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REVIEW OF KEY RICE STEM BORER SPECIES THREATENING MALAYSIA'S PADDY INDUSTRY

Siti Wan Rasidah Abdullah[1], Nur Azura Adam[1], Nor Elliza Tajidin[2] & Anis Syahirah Mokhtar[1*]
[1]Department of Plant Protection,
Faculty of Agriculture,
UPM, Malaysia
[2]Department of Crop Science,
Faculty of Agriculture,
UPM, Malaysia
*Corresponding author: *anissyahirah@upm.edu.my*

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ABSTRACT

Rice remains a primary staple food for the Malaysian population. However, the self-sufficiency level (SSL) of rice production in the country remains low. Crop production is increasingly threatened by stem borers, particularly the yellow stem borer (*Scirpophaga incertulas*), black-headed stem borer (*Chilo polychrysus*), pink stem borer (*Sesamia inferens*), and striped stem borer (*Chilo suppressalis*). Integrated Pest Management (IPM) offers an effective and sustainable strategy to control stem borer outbreaks, reduce yield losses, and minimise environmental and human health risks. This review synthesises current knowledge on the major rice stem borers in Malaysia, with emphasis on their distribution and occurrence of rice stem borers, biology and life cycle, host plant preferences, and associated damage levels. In addition, the review highlights the management strategies currently implemented by farmers and relevant authorities to mitigate their impact.

Keywords: Rice stem borer; *Scirpophaga incertulas*; *Chilo polychrysus*; *Sesamia inferens*; *Chilo suppressalis*; pest management

ABSTRAK

Nasi merupakan makanan ruji utama bagi penduduk Malaysia. Namun begitu, tahap sara diri (SSL) pengeluaran padi di negara ini masih rendah. Pengeluaran tanaman semakin terancam oleh serangan pengorek batang, terutamanya Pengorek Batang Kuning (*Scirpophaga incertulas*), Pengorek Batang Kepala Hitam (*Chilo polychrysus*), Pengorek Batang Merah Jambu (*Sesamia inferens*), dan Pengorek Batang Berjalur (*Chilo suppressalis*). Pengurusan Perosak Bersepadu (IPM) merupakan pendekatan yang berkesan dan mampan untuk mengawal wabak pengorek batang, mengurangkan kehilangan hasil tanaman, serta meminimumkan risiko terhadap alam sekitar dan kesihatan manusia. Ulasan ini menghimpunkan pengetahuan semasa berkaitan spesies utama pengorek batang padi di Malaysia, dengan penekanan terhadap taburan dan kehadiran spesies pengorek batang, biologi dan kitaran hidup, keutamaan tumbuhan perumah serta tahap kerosakan yang berkaitan. Selain itu, ulasan ini turut mengetengahkan strategi pengurusan yang sedang dilaksanakan oleh para petani dan pihak berkuasa bagi mengurangkan impaknya.

Kata kunci: Pengorek batang padi; *Scirpophaga incertulas*; *Chilo polychrysus*; *Sesamia inferens*; *Chilo suppressalis*; pengurusan perosak

INTRODUCTION

Rice (*Oryza sativa* L.) is a major cereal crop and the staple food for much of Asia, including Malaysia. Despite its importance, Malaysia's rice production remains insufficient to meet domestic demand. The country currently produces about 2.4 million tonnes of rice annually, while national consumption is approximately 3.4 million tonnes. This gives the country a rice self-sufficiency level (SSL) of just over 60% making it one of the lowest in the region (DoSM 2021). To address this gap, the Ministry of Agriculture and Food Industries (MAFI) has targeted an SSL of 75% by 2025 under the 12th Malaysia Plan.

Rice production in Malaysia is concentrated in 12 designated granary areas, recognised as the nation's primary producing areas under the National Agricultural Policy. These include the Muda Agricultural Development Authority (MADA), Kemubu Agricultural Development Authority (KADA), Integrated Agricultural Development Areas (IADA) Barat Laut Selangor, IADA Kerian, IADA Seberang Perak, IADA Kemasin Semerak, IADA KETARA, IADA Pulau Pinang, IADA Rompin, IADA Pekan, IADA Kota Belud, and IADA Batang Lupar. These granaries serve as the backbone of Malaysia's rice supply and are central to achieving the country's SSL targets.

Rice cultivation plays a crucial role in ensuring Malaysia's food security, as rice is the main staple food for most Malaysians. However, farmers in the major rice-growing regions continue to face serious challenges, especially from pest infestations that can drastically reduce yields. Among these pests, rice stem borers are considered the most destructive. They attack the rice plant by boring into the stem, disrupting the flow of nutrients and water, and eventually killing the plant. Under severe infestations, yield losses can reach as high as 80-90% (January et al. 2020; Khari et al. 2021).

In Malaysia, four main species of rice stem borers have been identified: the yellow stem borer (*Scirpophaga incertulas*), the black-headed stem borer (*Chilo polychrysus*), the pink stem borer (*Sesamia inferens*), and the striped stem borer (*Chilo suppressalis*) (Nik Mohd Noor et al. 2012). These pests attack the rice plant at different growth stages. During the vegetative stage, their feeding causes the central shoot to wither and die, a symptom known as "dead heart." At the reproductive and maturity stages, infestation results in "whitehead" symptoms, where the panicles become empty and fail to produce grains (Abdullah & Mokhtar 2024; Khari & Ab Hamid 2022).

The impact of stem borer infestations in Malaysia has been documented over the years, showing that outbreaks can be widespread and devastating. For instance, around 7,400 hectares of rice fields in Peninsular Malaysia were affected by stem borers, with peak infestations recorded in more than 6,000 hectares during a single cropping season (DoA 2019). A more recent outbreak in the central region of Peninsular Malaysia caused severe damage across 6,632.4 hectares, affecting nearly 98% of the cultivated area (MAFI 2021). Such incidents clearly demonstrate that rice stem borers remain a persistent and serious threat to the country's major rice granary areas.

