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REVIEW

Bio-ecology and management approaches of yellow peach moth, *Conogethes punctiferalis* (Lepidoptera: Crambidae)

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Key words. Agriculture, pest, damage potential, invasive species

Abstract. The yellow peach moth, *Conogethes punctiferalis* is a well-known agricultural pest with significant impacts on crops from Southeast Asia to Australia. It has also become one of the major pests of corn (*Zea mays*) in China. This review provides a comprehensive overview of the bio-ecology, potential damage, and management of *C. punctiferalis* on various economically important crops. The review discusses the current management strategies for *C. punctiferalis*, mainly based on chemical insecticides, and highlights their limitations and sustainability concerns. The authors emphasize the urgent need for sustainable integrated pest management (IPM) approaches tailored to the affected regions. Key research directions and recommendations are presented to fill knowledge gaps and improve the effective management of *C. punctiferalis* in agriculture.

INTRODUCTION

The yellow peach moth (YPM), *Conogethes punctiferalis* (Guenée, 1854) (Lepidoptera: Crambidae), formerly known as *Dichocrocis punctiferalis*, is a highly polyphagous lepidopteran pest. Larvae feed on and develop on the vegetative and reproductive parts of over 120 plant species from 19 families (Waterhouse, 1993; Xiao et al., 2012). Host phenology and environmental conditions directly or indirectly influence developmental parameters, which can play a key role in the spread of the pest. Many researchers have studied these effects extensively in laboratory and field conditions (Alagar et al., 2013). The development time and fertility of the pests decrease with increasing temperatures (15 to 27°C) (Du et al., 2012). Larvae can overwinter on fallen leaves, fruits and seeds of host plants (Ithnin et al., 2008; Molet, 2015). The development time of the larval stages varied between 20 and 23 days in August and September at 21–35°C and between 22 and 26 days in October and January at 14–28°C (Gundappa et al., 2015). Ithnin et al. (2008) reported a larval period of 14 to 21 days at 27 ± 2°C. The number of generations per year varies according to climatic conditions and host plants. For example, *C. punctiferalis* has two to three generations in Japan and China (FAO, 2007), and five to six generations in India (Krishnamurthy et al., 1989). The pest completes a life cycle in 25–40 days with 2–4 and 3–5 generations per year in northern and southern China, respectively, which is mainly due to climatic differences in both regions (Lu et al., 2010). The life cycle of *C. punctiferalis* is shown in Fig. 1. It causes significant economic damage to crops in several developed and developing countries and impacts agriculture, and forestry (Inoue & Yamanaka, 2006; Li et al., 2015). Research has confirmed the widespread presence of YPM from Southeast Asia to the Orient and Australia (Shaffer et al., 1996). *Conogethes punctiferalis* is a serious pest of various fruits and corn in China (Wang et al., 2016; Jing et al., 2019), papaya in Australia (Chay-Prove et al., 2000), lychee in Korea and durian in Thailand, sunflower in New Zealand (CPC, 2005) and fruits, corn, cotton and castor in India (Thyagaraj et al., 2003). The distribution area of C. Researchers have observed that the population of *C. punctiferalis* is increasing day by day, and they have discovered the pest that attacks mango

