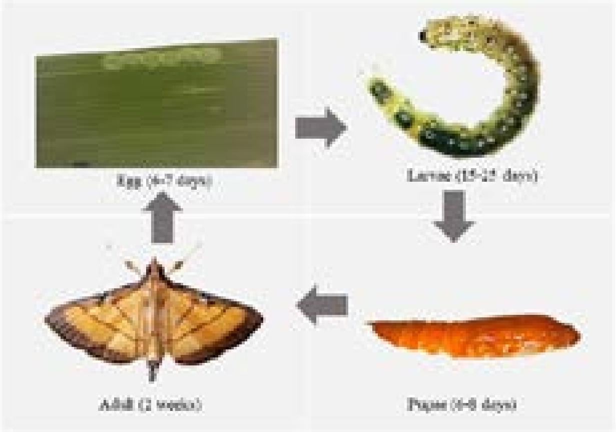

Figure 8. Life cycle of the rice leaffolder (*C. medinalis*), illustrating the egg, larval, pupal, and adult stages.

et al., 2015).

The severity and consequences of damage are strongly dependent on the crop growth stage. During the tillering phase, larval feeding reduces chlorophyll content and photosynthetic efficiency, thereby impairing tiller development and overall canopy architecture (Padmavathi et al., 2013). Early-stage damage is particularly critical, as it disrupts canopy establishment and reduces the plant's capacity to compensate for subsequent stress. At the reproductive stage, defoliation constrains assimilate production necessary for panicle initiation and grain set, while infestations extending into the ripening stage can further reduce grain weight and quality (Adhikari et al., 2022). Empirical evidence supports this stage-dependent impact; for example, infestations occurring at the tillering stage have been reported to cause yield reductions of 18–58% (Junaid & Khan, 2023).

Environmental conditions further modulate damage severity. Dense crop canopies and high humidity create favorable microclimatic conditions that enhance larval survival and feeding activity (Roseli et al., 2021). This indicates that crop management practices influencing canopy structure may indirectly regulate pest pressure. In addition, repeated or sequential infestations can weaken plant defenses, increasing susceptibility to secondary pests and diseases such as sheath blight caused by Sheath blight (Wilson, 1997).

Nevertheless, field-level damage is not solely determined by pest pressure but is also shaped by ecological regulation. A diverse assemblage of natural

Figure 9. Characteristic white, translucent streaks formed on folded rice leaves following mesophyll feeding by larvae of the rice leaffolder (*C. medinalis*).

Table 1. Feeding damage caused by the rice leaffolder (*C. medinalis*) at different rice growth stages

Growth stage	Damage symptoms
Tillering stage	Leaf folding and mesophyll scraping, resulting in pale linear streaks and membranous patches on leaves.
Reproductive stage	Extensive white translucent streaks on folded leaves, leading to reduced photosynthetic area and assimilate production.
Ripening stage	Impaired grain filling and reduced grain weight under severe infestation.

enemies—including egg and larval parasitoids, predators, and entomopathogens—plays a critical role in suppressing *C. medinalis* populations in both natural and managed rice ecosystems. These biotic interactions highlight the importance of conserving ecological balance as a foundation for sustainable pest management. Understanding these dynamics provides a basis for the following section, which explores the role of natural enemies and ecological control in regulating leaffolder populations.

NATURAL ENEMIES AND ECOLOGICAL REGULATIONS

A diverse assemblage of natural enemies associated with *C. medinalis* has been documented across Asian rice ecosystems, comprising parasitoids, predators, and other biotic regulators acting at multiple developmental stages. These natural enemies play a crucial role in suppressing leaffolder populations and maintaining ecological balance within rice agroecosystems. Table 2 summarizes the hymenopteran parasitoids reported on *C. medinalis*.

Among the most effective early-stage regulators are egg parasitoids belonging to the family Trichogrammatidae. Species such as *Trichogramma chilonis*, *T. japonicum*, and *T. dendrolimi* parasitize leaffolder eggs, thereby preventing larval emergence and reducing initial population buildup (de Kraker et al., 1999; CABI, 2021). By targeting the pest at its earliest developmental stage, these parasitoids impose a critical bottleneck that limits the potential for subsequent outbreaks.

Following egg hatch, a diverse guild of hymenopteran parasitoids regulates larval populations. Members of the Braconidae, including, *Apanteles, Cardiochiles* (Figure 10A), and *Macrocentrus* spp. (Figure 10B), function as koinobiont endoparasitoids, allowing partial host development prior to host mortality (Quicke, 2015). Similarly, ichneumonids such as *Temelucha philippinensis* and *Trichomma cnaphalocrocis* attack mid- to late-instar larvae within leaf folds, while bethylids such as *Goniozus* spp. act as ectoparasitoids that paralyze hosts and immediately halt feeding (Stireman et al., 2006; Quicke, 2015). Collectively, these larval parasitoids exert substantial mortality during the most destructive feeding stage, directly reducing crop damage.