Given their significant impact, understanding the biology, distribution, and management of rice stem borers is critical. This review compiles and discusses current knowledge about these pests in Malaysia, including their occurrence, life cycle, host plant preferences, and existing management strategies. It also highlights knowledge gaps that need to be addressed to develop more effective and sustainable pest management approaches in the future.

YELLOW STEM BORER, *Scirpophaga incertulas*

Occurrence and Distribution

Scirpophaga incertulas (Walker) is a major pest of rice throughout Asia, including India, Bangladesh, Thailand, Vietnam, China, Japan, Indonesia, Philippines, and Malaysia (Babendreier et al. 2022). YSB is well adapted to flood-prone ecosystems and areas with continuous rice cultivation, feeding primarily on cultivated rice and its wild relatives.

In Malaysia, *S. incertulas* has been consistently reported as the predominant and most destructive rice stem borer species. Studies have documented a high abundance of *S. incertulas* at Sungai Leman, Sungai Panjang, and Sabak Bernam in Selangor, as well as Sungai Manik and Labu Kubong in Perak (DoA 2021). Within the Muda Agricultural Development Authority (MADA) region, this species was also abundantly recorded in Region 2, 3, and 4 (Khari & Ab Hamid 2022). Similarly, field studies in Sabak Bernam further reported higher abundance during the maturation stage (23%) compared with the vegetative stage (11%), indicating distinct periods of crop vulnerability. This is consistent with findings that *S. incertulas* can persist across almost all growth stages of rice (Yaakop et al. 2020).

Collectively, these findings highlight that *S. incertulas* remains the most significant stem borer species in Malaysia, capable of persisting across different rice growth stages and production systems. Its wide distribution, adaptability to local agronomic practices, and capacity to inflict high yield losses make it a priority target for integrated pest management strategies in the country.

Biology and Life Cycle

Scirpophaga incertulas (Walker), commonly called the yellow stem borer (YSB), is a lepidopteran pest belonging to Crambidae. Adults exhibit sexual dimorphisms where males are light brown with scattered brownish dots, including five subterminal and eight to nine apical markings on the forewings and lack abdominal hair tufts (Figure 1c). Males possess a wingspan of 18-22 mm while females are larger (34 mm) and display a pale-yellow abdomen with fine hairs before oviposition, where this feature is lost afterwards (Figure 1d). Both sexes bear a small black spot on the forewing's lower angle. The females deposit egg masses (150-200 eggs per cluster) on leaf blades. Each egg is flattened, oval (1.42 mm × 1.2 mm), and coated with buff-coloured hairs (Figure 1a). Embryonic development concludes within 5-8 days. Larvae progress through six instars, growing from 1.5 mm (first instar) to 12 mm (final instar) with colouration shifting from dark to pale yellow or greenish-yellow (Figure 1b). They are distributed by wind by developing a silken thread to another plant (Sirvi et al. 2021). Neonates feed on leaf sheaths, creating longitudinal chlorotic lesions before boring into stems. A single larva may infest 3-4 stems before pupating. Pupation occurs within the stem's basal portion, lasting 6-10 days, with silken white pupae forming. Adults emerge predominantly between

19:00-21:00, exhibiting nocturnal activity and diurnal concealment in tillers. Larval development spans 33-41 days, influenced by climatic conditions, while the entire life cycle ranges from 35-70 days. Annually, *S. incertulas* completes 4-6 generations (Sirvi et al. 2021).