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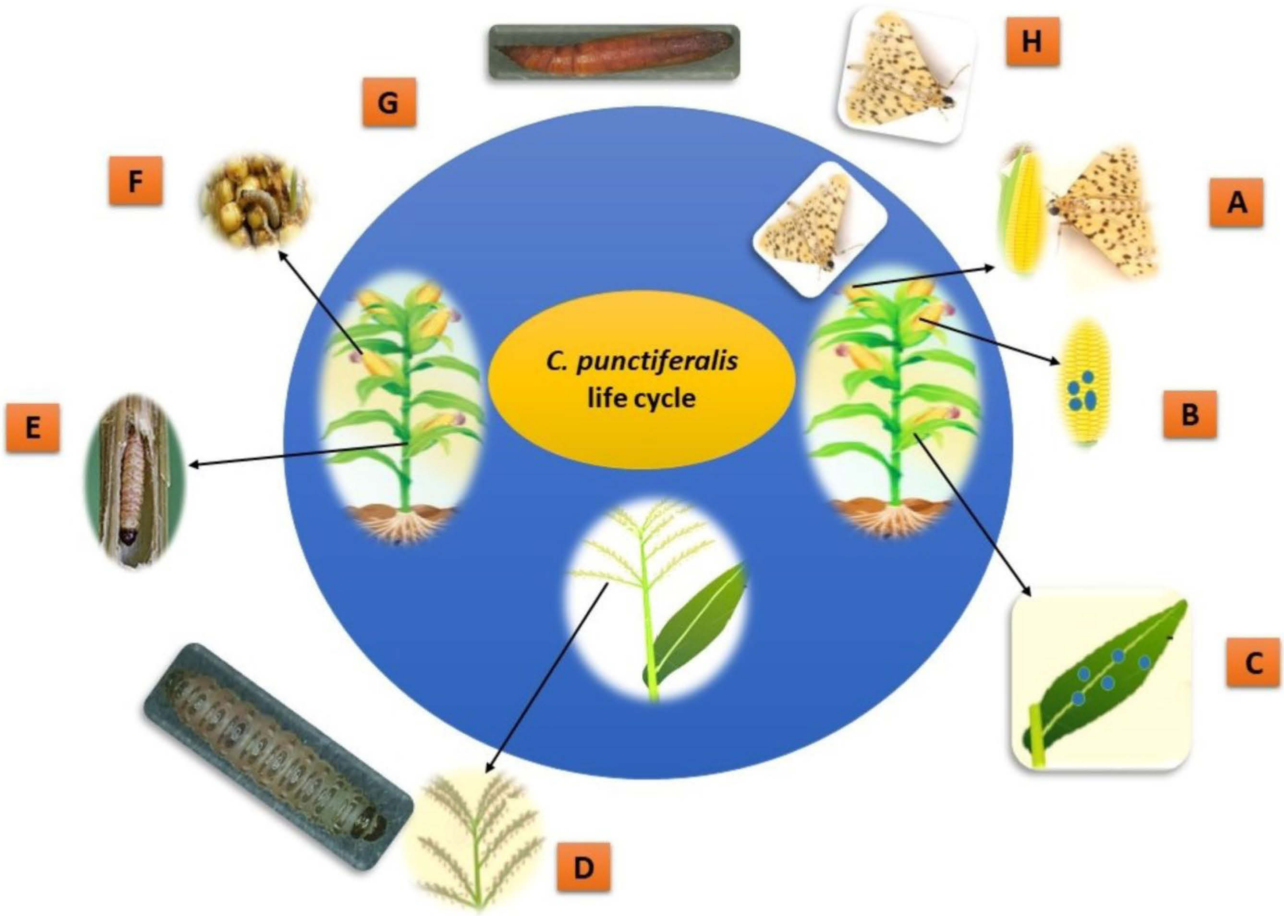

Fig. 1. The life cycle of *C. punctiferalis* on corn host plant. (A) adult migration to corn; (B) adult lays eggs on the cobs; (C) adult lays eggs on leaves; (D) eggs hatch and larvae feed on tassels/silk; (E) sometimes larvae bore into the stem, feed after making tunnels in the stem and cause a dead heart; (F) mature larvae feed on corn grains/cobs and cause huge economic losses; (G) older instars converted into pupae inside the host parts/cobs or stems; (H) adults emerge and start searching for host plants/corn for oviposition.

fruits, indicating its potential as a major pest (Sing & Kaur, 2014; Kumar et al., 2017a). Climate change increases the population of *C. punctiferalis* during the harvesting season of fruits and flowers, resulting in heavy losses (Thyagaraj, 2003). Researchers have documented peak activity of the pest during specific periods in several fruits and crops worldwide (Korycinska, 2012; Sing & Kaur, 2014; Gundappa et al., 2018). The feeding activity of C. punctiferalis can cause significant damage, including tunneling in the fruits and stems of crops, reducing the quality and marketability of products. *C. punctiferalis* excretes sugary materials onto the host during feeding, attracting other insect pests and pathogens that further damage the infected host (Chakravarthy et al., 2015). Secondary insect pests, diseases or pathogens such as Phytophthora and blight result in economic losses for farmers, especially those who rely on these crops as a source of income (Rojas-Sandoval, 2023). Fruits affected by pests may not meet the quality standards required for market access at home and abroad, potentially leading to restrictions on the export of affected crops, and negatively impacting a country's agricultural trade and the reputation of the agricultural industry. YPM larvae have been observed in ports of many countries during the import and export of goods and spread through plant parts such as shoots, stems, fruits, and seeds. Therefore, *C. punctiferalis* has been classified as a quarantine pest in several countries (Molet, 2015). International trade in its host plants such as mango, guava, peach, plum, chestnut and many others, has been restricted by the European and Mediterranean Plant Protection Organization (EPPO) to regions where this pest has not spread (EPPO, 2023). To address these challenges, it is essential to implement effective pest management strategies, including vigilant monitoring, preventative measures and targeted control methods to minimize the impact of this pest on crop production and agricultural sustainability. The current literature provides an updated and comprehensive overview of *C. punctiferalis*, providing an in-depth understanding of its bio-ecology, its potential to damage economically important crops, with corn being a notable example, and various management approaches to control *C. punctiferalis*. Our conclusions can be valuable for researchers, agricultural professionals and policymakers concerned with pest control and crop protection in regions where *C. punctiferalis* is a significant problem.