Additional mortality is imposed at the pupal stage by parasitoids from several hymenopteran families. Chalcidids (*Brachymeria* spp.), Eulophids (*Elasmus* spp.), and Ichneumonids such as *Xanthopimpla* spp. (Figure 11) attack pupae within folded leaves or crop residues, thereby preventing adult emergence and reducing reproductive carryover (de Kraker et al., 1999; Quicke, 2015). Pupal parasitism is particularly important in disrupting the continuity of overlapping generations under tropical rice production systems.

Dipteran parasitoids further complement hymenopteran activity by targeting later developmental stages. Members of Tachinidae, Phoridae, and Sarcophagidae (Figure 12; Table 3), contribute

Table 2. Hymenopteran parasitoids associated with the rice leaffolder (*C. medinalis*) reported in Asia

Life stage targeted	Family	Species
Egg	Trichogrammatidae	*Trichogramma chilonis*
		Trichogramma closterae
		Trichogramma confusum
		Trichogramma dendrolimi
		Trichogramma japonicum
		Trichogramma leucaniae
		Trichogramma ostriniae
Larvae/Pupae	Braconidae	*Apanteles angaleti*
		Apanteles angustibasis
		Apanteles cypris
		Apanteles flavipes
		Apanteles opacus
		Apanteles ruficrus
		Apanteles syleptae
		Bracon gelechiae
		Bracon hebetor
		Bracon ricinicola
		Cardiochiles fuscipennis
		Cardiochiles laevifossa
		Cardiochiles philippinensis
		Cedria sp.
		Chelonus munakatae
		Exoryza schoenobii
		Habrobracon sp.
		Hormius sp.
		Kriechbaumerella sp.
		Macrocentrus cnaphalocrocis
		Macrocentrus philippinensis
		Meteorus bacoorensis
		Microplitis sp.
		Opius sp.
		Orgilus sp.
		Tropobracon schoenobii
	Ichenumonidae	*Temelucha philippinensis*
		Temelucha stangil
		Trichomma cnaphalocrosis
	Bethylidae	*Goniozus hanoiensis*
		Goniozus indicus
		Goniozus triangulifer
		Goniozus hanoiensis
	Ceraphronidae	*Ceraphron manilae*

Table 2. Continued. Hymenopteran parasitoids associated with the rice leaffolder (*C. medinalis*) reported in Asia

Life stage targeted	Family	Species
		Aphanogmus fijiensis
	Chalcididae	*Antrocephalus apicalis*
		Brachymeria excarinata
		Brachymeria lasus
		Brachymeria tachardiae
		Brachymeria sp. cf. *tarsalis*
		Dirhinus sp.
		Trichospilus pupivora
	Elasmidae	*Elasmus anticles*
		Elasmus brevicornis
		Elasmus claripennis
		Elasmus cnaphalocrocis
		Elasmus corbetti
		Elasmus hyblaeae
		Elasmus philippinensis
	Encyrtidae	*Copidosoma* sp.
		Copidosomopsis coni
		Copidosomopsis nacoleiae
	Eulophidae	*Dimmockia parnarae*
		Stenomesius macullatus
		Stenomesius tabashii
		Tetrastichus ayyari
		Tetrastichus howardi
		Tetrastichus israelensis
		Tetrastichus schoenobii
	Eurytomidae	*Eurytoma* sp.
	Ichneumonidae	*Acropimpla hapaliae*
		Agrypan susukii
		Barylypa apicalis
		Casinaria simillima
		Charops bicolor
		Charops brachypterum
		Charops nigrita
		Chorinacus facialis
		Coccygomimus aethiops
		Coccygomimus nipponicus
		Diatora lissonata
		Eriborus argenteopilosus
		Eriborus sinicus
		Eriborus vulgaris
		Gambroides sp.