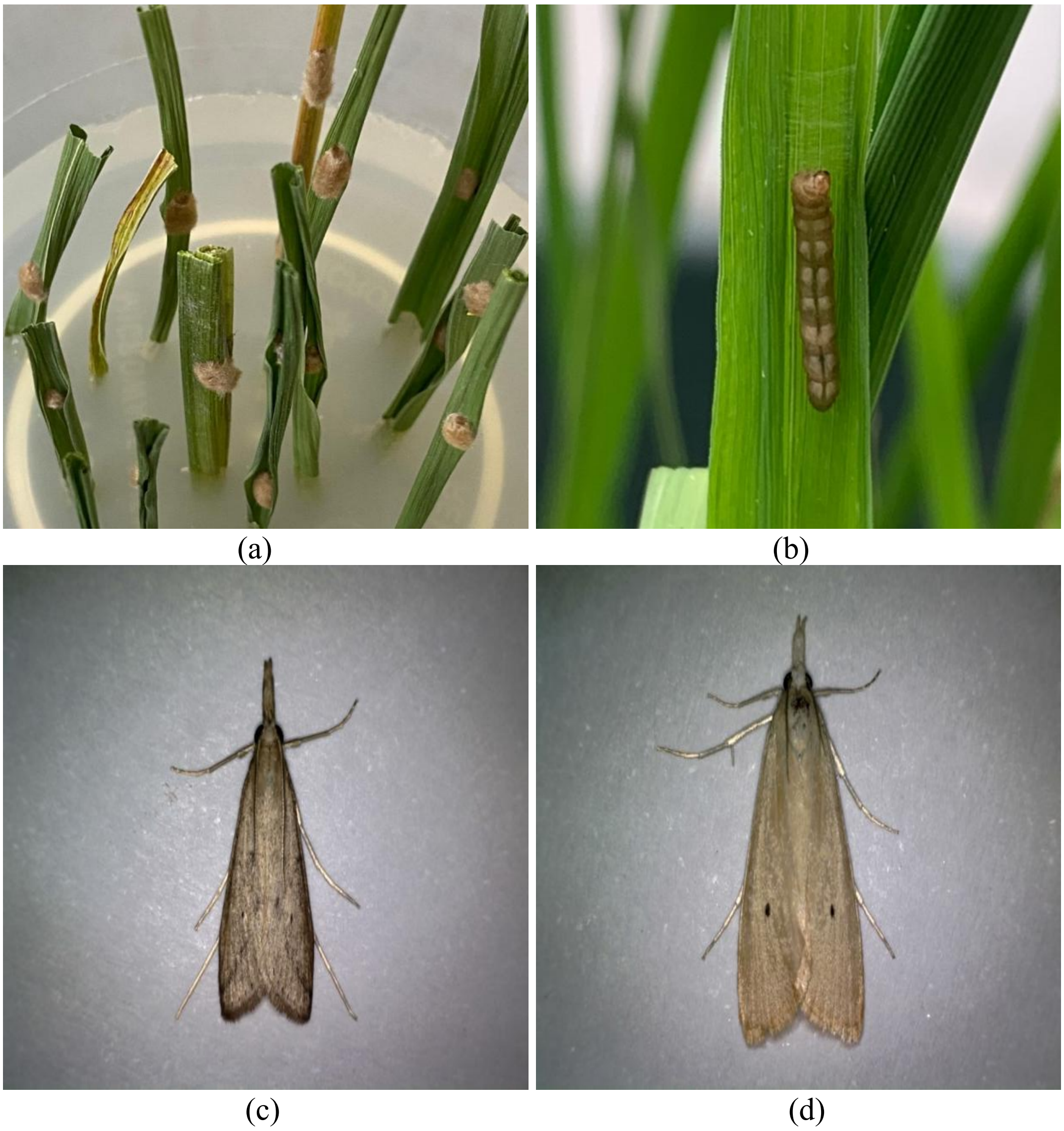


Figure 1. *Scirpophaga incertulas*: (a) Egg, (b) Larva, (c) Male, and (d) Female

Nature of Damage

Scirpophaga incertulas causes significant damage to rice crops throughout all growth stages, with larval infestation typically during the vegetative phase. The insect's feeding activity produces distinct symptomatic damage patterns, such as dead hearts (dried central shoots) during vegetative growth and whiteheads (empty panicles) during reproductive development. The larval damage initiates when neonates consume leaf sheath tissues and tassel buds before boring into stems. This internodal penetration during vegetative stages leads to chlorosis and desiccation of young shoots, resulting in characteristic dead heart formation. This damage manifests as sterile and whitened panicles (whiteheads) during reproductive stages due to disrupted nutrient flow. Yang et al. (2011) further observed that infested plants exhibit progressive wilting and tassel necrosis, ultimately leading to complete panicle infertility. The economic impact of *S. incertulas* infestation is substantial, with documented yield losses of up to 80% depending on infestation severity (January et al. 2020). This underscores the importance of implementing early-stage control measures to mitigate potential production losses in affected rice cultivation systems.

Host Plant

Scirpophaga incertulas is primarily a monophagous pest specialising in cultivated rice (*Oryza* spp.), though it exhibits limited polyphagy. The larvae demonstrate stem boring behaviour predominantly in gramineous hosts (Sutrisno 2007). Historical records document occasional infestation of alternative plant species, including *Coix lachrymal*, *Ischoemum aristum*, *Adropogon odoratus*, *Anthistiria ciliate*, *Cyperus* spp., and *Hypolytrum nemorum* (Sutrisno 2007). This secondary host range appears restricted, reinforcing the species' strong ecological association with rice ecosystems.

BLACK-HEADED STEM BORER, *Chilo polychrysus*

Occurrence and Distribution

Beyond the predominant YSB, other stem borer species also contribute to rice production losses in Asia and Malaysia, with their abundance and impact varying across regions. The black-headed stem borer (BHSB), *Chilo polychrysus* (Meyrick) (Lepidoptera: Crambidae), is regarded as a major pest in rice-growing areas of North Africa, Southern Europe, and Asia, including India, Indonesia, South China, and Malaysia (Hajjar et al. 2023). In Peninsular Malaysia, its status as a pest has long been recognised, although its relative importance has shifted over time. In Malaysia, historical records indicate that *C. polychrysus* was a dominant stem borer species before the 1960s, but its significance declined following the adoption of double cropping systems with short maturing rice varieties which also increased the rice production (Dorairaj & Govender 2023).

Recent studies highlight its continued importance in specific agroecological areas. Within the Muda Agricultural Development Authority (MADA), *C. polychrysus* was reported as the most abundant species in Region 1 and was identified as the dominant dry season pest north of Alor Setar, Kedah (Khari & Ab Hamid 2022). Similarly, Razali et al. (2015) documented *C. polychrysus* as the only stem borer species present in Tanjung Karang, Selangor. This suggests that the species was dominant in that locality. A significant outbreak was also reported in the IADA Seberang Perak, where the species damaged 4,306.88 hectares of rice and affected 2,155 farmers (DoA 2021).

Biology and Life Cycle

Chilo polychrysus is commonly known as the black-headed stem borer or dark-headed rice stem borer. The eggs (Figure 2a), resembling shining scales, are laid in clusters of 20-150 underneath the leaf blade, positioned near the base of leaves or leaf sheaths. They are creamy white, without hair covering, and exhibit overlapping within the egg mass. It takes 26 to 61 days to complete its life cycle through 3 instars, pupa, and adult (Bhatt et al. 2018). The newly hatched larvae (Figure 2b) exhibit a robust negative geotropism, curling upward towards the tip of the plant (Mashhoor et al. 2018). The head of *C. polychrysus* is black to dark brown and the abdomen is dull white with three distinct brown stripes on the top and two on the sides. The adult of *C. polychrysus* (Figure 2c and 2d) is yellowish brown, with 2-3 small black dots positioned at the centre of its white-yellow forewing (PBPI 2017).