GEOGRAPHIC DISTRIBUTION, POTENTIAL EXPANSION AND QUARANTINE PEST STATUS

The presence of *C. punctiferalis* larvae has been documented in various regions outside their typical distribution,

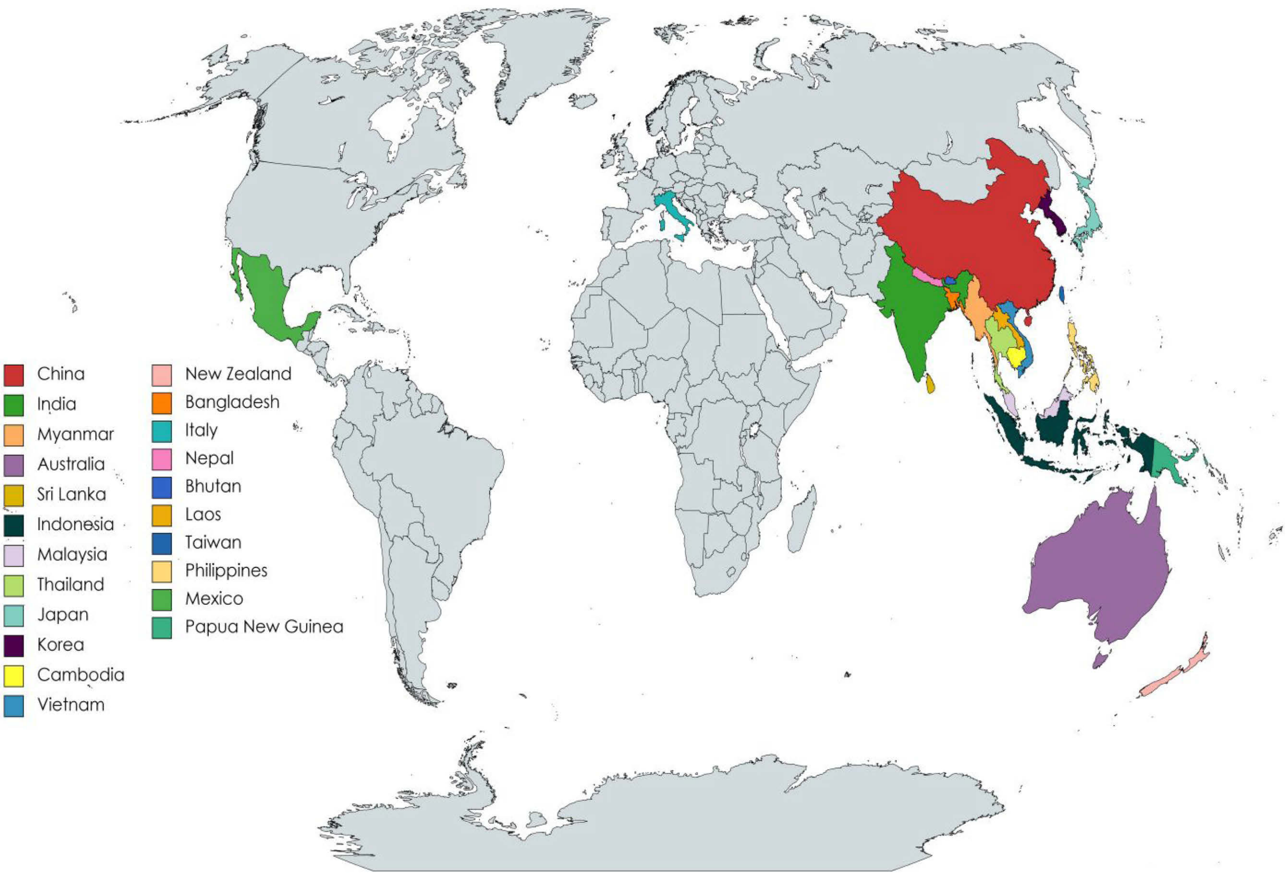

Fig. 2. The map showing the geographical distributions of *Conogethes punctiferalis*.