Table 2. Continued. Hymenopteran parasitoids associated with the rice leaffolder (*C. medinalis*) reported in Asia

Life Stage Targeted	Family	Species
		Gambrus ruficoxatus
		Goryphus basilaris
		Ischnojoppa luteator
		Iseropus kuwanae
		Itoplectis narangae
		Leptobatopsis indica
		Phaeogenes sp.
		Stictopisthus chinensis
		Temelucha basimacula
		Temelucha biguttula
		Temelucha philippinensis
		Temelucha nr. philippinensis
		Temelucha stangli
		Trathala flavo-orbitalis
		Trichionotus suzukili
		Triclistus aitkiai
		Trichomma cnaphalocrocis
		Vulgichneumon diminutus
		Xanthopimpla enderleini
		Xanthopimpla flavolineata
		Xanthopimpla punctata
	Pteromalidae	*Trichomalopsis apanteloctena*
	Scelionidae	*Telenomus dignus*

Source: Gurr et al. (2012).

significantly to population regulation. Tachinid species such as *Argyrophylax fransseni, Exorista japonica, Chaetexorista javana,* and *Lydella grisescens* are among the most frequently reported parasitoids of late-instar larvae and prepupae (Gurr et al., 2012). Females typically oviposit on the host cuticle or surrounding foliage, and the emerging larvae penetrate and develop within the host, ultimately causing death (Stireman et al., 2006). This parasitic strategy often results in density-dependent mortality, particularly during outbreak conditions when host availability is high (de Kraker et al., 1999).

In addition, facultative parasitoids such as *Megaselia scalaris* (Phoridae) exploit weakened or moribund hosts, while sarcophagid flies such as *Pierretia caudagalli* attack exposed pupae, further contributing to mortality in late developmental stages (Disney, 2008; de Kraker et al., 1999). These dipteran parasitoids broaden the regulatory spectrum by targeting stages less accessible to hymenopteran parasitoids, enhancing overall suppression efficiency.

Predation represents another major ecological force regulating *C. medinalis* populations. Unlike parasitoids, which are often stage-specific, predators exert continuous pressure across multiple life stages. A wide range of generalist predators (Table 4), including ants (*Odontoponera transversa*), carabid beetles (*Ophionea ishii*) (Figure 13), rove beetles (*Paederus fuscipes*), crickets (*Metiocha vittaticollis*), and spiders such as *Lycosa pseudoannulata* and *Oxyopes javanus*, contribute to mortality of eggs, larvae, and pupae (Reissig et al., 1986; Gurr et al., 2017). These predators provide consistent, density-independent suppression that complements the more specialized action of parasitoids.

Collectively, these natural enemy guilds impose stage-specific mortality that regulates *C. medinalis* populations across cropping cycles. Egg parasitoids limit initial recruitment, larval parasitoids and predators suppress the most damaging stages, and pupal as

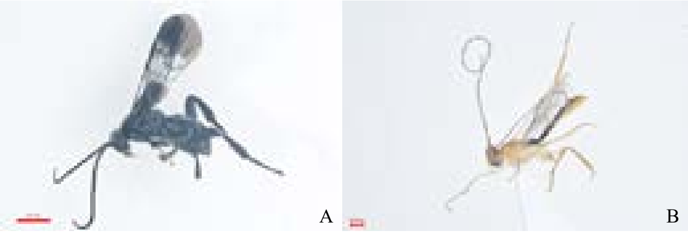

Figure 10. Larval parasitoids from the family Braconidae. A. *Carchiochiles fuscipennis*; B. *Macrocentrus* spp.

Figure 11. Pupal parasitoid of the family Ichneumonidae, *Xanthopimpla punctata*.

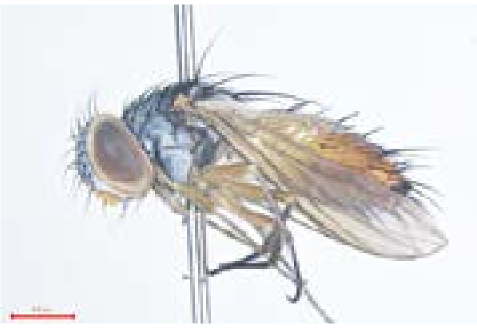

Figure 12. Dipteran parasitoid of the family Tachinidae associated with the rice leaffolder (*C. medinalis*).

well as dipteran parasitoids reduce adult emergence and reproductive potential. This complementary and multi-trophic regulatory system forms the ecological foundation for sustainable pest suppression and highlights the importance of conserving biodiversity within rice agroecosystems.

However, under Malaysia rice-growing conditions, the relative contributions of these natural enemy guilds remain poorly quantified. While parasitoids are widely recognized as key regulatory agents, there is limited empirical evidence comparing the effectiveness of egg, larval, and pupal parasitoids, as well as generalist predators, under local field conditions.

Studies conducted outside Malaysia provide indirect insights into these dynamics. For example, herbivore-induced plant volatiles released during leaf folding by *C. medinalis* have been shown to attract parasitoids such as *Itoplectis naranyae* and *Apanteles* spp., suggesting a mechanism for enhanced biological control (Shi et al., 2019). Additionally, ecological modeling demonstrated that predatory crickets, including Metioche vittaticollis and Anaxipha longipennis, accounted for over 90% of egg predation in certain rice systems, underscoring their critical role in early-stage suppression (de Kraker, 1996).