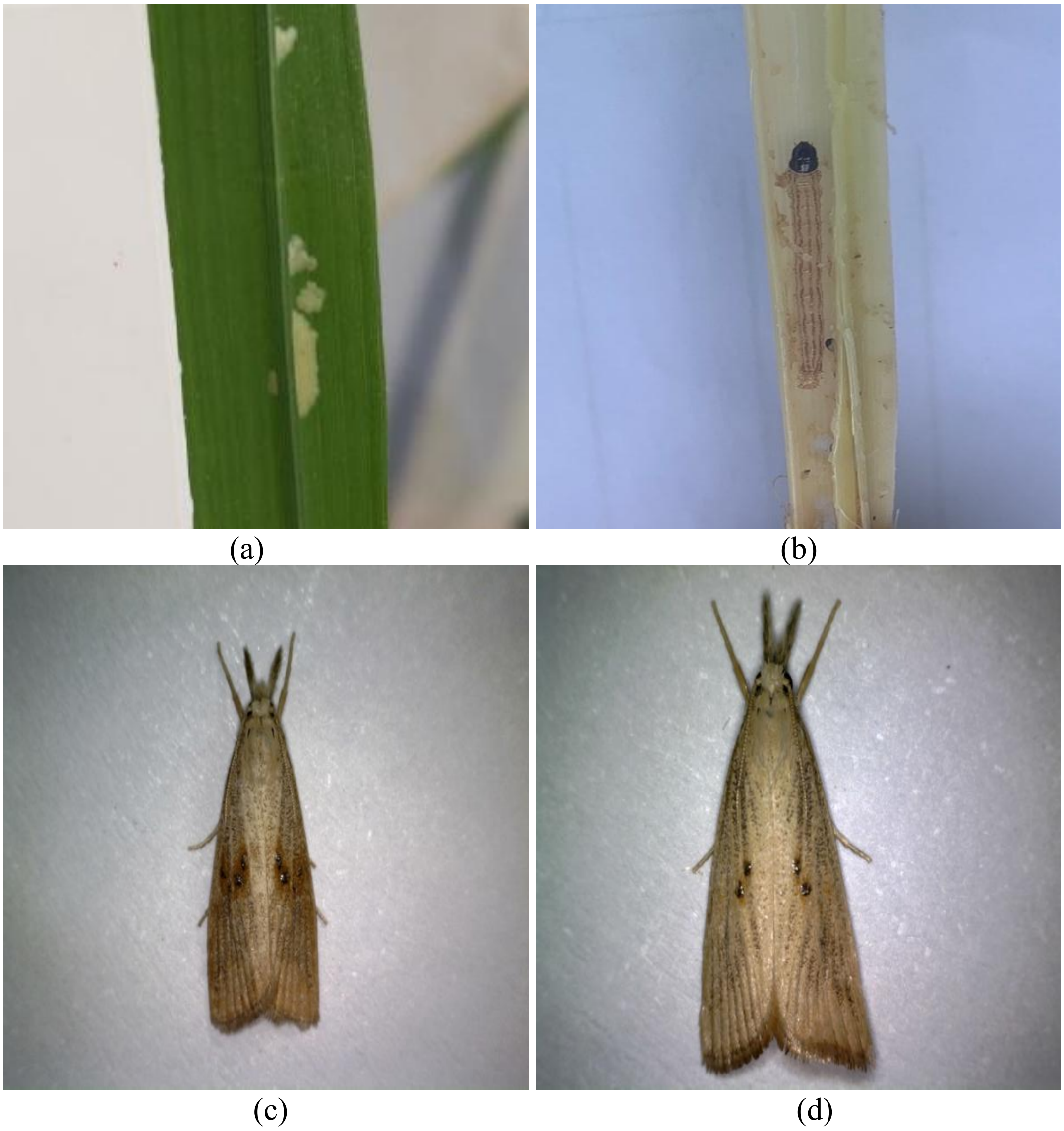


Figure 2. *Chilo polychrysus* (a) Egg (Khari 2021), (b) Larva, (c) Male, and (d) Female

Nature of Damage
The damage occurs as the larvae bore into the growing points, causing the central leaf to fail to unfold. It leads to the leaf sheath of plant cane developing irregular holes and mature larvae penetrating the stems. The symptoms of damage caused by *C. polychrysus* closely resemble those observed with *S. incertulas*. The initial boring and feeding activity on the leaf sheath creates broad, whitish, discoloured areas known as white heads at the feeding sites. However, wilting and drying of the leaf blades, referred to as dead heart which only occur infrequently. According to Bhatt et al. (2018), this prevents tillers from producing panicles. In the later stages of plant growth, larval feeding results in empty or partially filled grains in the panicle.

Host Plant
Moreover, *C. polychrysus* imposes significant damage on various crops such as water bamboo, sugarcane, sorghum, corn, wheat, millet, horsebean, and rape (Li et al. 2006). It was recorded that *S. polychrysus* thrived on various wild hosts, such as *Setaria spp Cyperus digitatus, Oryza latifolia*, *Eriochola* sp., *Scripus grossus*, and *Panicum* sp. (CABI 2019).