mainly due to the transport of infested fruit via trade networks. The geographical distribution of *C. punctiferalis* has been documented in Asia, Australia, Italy (IBPGR, 1988), Mexico (Anonymous, 2005), Hawaii (Nishida, 2002) and England (Truscott, 2007). *C. punctiferalis* remains a major problem in Asia and Australia, while it as major quarantine pest status in Argentina, Brazil, Chile, Mexico, Canada, the United Kingdom, Africa and the United States of America (Du et al., 2012; Xiao et al., 2012). Its potential to invade these regions is largely attributed to the favorable climatic conditions that facilitate the spread and establishment of pests in these countries (Sridhar et al., 2015; EPPO, 2023). Western parts of Palma, Spain, Portugal, the coastal region of Sicilica, Italy, Malta, Crose, Sardinia, Greece, southern parts of Moldova, Ukraine, Romania and western and southern parts of France are favorable regions for the p establishment and spread of pests (Sridhar et al., 2018). The specified threshold temperatures for eggs, larvae and pupae are 8.4°C, 7.3°C, and 11.3°C, respectively (Korycinska, 2012). Notably, the Canadian Food Inspection Agency (CFIA, 2016) has officially recognized *C. punctiferalis* as a regulated pest andadded to its list of regulated pests in Canada. The invasiveness of this pest in these areas is crucial, and measures must be planned to control the invasion of the pest, particularly into commercial establishment. *C. punctiferalis* has been observed in Brunei, Darussalam, and Europe (Rojas-Sandoval, 2023). Fig. 2. shows the geographical distribution of *C. punctiferalis*.

HOST RANGE, DAMAGE TO CROPS, AND ECONOMIC IMPACT

Conogethes punctiferalis proving to be a highly destructive pest affecting numerous host plants due to its wide host range, invasive behavior and impressive adaptability (Shashank et al., 2014). This harmful pest reportedly affects over 120 plant species, including important crops such as cocoa, corn, cotton, mango, peach, guava, orange and grapes. In India, 35 plant species belonging to 19 families have been reported as major hosts of *C. punctiferalis* (Shashank et al., 2014). *Conogethes punctiferalis* has been identified as a major pest of peaches and corn in China (Kimura & Honda, 1999; Jing et al., 2019), peaches in Japan (Abe & Sanari, 1992) and durians in the Philippines, Australia and Thailand (Rojas-Sandoval, 2023), guava, castor, cardamom and pomegranate in India (Kumar et al., 2017a; Shashank et al., 2018), mango in Bangladesh (Hussain et al., 1987), turmeric in Sri Lanka (Devasahayam & Abdulla Koya, 2005) and longan in Malaysia (Shashank et al., 2018). Significant losses of *C. punctiferalis* have been documented in various countries, such as studies by Inoue & Yamanaka (2006) and Li et al. (2015). Alagar et al. (2013) reported *C. punctiferalis* as an emerging cacoa pest in India. The larvae of this pest feed on cocoa pods, causing fruits and flower to drop and dry out. Singh & Kaur (2015b) surveyed litchi orchards and observed 10% infestation in May and June. The larvae bore into mango fruits and sprouts and feed on soft tissue and pulp (Gundappa &