These findings highlight a significant knowledge gap in Malaysia, where guild-specific mortality rates and their interactions with agronomic practices have not been systematically evaluated. Addressing this gap requires integrative ecological studies that quantify parasitism and predation rates, assess their relative contributions under field conditions, and develop habitat management strategies to enhance natural enemy effectiveness. Such efforts are essential for strengthening Integrated Pest Management (IPM) programs and reducing reliance on chemical control in sustainable rice production systems.

SUSTAINABLE MANAGEMENT OF RICE LEAFFOLDERS IN MALAYSIA: PRESENT PRACTICES AND FUTURE DIRECTIONS

Recent research in Malaysia indicates a clear transition from insecticide-dependent control toward integrated strategies that combine ecological and biological approaches for managing *C. medinalis*. Long-term monitoring and life-table analyses conducted in Perak and other rice-growing regions have identified consistent seasonal peaks in leaffolder abundance, closely associated with high relative humidity and dense crop canopies (Roseli et al., 2019; Roseli et al., 2021). These patterns demonstrate that pest outbreaks are strongly governed by the interaction between climate and crop phenology, providing a predictive basis for timing management interventions. (Heong et al., 2021).

In addition to climatic drivers, agronomic practices—particularly nitrogen fertilization—significantly influence leaffolder population dynamics. Elevated nitrogen levels have been shown to increase oviposition rates of adult females, while improving larval nutritional intake through higher leaf protein and sugar content, thereby enhancing growth, survival, and fecundity (Ge et al., 2013; Roseli et al., 2021). This interaction suggests that nutrient management is not only a productivity factor but also a key ecological lever in pest regulation. Consequently, integrating climate-based forecasting with agronomic decision-making is essential for developing site- and season-specific management strategies.

A substantial body of evidence demonstrates that rice leaffolder populations are naturally regulated by a diverse assemblage of parasitoids and predators. For example, larval parasitism rates of up to 56%

Table 3. Dipteran parasitoids associated with the rice leaffolder (*C. medinalis*) reported in Asia

Family	Species
Tachinidae	*Argyrophylax fransseni*
	Argyrophylax nigrotibialis
	Chaetexorista javana
	Exorista japonica
	Halidaya luteicornis
	Lydella grisescens
	Nemorilla floralis
	Nemorilla maculose
	Pseudoperichaeta nigrolinea
	Pseudoperichaeta nigrolinea
	Thecocarcelia oculate
	Zygobothria ciliata
Phoridae	*Megaselia scalaris*
Sarcophagidae	*Pierretia caudagalli*

Source: Gurr et al. (2012).

Table 4. Predators associated with the rice leaffolder (*C. medinalis*) reported in Asia

Family	Species
Formicidae	*Odontoponera transversa*
Carabidae	*Ophinonea ishii*
	Chiaenius pasticalis
Gryllidae	*Metiocha vittaticollis*
	Anaxipha sp.
Staphylinidae	*Paederus fuscipes*
Lycosidae	*Lycosa pseudoannulata*
Oxyopidae	*Oxyopes javanus*

Source: Reissig et al. (1986).

have been reported in irrigated rice systems in the Philippines, while egg parasitism by *Trichogramma* spp. averages around 27% (de Kraker et al., 1999). Bio-intensive management modules evaluated in India further indicate that enhancing natural enemy populations can significantly increase larval mortality and reduce pest pressure (Reddy et al., 2021).

In Malaysia, habitat management practices—such as the introduction of flowering plants like *Turnera trioniflora* along rice bunds—have been shown to increase the abundance and diversity of hymenopteran parasitoids and generalist predators, resulting in improved biological control compared to conventional systems (Hamdan et al., 2023) (Figure 14). These findings underscore the potential of ecological engineering as a practical strategy to enhance in situ pest regulation within rice agroecosystems.

More recently, augmentative biological control has emerged as a promising complementary approach in Malaysia, supported by capacity-building initiatives and technical programs led by organizations such as Centre for Agriculture and Bioscience International and Malaysian Agricultural Research and Development Institute. This approach involves the mass-rearing and field deployment of *Trichogramma* spp. (Figure 15) for targeted egg parasitism, effectively suppressing egg hatch and reducing subsequent larval damage (CABI, 2024). By intervening at the earliest stage of

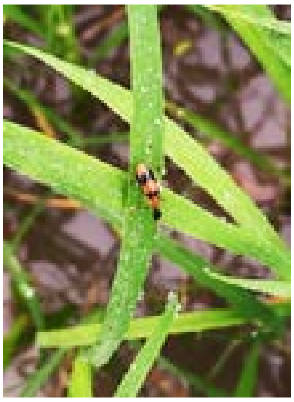

Figure 13. *Ophionea ishii* (Coleoptera: Carabidae), a predatory ground beetle associated with the rice leaffolder (*C. medinalis*).