PINK STEM BORER, *Sesamia inferens*

Occurrence and Distribution

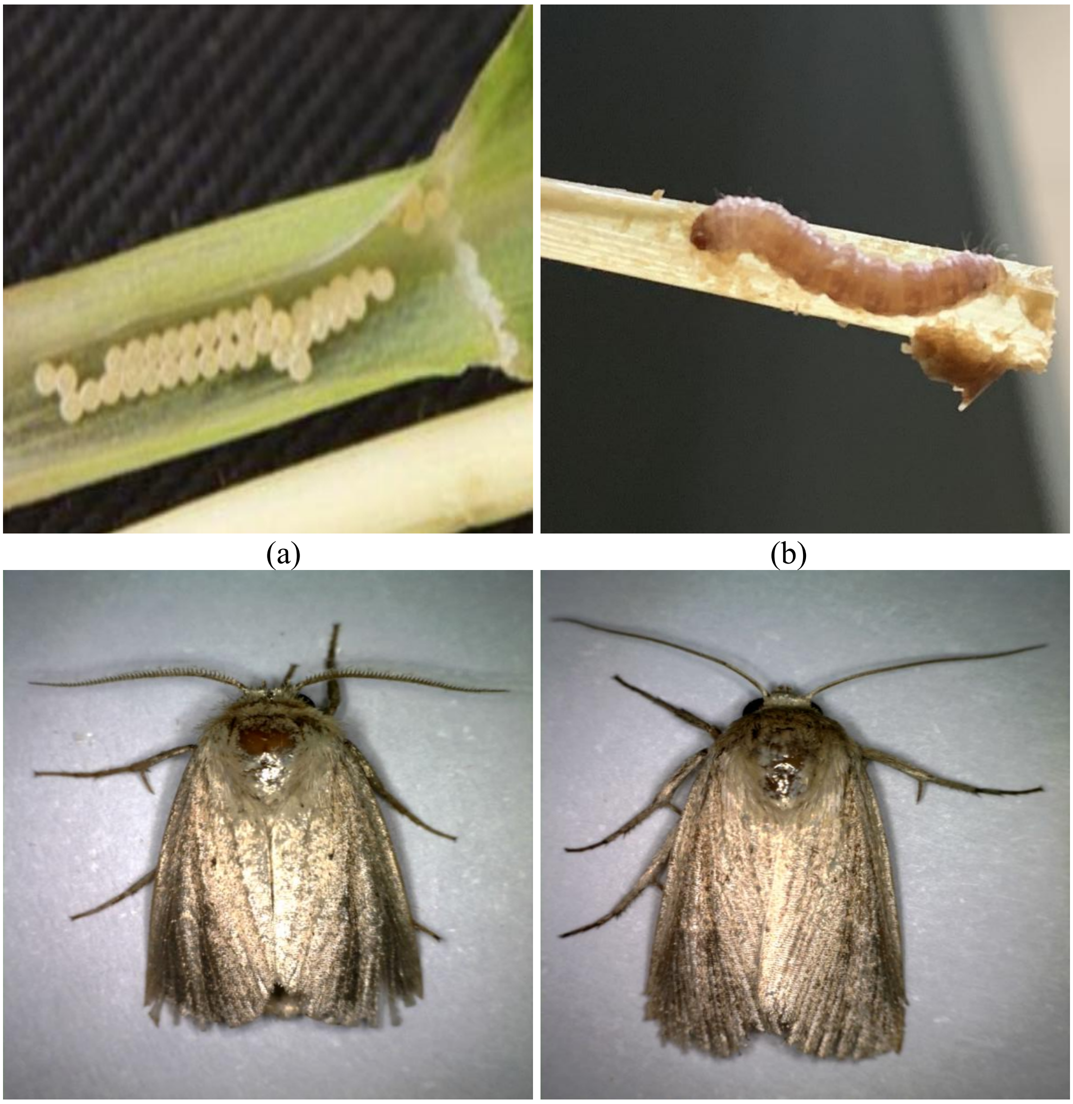
The pink stem borer (PSB), *Sesamia inferens* (Walker), is widely distributed across Asia and has been reported in India, Pakistan, Bangladesh, Myanmar, China, Sri Lanka, Malaysia, Taiwan, Japan, Indonesia, and the Philippines (Hajjar et al. 2023). Beyond Asia, its occurrence has also been documented in Hawaii and Guam, United States. Although generally regarded as a secondary pest compared to *S. incertulas*, the abundance and damage levels of this species can vary with rice growing environments.

In Malaysia, *S. inferens* has been detected but usually at lower abundance relative to other stem borer species. For example, in organic paddy fields under the System of Rice Intensification (SRI), PSB population was reported at moderate levels (Sulaiman et al. 2013). In contrast, studies in conventional rice fields have recorded only a limited presence, where 17 individuals were collected, representing the lowest abundance among the stem borer species surveyed (Yaakop et al. 2020).

These findings indicate that while *S. inferens* is present in Malaysian rice ecosystems, its role as a pest remains relatively minor compared to dominant species such as *S. incertulas* and *C. polychrysus*. Nevertheless, its documented presence across diverse rice production systems suggests the need for continued monitoring, particularly under changing cultivation practices and climatic conditions that may alter its abundance and pest status.

Biology and Life Cycle

Sesamia inferens is a moth species of lepidopteran from the family of Noctuidae and was first described by Francis Walker in 1856. The pink stem borer belongs to a family distinct from the rest. Unlike other stem borer species, the *S. inferens* distinguishes itself by depositing its creamy white eggs (Figure 3a) openly and hairless in the area between the leaf sheath and the stem (Narayan 2018), and it is likely to have the most effective protection. The eggs are hemispherical and have delicate features arranged in 2-4 longitudinal row (Sharma et al. 2017). The larvae (Figure 3b) hatch in approximately seven days (Baladhiya et al. 2018). As *S. inferens* neonate ages, its colouration transforms into a combination of pink and black hues. According to Narayan (2018), newly hatched larvae exhibit a golden skin tone with black head capsules, while mature larvae transform pinkish-purple head capsules that adopt hues of brown or orange-red. The larvae hatch in clusters either inside or behind the leaf sheath, keep feeding on the outer layer of the sheath, and then continue to bore through the stems during the central growing stage of plants. The larvae develop through six to eight instars, with the complete larval phase lasting around 23 to 39 days (Baladhiya et al. 2018). The larvae will undergo the pupa stage, where the body of the larvae shrinks due to feeding cessation. The pupation is 9-12 days, and during this process, the pupa will become firm while turning dark brown (Baladhiya et al. 2018). The moths of *S. inferens* display a straw colouration with a broad dark brown triangular stripe running along the mid-longitudinal axis, where the male moth is marginally more diminutive in size compared to the female (Baladhiya et al. 2018). It was documented by Viswajyothi et al. (2019) that adults can be differentiated by their antennae, where the male (Figure 3c) has pectinate antennae and the female (Figure 3d) has filiform antennae.