Figure 14. Beneficial flowering plant, *Turnera trioniflora*, established along rice bunds in Terengganu, Malaysia (Photo source: Hamdan et al., 2023).

Figure 15. *Trichogramma* sp. an egg parasitoid of the rice leaffolder (*C. medinalis*).

the pest life cycle, this method represents a preventive and ecologically sound alternative to reactive chemical control.

Evidence from other regions further supports the effectiveness of this approach. In India, augmentative releases of *T. japonicum* and *T. chilonis* have been shown to effectively suppress leaffolder and stem borer populations while reducing the need for insecticide applications (Karthikeyan et al., 2007). Similarly, IPM programs in the Greater Mekong subregion have demonstrated that the use of *Trichogramma* egg-card technology can reduce pesticide use, enhance natural enemy conservation, and increase yields by 10–15% under farmer field conditions (Babendreier et al., 2019). These regional successes provide strong empirical support for scaling up augmentative biological control within Malaysian rice systems.

These findings strongly support the potential for up-scaling such measures in Malaysia, where integration into ecological engineering and IPM principles could have a significant impact on sustainable rice pest management.

Institutional support and farmer engagement are increasingly recognized as critical components of sustainable pest management. In Malaysia, initiatives promoting biopesticides and safer pesticide practices reflect a growing shift in regulatory frameworks and farmer awareness (Sivapragasam & Goh, 2025). In areas such as Sungai Burung, adoption of threshold-based spraying aligned with Department of Agriculture guidelines has demonstrated the potential to reduce unnecessary pesticide applications while minimizing environmental impacts (Mairghany et al., 2018). Such approaches emphasize the importance of decision-based pest management rather than calendar-based spraying.

Overall, an effective IPM strategy for C. medinalis in Malaysia must integrate multiple complementary tactics. These include: (i) regular monitoring of pest and natural enemy populations to inform timely interventions; (ii) habitat management through ecological engineering to enhance biological control; (iii) augmentative releases of egg parasitoids, particularly *Trichogramma*, synchronized with pest oviposition; and (iv) judicious use of selective insecticides based on economic thresholds to minimize disruption of beneficial organisms. In addition, farmer training and institutional support under national frameworks such as the National Agrofood Policy 2.0 are essential for large-scale implementation and long-term sustainability.

Collectively, these strategies represent a paradigm shift toward ecologically based pest management, where the integration of biological control, agronomic optimization, and farmer-centered extension forms the foundation for resilient and sustainable rice production systems in Malaysia.

CONCLUSION

The rice leaffolder, *Cnaphalocrocis medinalis*, remains a major foliar pest in rice agroecosystems of Malaysia. This review highlights its biology, ecology, and the important role of natural enemies in regulating field populations. However, knowledge on its current status in Malaysia remains fragmented, particularly regarding outbreak dynamics, yield losses, and the effectiveness of biological control. Sustainable management requires strengthening Integrated Pest Management (IPM) strategies through habitat manipulation, conservation and augmentation of natural enemies, and judicious use of selective insecticides. Approaches such as *Trichogramma* releases, ecological engineering, and farmer-based extension programs provide practical pathways to reduce chemical dependency. Future research should focus on developing locally adapted IPM modules, quantifying pest–natural enemy interactions, and improving farmer adoption. These efforts are essential to enhance rice productivity, support farmer livelihoods, and ensure long-term sustainability of rice production systems in Malaysia.

ACKNOWLEDGMENTS

The authors express their sincere gratitude to the Ministry of Higher Education Malaysia for financial support through the Fundamental Research Grant Scheme (FRGS) (Grant No.: FRGS/1/2023/WAB04/UNISZA/02/7), and to Universiti Sultan Zainal Abidin for providing research facilities and institutional support. The authors also thank Masatoshi Sone (University of Malaya, Kuala Lumpur), Jeong Jae Yoo (Royal Ontario Museum, Canada), and Shail Sharma for kindly providing photographs of *Cnaphalocrocis medinalis*, *Trichogramma* sp., and *Xanthopimpla punctata* used in this manuscript.

FUNDING

This research was financially supported by the Ministry of Higher Education Malaysia under the Fundamental Research Grant Scheme (FRGS) (Grant No.: FRGS/1/2023/WAB04/UNISZA/02/7).

AUTHORS' CONTRIBUTIONS

NASM prepared the initial manuscript draft and compiled the literature. NAMY conceptualized the study and substantially revised the manuscript. SM and MR contributed photographic materials and prepared the figures. All authors reviewed and approved the final version of the manuscript.