(a) (b)

(c) (d)

Figure 3. *Sesamia inferens*: (a) Egg (Baladhiya et al. 2018), (b) Larva, (c) Male, and (d) Female

Nature of Damage

The primary impact of the *S. inferens* is predominantly localised to the neighbouring and close proximity areas (Xiang et al. 2023), causing the leaves to develop elongated holes, about 2-3 mm in size and arranged in rows when the leaves unfold. As the plant grows, these holes damaged by *S. inferens* expand and transform into slits and streaks (Li et al. 2023). Further boring and feeding on plant stems results in a dead heart symptom in rice, maize, sugarcane, barley, and sorghum at the vegetative stage (Baladhiya et al. 2018; Li et al. 2023) due to failure of water and nutrient transport. The white head symptom can be observed at the heading stage of rice, wheat, barley, and millet, where the panicles of the crops will be white and empty or partially filled (Sidar et al. 2017b; Sasmal 2018).

Host Plant

S. inferens is a polyphagous pest that poses a threat to a variety of gramineous crops, including rice, maize, pearl millet, finger millet, wheat, oats, barley, sugarcane, and certain grasses such as tropical cup grass, saramolla grass, citronella grass, barnyard grass and lemon grass (Baladhiya et al. 2018; Sidar et al. 2017a). According to Jalali and Singh (2002), the larvae of

S. inferens were primarily found on rabi maize. While surveying insect pests affecting glutinous sorghum used for Chinese liquor production in Guizhou Province, it was observed that *S. inferens* has been responsible for significant damage to the local sorghum in recent years (Li et al. 2023).

STRIPED STEM BORER, *Chilo suppressalis*

Occurrence and Distribution

Chilo suppressalis (Walker), commonly referred to as the striped stem borer (SSB) or Asiatic stem borer, is a major insect pest of rice across a wide range of subtropical and tropical agroecosystems. It holds a significant pest status in Asia, North Africa, and Southern Europe. The species is widely distributed in East Asia, India, Indonesia, and Malaysia (Nik Mohd Noor et al. 2012). Besides, SSB is also capable of thriving in temperate environments such as Japan, Korea, and Iran, as well as in both wet and dry ecosystems of Taiwan (Ghahari et al. 2009). This broad ecological adaptability underlines its importance as a pest of rice globally. In Malaysia, Sulaiman et al. (2013) reported that *C. suppressalis* was the most abundant stem borer species recorded in Melaka, under organic paddy cultivation. *C. suppressalis* demonstrates its greater relevance in certain localised agroecosystems despite being less dominant nationwide. These findings suggest that *C. suppressalis* may play a more significant role in certain localised agroecosystems in Malaysia, particularly under organic or non-conventional rice farming systems, but it is generally less abundant than other stem borers at the national scale.

Biology and Life Cycle

A female of *C. suppressalis* can deposit 5-6 clusters of eggs, totalling 200-700 eggs over its life cycle (Xiang et al. 2023). The eggs (Figure 4a) of the striped stem borer are disc-shaped, with newly deposited eggs appearing white, transitioning to yellow as they age, and ultimately turning black when ready to hatch (Narayan 2018). After hatching, *C. suppressalis* larvae (Figure 4b) exhibit gregarious behaviour during the initial three instars, but they disperse in later instars. The first generation of larvae imposes specific conditions for survival. Besides, the recently hatched larvae typically show a behaviour where they enter either the third or fourth leaf sheath directly without proceeding towards the tip of the plant, which happens in the second and third broods. The *C. suppressalis* larvae have a vast, shiny brown or orange head, and their body are light brown or pink with five rows of stripes that start from the head to the tail. According to Xiang et al. (2023), the larvae of *C. suppressalis* can be classified into seven different instars based on the width of the head shell. As claimed by Narayan (2018), the adult *C. suppressalis* (Figure 4c) displays a brownish-yellow colouration with silvery scales, displaying a row of seven or eight small black spots on the terminal border of each forewing, with the forewings exhibiting a lighter hue compared to the hind wings.

(a) (b) (c)

Figure 4. *Chilo suppressalis*: (a) Egg (Mueller 2017), (b) Larva (Nature 2019a), and (c) Adult (Nature 2019b)

Nature of Damage

Chilo suppressalis larvae cause damage to rice plants by feeding on the inner cells of the stem and devouring their way towards the plant's base, which cuts off the water and nutrients to the plants. After infestation, it will show the symptoms of dead leaf sheath, dead heart, and white head at the tillering, booting, and heading stages, respectively. However, the initial damage of *C. suppressalis* can be seen in the central rice field during the rice's complete growth and development stage. The damage can affect the growth of rice plants up to the maturity stage (Xiang et al. 2023). *Chilo suppressalis* causes significant damage, causing considerable crop yield reductions and devastation across rice fields (Hassani et al. 2022).

Host Plant

Chilo suppressalis, commonly known as the rice stem borer, has been recognised historically as an insect pest with a wide-ranging diet, having been documented to feed on more than 40 plant species, such as rice, water-oat, wild water-oat, corn, sugarcane, grape, broad bean, wheat, and various winter cover greens. It was reported that *C. suppressalis* larvae were found on 17 different overwintering plant species belonging to 7 plant families, such as Amarantaceae, Compositae, Cruciferae, Cyperaceae, Poaceae, Sparganiaceae, and Typhaceae (Ghahari et al. 2009).