COMPETING INTEREST

The authors declare that they have no financial or non-financial competing interests, professional affiliations, or personal relationships that could have influenced the content of this publication.

REFERENCE

Adhikari B, Mohapatra LN, Mohapatra SD, Senapati R, & Satapathy SN. 2022. The effect of differential pest load of leaf folder, *Cnaphalocrocis medinalis* (Guenee) on extent of leaf damage and alteration in leaf biochemical composition in rice. *Int. J. Plant Soil Sci*. 34(22): 1360–1368. https://doi.org/10.9734/ijpss/2022/v34i2231507

Annuar A & Hisham H. 2025. *Malaysia faces uphill battle to boost rice self-sufficiency*. https://themalaysianreserve.com/2025/04/14/malaysia-faces-uphill-battle-to-boost-rice-self-sufficiency/. Accessed 25 September 2025.

Babendreier D, Wan M, Tang R, Gu R, Tambo J, Liu Z, Grossrieder M, Kansiime M, Wood A, Zhang F, & Romney D. 2019. Impact assessment of biological control-based integrated pest management in rice and maize in the Greater Mekong Subregion. *Insects*. 10(8): 226. https://doi.org/10.3390/insects10080226

Bilal M, Hussain M, Umer M, Ejaz N, Noushahi HA, Atta B, & Rizwan M. 2019. Population incidence and efficacy of chemical control against rice leaffolder (*Cnaphalocrocis medinalis* Guenee) (Pyralidae: Lepidoptera). *Asian Plant Res. J.* 2(2): 1–7. https://doi.org/10.9734/aprj/2019/v2i230040

CABI. 2021. *Cnaphalocrocis medinalis* (rice leaf folder). CABI Compendium. https://doi.org/10.1079/cabicompendium.14493. Accessed 28 September 2025.

CABI. 2024. *Workshop explores Trichogramma production system to fight crop pests that threaten food security in Malaysia.* https://blog.cabi.org/2024/01/18/workshop-explores-trichogramma-production-system-to-fight-crop-pests-that-threatens-food-security-in-malaysia/. Accessed 28 September 2025.

Choy NY. 2023. *Govt targets rice self-sufficiency ratio of 75% by 2025, 80% by 2030.* https://theedgemalaysia.com/node/688941. Accessed 28 September 2025.

de Kraker J. 1996. The Potential of Natural Enemies to Suppress Rice Leaffolder Populations. *Thesis*. Wageningen University & Research. Netherlands. https://doi.org/10.18174/210515

de Kraker J, van Huis A, Heong KL, van Lenteren JC, & Rabbinge R. 1999. Population dynamics of rice leaffolders (Lepidoptera: Pyralidae) and their natural enemies in irrigated rice in the Philippines. *Bull. Entomol. Res*. 89(5): 411–421. https://doi.org/10.1017/s0007485399000541

Disney RHL. 2008. Natural history of the scuttle fly, *Megaselia scalaris. Annu. Rev. Entomol.* 53(1): 39–60. https://doi.org/10.1146/annurev.ento.53.103106.093415

Dorairaj D & Govender NT. 2023. Rice and paddy industry in Malaysia: Governance and policies, research trends, technology adoption and resilience. *Front. Sustain. Food Syst*. 7: 1093605. https://doi.org/10.3389/fsufs.2023.1093605

Ge LQ, Wan DJ, Xu J, Jiang LB, & Wu JC. 2013. Effects of nitrogen fertilizer and magnesium manipulation on the *Cnaphalocrocis medinalis* (Lepidoptera: Pyralidae). *J. Econ. Entomol.* 106(1): 196–205. https://doi.org/10.1603/ec12228

Gurr GM, Read DMY, Catindig JLA, Cheng J, Liu J, Lan LP, & Heong KL. 2012. Parasitoids of the rice leaffolder *Cnaphalocrocis medinalis* and prospects for enhancing biological control with nectar plants. *Agric. For. Entomol.* 14(1): 1–12. https://doi.org/10.1111/j.1461-9563.2011.00550.x

Gurr GM, Wratten SD, Landis DA, & You M. 2017. Habitat management to suppress pest populations: Progress and prospects. *Annu. Rev. Entomol*. 62(1): 91–109. https://doi.org/10.1146/annurev-ento-031616-035050

Hamdan MH, Mohamed S, Mustapar NAS, Ngah N, Roseli M, & Adam NA. 2023. Exploring the abundance and diversity of hymenopteran parasitoids in paddy fields cultivated with beneficial plant, *Turnera trioniflora* Sims. *Serangga*. 28(3): 50–65. https://doi.org/10.17576/serangga-2023-2803-04

Han Y, Lei W, Wen L, & Hou M. 2015. Silicon-mediated resistance in a susceptible rice variety to the rice leaf folder, *Cnaphalocrocis medinalis* Guenée (Lepidoptera: Pyralidae). *PLoS ONE*. 10(4): e0120557. https://doi.org/10.1371/journal.pone.0120557

Hao BTM. 2013. *Rice Leaf Folder*. PlantwisePlus Knowledge Bank. https://plantwiseplusknowledgebank.org/doi/10.1079/pwkb.20157800705. Accessed 28 September 2025.