MANAGEMENT STRATEGIES FOR RICE STEM BORERS

The rice stem borer is one of the pests that significantly affects rice yield production. With the increasing human population, management strategies must be implemented to control rice stem borers while minimising crop damage.

Cultural Method

Management of the Rice Field

Cultural practices represent one of the oldest and most sustainable approaches for insect pest management in rice ecosystems. These strategies primarily involve manipulating agricultural practices to minimise pest incidence with common methods including crop rotation, removal of residual plant material, and adjustment of planting schedules. Such practices have been demonstrated to effectively suppress rice stem borer populations in various regions. Water management is another critical factor, as alternating wetting and drying cycles in paddy fields, particularly during the early growth stages, have been shown to reduce stem borer infestations by disrupting their development.

However, in Malaysia, the applicability of these methods is constrained by the production system. Rice cultivation predominantly follows a monoculture practice with biannual planting cycles, limiting the feasibility of crop rotation as a management tool. Besides, the major rice granary areas are supported by large-scale irrigation networks, each covering more than 4,000 hectares, and irrigation schedules are carefully coordinated to ensure adequate water supply for crop growth. While this system ensures reliable production, the continuous availability of host plants and stable water conditions may inadvertently favour the persistence of stem borer populations. Another cultural factor influencing stem borer infestations is the choice of establishment method. The two primary techniques for cultivating rice in Malaysia are direct seeding and transplanting. Direct seeding has become the dominant practice due to its economic advantages (Elsoragaby et al. 2018). However, the preference for direct seeding poses additional risks for pest management. Studies consistently show that direct-seeded fields harbour higher stem borer populations than transplanted fields, highlighting their greater vulnerability to infestation. This finding suggests that higher plant density in direct-seeded plots increased rice stem borer abundance, while wider spacing in transplanted plots reduced it.

Utilisation of the Resistant Rice Variety

Research on rice stem borer interactions, particularly host plant resistance as a sustainable pest management strategy, remains relatively limited. Resistant rice varieties are often associated with specific morphological and biophysical traits such as enhanced stem hardness and leaf pubescence, which can reduce susceptibility to stem borer attack. Genetic approaches for resistance breeding have largely focused on exploiting natural resistance in cultivated rice and wild relatives and incorporating resistance genes from exogenous sources. In India and Nepal, several rice cultivars, including Ratna, Sasyasree, Vikas, Pantdhan 6, Sarju 52, and Silki have demonstrated resistance to stem borers (Nyaupane 2022). However, in Malaysia, the situation is notably different. Local breeding programmes have made significant progress in developing varieties resistant to major pests and diseases such as brown planthopper (*Nilaparvata lugens*) and rice tungro virus. Despite this progress, no rice cultivar has yet been officially reported as resistant to rice stem borers (Khari 2021). Nevertheless, certain Malaysian varieties appear to possess tolerance traits that may indirectly reduce stem borer infestation. For example, rice lines with smaller stem diameters, higher tillering ability, and narrower flag leaf angles were observed to sustain lower levels of stem borer attack (Khari et al. 2021).

Application of Fertiliser

Nutrient management plays a crucial role in shaping rice susceptibility to stem borer attack. Excessive nitrogen application is often associated with higher pest incidence, whereas optimised or staged nitrogen use can sustain yield while reducing pest pressure (Teng et al. 2016). Potassium also contributes to plant resilience by reducing damage symptoms and improving recovery in infested plants (Sarwar 2012). In Malaysia, fertiliser recommendations follow a staged application strategy that coincides with key rice growth phases. Nitrogen is supplied at each stage, while potassium is consistently incorporated, reflecting a dual focus on productivity and plant health. Although these practices are not always assessed directly in relation to pest suppression, they represent an important foundation for integrating nutrient management with pest management strategies.

Among other nutrients, silicon (Si) offers particular promise by strengthening plant stems and impeding stem borer larval feeding. Studies have demonstrated that Si fertilisation improves plant resistance and reduces lodging (Jawahar et al. 2015). In Malaysia, the use of Si-based fertilisers for pest management is still in its early stages, presenting opportunities for further research and application. While neighbouring countries have reported significant benefits of Si amendments on paddy soils, crop growth, and pest suppression (Mahmad-Toher et al. 2021). However, farmers in Kedah have independently reported positive experiences with Si fertilisers, citing improvements in crop growth, yield, and reduced pest and disease incidence. These observations suggest an underutilised potential for integrating Si fertilisation into Malaysian pest management strategies.

Physical Control

Monitoring is a key component of pest management to enable early detection of outbreaks and timely control decisions. Light traps are particularly effective for rice stem borers as these nocturnal moths are strongly attracted to light sources at the favourable time of monitoring (Uddin et al. 2025). These traps provide insights into population dynamics and can serve as reliable outbreak forecasts, as shown in India, where YSB captures corresponded closely with field symptoms such as dead heart and whitehead (Chatterjee et al. 2017). In Malaysia, research on light traps for rice stem borers remains exploratory, with most work focusing on other pests such as the brown planthopper. Nonetheless, light traps have been deployed operationally. For example, during outbreaks in IADA Seberang Perak, the Department of Agriculture installed light traps to strengthen surveillance (Mohamed 2019). Solar-powered light traps have also been introduced in Pahang as part of sustainable pest management programmes. While these efforts highlight the recognition of light traps as a monitoring tool, quantitative evaluations of their effectiveness under Malaysian conditions are still needed. Neighbouring countries provide valuable insights. In Indonesia, solar-powered traps successfully captured multiple rice pests, including *Scirpophaga innotata* and *Leptocorisa acuta* (Syahta et al. 2018). Beyond light traps, pheromone-based technologies are increasingly being explored. In Malaysia, pheromone traps are commonly used for monitoring and controlling the rhinoceros beetle, *Oryctes rhinoceros* (L.), a major oil palm pest. By contrast, studies in Indonesia showed that pheromone-mediated mating disruption reduced YSB catches by over 70% (Iqbal et al. 2023). Overall, light and pheromone traps represent promising and environmentally friendly monitoring tools.

Biological Control

Biological control offers an eco-friendly and sustainable alternative to chemical insecticides in managing rice stem borers. Globally, a wide range of agents has been investigated, including nano-organometallic compounds that reduce the survival of *C. polychrysus* and entomopathogenic bacteria such as *Skermanella* sp. and *Serratia* sp., which exhibit larvicidal activity against *S. inferens* (Panneerselvam et al. 2018; Patitungkho et al. 2023). In addition, parasitoids including *Tetrastichus schoenobii*, *Telenomus dignus*, and *Trichogramma japonicum* can parasitise up to 90% of *S. incertulas* egg masses, highlighting their efficiency in regulating populations. The conservation of these natural enemies is often enhanced through habitat management and the reduction of broad-spectrum insecticide use (Togola et al. 2020).

In Malaysia, the conservation of natural enemies in rice ecosystems has received increasing attention. Sustaining parasitoid populations also requires adequate nectar sources, which can be provided by flowering plants. Local initiatives have demonstrated the value of planting ornamental and flowering species such as *Lantana camara*, *Turnera* sp., *Cosmos* sp., *Portulaca grandiflora* and *Helianthus annuus* around rice fields to provide shelter, alternative food, and breeding sites for natural enemies (Sahabudin 2023). Recent field research in Malaysia reported that plots planted with *Turnera trioniflora* hosted 73% higher parasitoid abundance than plots without the plant, across two consecutive cropping seasons in IADA KETARA (Hamdan et al. 2023). These findings underscore the potential of habitat manipulation for enhancing parasitoid populations under Malaysian rice ecosystems.

Chemical Control

Application of Chemical Insecticide

Insecticides are widely applied in non-resistant rice varieties to control pests. Farmers commonly use organophosphates, carbamates, pyrethroids, and other chemical classes. While effective against severe infestations, their efficacy is limited against stem borers due to larvae's brief external exposure before stem entry (Ogah & Nwilene 2017). Systemic insecticides are generally more effective when applied during the vegetative growth stage of the rice plant, as they are absorbed and translocated throughout the plant tissues, allowing them to reach and control early infestations more effectively. The application of insecticides is based on Economic Threshold Levels (ETL) that should occur at 5% infestation to balance control costs and yield loss. However, overuse risks pest resistance and harms natural enemies and ecosystems (El-Wakeil et al. 2013; Kole et al. 2019).

In Malaysia, insecticide regulation is stringent, with products assessed for biological efficacy, environmental safety, and human health risk before registration (DoA 2025). Farmers are also guided by the Pesticide Information System (SISMARP) for updated recommendations on registered products. Currently, active ingredients such as buprofezin + cartap hydrochloride, fipronil, indoxacarb, chlorantraniliprole, and flubendiamide are approved for stem borer management (DoA 2025; MADA 2024). Importantly, local studies have generated efficacy data under Malaysian field conditions. For instance, Khari & Hamid (2021) reported that fipronil showed the highest toxicity against *C. polychrysus* (LC_{50} = 16.12 mg/L), followed by chlorantraniliprole (43.25 mg/L) and flubendiamide (76.43 mg/L). To minimise the risk of insecticide resistance, it is recommended for farmers to rotate or alternate insecticides with different active ingredients across seasons or years. This strategy reduces the selection pressure on pest populations, thereby slowing the development of resistance.

Integrated Pest Management (IPM)

Integrated Pest Management (IPM) is an environmentally friendly approach that combines cultural, biological, physical and chemical methods to control pests while minimising risks to human health and the environment. By adopting IPM practices, farmers can reduce dependence on pesticides and gain greater awareness of sustainable strategies for managing pests in rice fields. In Malaysia, successful implementation of IPM has been demonstrated under the MADA programme, which reported improvements in water quality, food safety, pesticide application safety and the overall sustainability of pest management systems. The programme also achieved substantial economic benefits with estimated cost savings per season of RM 756,393 for insecticides, RM 40,537 for herbicides, and RM 94,753 for fungicides across 454 farmers (Amir et al. 2012).

CONCLUSION

Rice stem borers remain among the most destructive insect pests threatening Malaysia’s paddy industry, with the yellow stem borer (*Scirpophaga incertulas*), black-headed stem borer (*Chilo polychrysus*), pink stem borer (*Sesamia inferens*), and striped stem borer (*Chilo suppressalis*) continuing to inflict substantial yield losses across major granary areas. Despite decades of research and management efforts, their persistence reflects the complex interplay between pest biology, climatic variability, and intensive cultivation systems. Sustainable management therefore requires an integrated, site-specific approach combining resistant rice varieties, improved nutrient and water management, timely monitoring through light and pheromone traps, and the conservation of natural enemies within rice ecosystems. Strengthening farmer awareness and capacity in Integrated Pest Management (IPM) remains vital to reducing pesticide dependence and ensuring long-term field resilience. Future research should focus on identifying locally adapted resistant cultivars, exploiting biological control agents, and advancing precision-based pest surveillance technologies. Through coordinated efforts among researchers, policymakers, and farmers, Malaysia can progress toward a more sustainable and resilient rice production system that safeguards both productivity and environmental integrity.

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The authors declare that they have no conflict of interest.

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This manuscript has no associated data.

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Siti Wan Rasidah Abdullah (SWRA) and Anis Syahirah Mokhtar (ASM) developed the scope and outline of the review. SWRA performed the literature search, analysis and drafted the manuscript. ASM, Nur Azura Adam (NAA) and Nor Elliza Tajidin (NET) contributed to the interpretation of the results and reviewed the manuscript. All authors reviewed and edited the manuscript and approved the final version.

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