Heong KL, Lu ZX, Chien HV, Escalada M, Settele J, Zhu ZR, & Cheng JA. 2021. Ecological engineering for rice insect pest management: The need to communicate widely, improve farmers' ecological literacy and policy reforms to sustain adoption. *Agronomy*. 11(11): 2208. https://doi.org/10.3390/agronomy11112208

Jamil ZS, Saranum M, Hudin L, & Ali W. 2021. First incidence of the invasive fall armyworm, *Spodoptera frugiperda* (J.E. Smith, 1797) attacking maize in Malaysia. *BioInvasions Rec.* 10(1): 81–90. https://doi.org/10.3391/bir.2021.10.1.10

Junaid K & Khan SA. 2023. Compatible and non-compatible interaction of rice germplasms against rice leaf folder *Cnaphalocrocis medinalis* (Guenee) (Lepidoptera: Pyralidae). *Pak. J. Zool.* 55(6): 2671–2676. https://doi.org/10.17582/journal.pjz/20220920060917

Kamaruddin R & Rashid NNA. 2025. Sustainable farming management: Key factors and impact on paddy yields in Malaysia's granary areas. *Agric. & Food Secur.* 14(1): 4. https://doi.org/10.1186/s40066-025-00524-5

Karthikeyan K, Jacob S, & Purushothaman SM. 2007. Field evaluation of egg parasitoids, *Trichogramma japonicum* Ashmead and *Trichogramma chilonis* Ishii, against rice yellow stem borer and leaf folder. *J. Biol. Control*. 21(2): 261–265. https://doi.org/10.18311/jbc/2007/3858

Mairghany M, Yahya A, Adam NM, Su AHM, & Elsoragaby S. 2018. Sustainability practices for pesticide spraying in wet paddy cultivation in Malaysia. *Proceeding of the 2018 MSAE Conference*. pp. 411–421. Serdang, Selangor Malaysia.

Md Yusof NA, Azura AN, & Lau WH. 2015. Illustrated larval key to lepidopteran pests of rice in Malaysia. *Zootaxa*. 3986(2): 243–248. https://doi.org/10.11646/zootaxa.3986.2.8

Md Yusof NA, Nur Azura A, & Marina R. 2021. Descriptions of immature stages of *Mythimna venalba* (Moore) (Lepidoptera: Noctuidae). *Serangga*. 26(4): 189–205.

Mondal D, Ghosh A, Roy D, Kumar A, Shamurailatpam D, Bera S, Ghosh R, Bandopadhyay P, & Majumder A. 2017. Yield loss assessment of rice (*Oryza sativa* L.) due to different biotic stresses under system of rice intensification (SRI). *J. Entomol. Zool. Stud.* 5(4): 1974–1980.

National Plant Protection Centre (NPPC). 2025. *Rice leaf folder*: *Pests of Bhutan*. https://pestsofbhutan.nppc.gov.bt/crop-and-pest-identification/insects/rice-leaf-folder/. Accessed 17 May 2026.

Ooi PAC & Yazid ME. 1982. An outbreak of the rice leaffolder in Sekinchan, Selangor. *MAPPS Newsletter*. 6(3): 5–6.

Padmavathi Ch, Katti G, Padmakumari AP, Voleti SR, & Rao LVS. 2013. The effect of leaffolder *Cnaphalocrocis medinalis* (Guenee) [Lepidoptera: Pyralidae] injury on plant physiology and yield loss in rice. *J. Appl. Entomol.* 137(4): 249–256. https://doi.org/10.1111/j.1439-0418.2012.01741.x

Pauzi SSA. 2025. *Pesawah Alor Pongsu Resah Padi Diserang Ulat Gulung Daun [Alor Pongsu Rice Farmers are Anxious as their Paddy Crops are Being Attacked by Leaf-roller Caterpillars]*. https://www.hmetro.com.my/mutakhir/2025/08/1249636/pesawah-alor-pongsu-resah-padi-diserang-ulat-gulung-daun?source=widget. Accessed 28 September 2025.

Pathak MD & Khan ZR. 1994. *Insect Pests of Rice*. International Rice Research Institute. Manila, Philippines.

Quicke DLJ. 2015. *The Braconid and Ichneumonid Parasitoid Wasps: Biology, Systematics,* *Evolution and Ecology*. Wiley-Blackwell. UK. https://doi.org/10.1002/9781118907085

Reissig WH, Heinrichs EA, Litsinger JA, Moody K, Fiedler L, Mew TW, & Barrion AT. 1986. *Illustrated Guide to Integrated Pest Management in Rice in Tropical Asia*. International Rice Research Institute (IRRI). Philippines.

Roseli M, Adam NA, Lau WH, & Yaakop S. 2019. Life table and demographic parameters of rice leaffolder, *Cnaphalocrocis medinalis* Guenee (Lepidoptera: Pyralidae). *Serangga*. 24(2): 45–56.

Roseli M, Adam NA Hong LW, & Yaakop S. 2021. Population fluctuation of rice leaffolder, (*Cnaphalocrocis medinalis*) in two consecutive rice seasons. *J. Agrobiotechnol*. 12(1): 10–22. https://doi.org/10.37231/jab.2021.12.1.245

Sharif AS. 2024. *Sawah di Perlis Turut Alami Serangan Ulat Gulung Daun [Rice Fields in Perlis are also Experiencing Leaf-roller Caterpillar Infestations]*. https://www.bharian.com.my/berita/kes/2024/08/1290695/sawah-di-perlis-turut-alami-serangan-ulat-gulung-daun. Accessed 28 September 2025.

Shi JH, Sun Z, Hu XJ, Jin H, Foba CN, Liu H, Wang C, Liu L, Li FF, & Wang MQ. 2019. Rice defense responses are induced upon leaf rolling by an insect herbivore. *BMC Plant Biology*. 19(1): 514. https://doi.org/10.1186/s12870-019-2116-0

Sivapragasam A & Goh MCF. 2025. *Mainstreaming Biopesticide Use in Malaysia: Farmer and Industry Perspectives*. Asia-Pacific Biofertilizers and Biopesticides Information Platform. The Food and Fertilizer Technology Center for the Asian and Pasific Region. https://apbb.fftc.org.tw/article/715. Accessed 28 September 2025.

Stireman III JO, O'Hara JE, & Wood DM. 2006. Tachinidae: Evolution, behavior, and ecology. *Annu. Rev. Entomol*. 51: 525–555. https://doi.org/10.1146/annurev.ento.51.110104.151133

Subhagan SR, Pathrose B, Nair S, Chellappan M, & Dharaneedharan D. 2025. First report of fipronil resistance in field populations of rice leaf folder, *Cnaphalocrocis medinalis*: Insights into biochemical and molecular mechanisms. *Pest Manag. Sci.* 81(12): 8050–8063. https://doi.org/10.1002/ps.70113

Usyati N, Kurniawati N, & Rumasa O. 2020. Impact of ecological engineering on the type and population of pests, natural enemies, and yields of the rice. *J. Trop. Plant Pests Dis*. 20(2): 140–149. https://doi.org/10.23960/jhptt.220140-149

Reddy NV, Shanker C, Kannan C, & Rana DK. 2021. Mortality factors of *Cnaphalocrocis medinalis* Guenee (Lepidoptera: Crambidae) in bio-intensive pest management modules of rice. *Indian J. Plant Prot*. 49(3): 161–165.

Wahid AS. 2024. *200 hektar Padi Diserang Serangga Perosak, Ulat Gulung Daun [200 Hectares of Rice Crops Have Been Attacked by the Leaf-roller Caterpillar Pest]*. https://www.sinarharian.com.my/article/687339/edisi/kelantan/200-hektar-padi-diserang-serangga-perosak-ulat-gulung-daun. Accessed 28 September 2025.

Wilson. 1997. Biology and management of rice insects. *Bull. Entomol. Res.* 87(5): 551–552. https://doi.org/10.1017/s0007485300041432

Wilyus, Nurdiansyah F, Herlinda S, Irsan C, Pujiastuti Y. 2012. Potential of egg parasitoids of the yellow rice stem borer Scirpophaga incertulas Walker in several land typologies in Jambi Province. *J Trop Plant Pests Dis*. 12(1): 56–63. https://doi.org/10.23960/j.hptt.11256-63

Yaakop S, David-Dass A, Shaharuddin US, Sabri S, Badrulisham AS, & Che-Radziah CMZ. 2020. Species richness of leaf roller and stem borers (Lepidoptera) associated with different paddy growth and first documentation of its DNA barcode. *Pertanika J. Trop. Agric. Sci.* 43(4): 523–535. https://doi.org/10.47836/pjtas.43.4.08