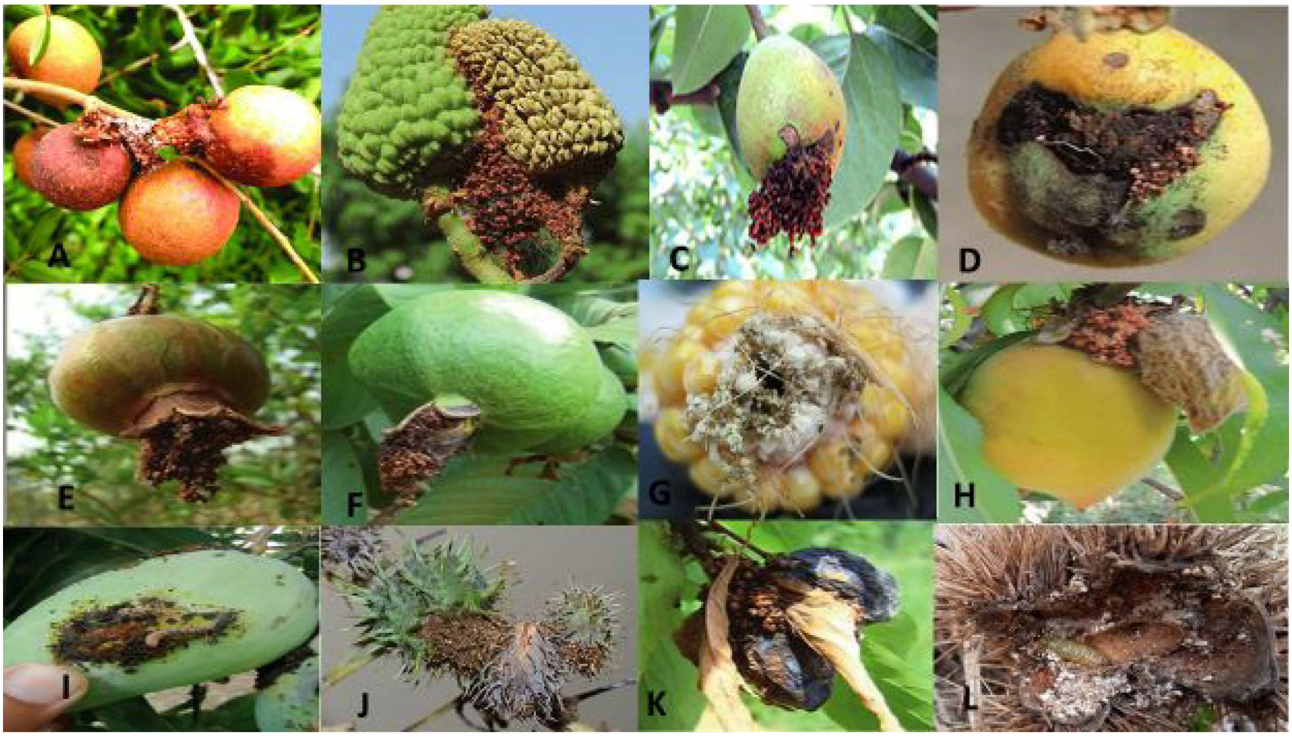

Fig. 3. Mode of damage on different hosts. A: Longan (Tran et al., 2019), B: Litchi (Singh et al., 2018), C: Pear (https://pheromonechemicals.in/punctiferalis.html), D: Loquat, E: Pomegranate (Singh et al., 2018), F: Guava (Kumar & Kalkal, 2022), G: Corn (https://thebeatsheet.com.au), H: Peach (Singh et al., 2018), I: Mango, J: Durian (Sivapragasam et al., 2018), K: Plum (Singh et al., 2018), L: Chestnut (https://thebeatsheet.com.au).

Kumar, 2015). Singh & Kaur (2014) recorded about 10% damage by one larva per fruit, which resulted the mango fruits rottingand becoming unfit for human consumption (Singh & Kaur, 2016). In the Philippines, *C. punctiferalis* caused an infestation of 21–30% in durian fruit (Anonymous, 2008) and 6.66–31.82% infestation in durian fruit (*Durio zibethinus*) (Evangelista, 1995), resulting in significant production losses. Turmeric and ginger are heavily infested crops in India, leading to significant yield loss (Devasahayam et al., 2010). Approximately 50% of grape losses were reported by Ram et al. (1997) in India and pest infestation in guava plantations between July and October resulted in losses of 9–14.6% (Anonymous, 2000). According to reports by Singh et al. (2002) and Gundappa & Kumar (2015), the pest is spreading to other fruit crops such as mango in India, posing a serious threat to the export of mangoes and other commodities not only in India but also in neighboring countries like China and Pakistan. The mode of damage on different hosts is shown in Fig. 3, while minor and major host plants of *C. punctiferalis* are listed in Table 1. The yield losses caused by the pests in different crops are detailed in Fig. 4. The damage symptoms of *C. punctiferalis* are different from Peach Month, *Anarsia lineatella* Zeller (Lepidoptera: Gelechiidae) which is a common and serious pest in the Mediterranean. *Anarsia lineatella* attacks twigs, petals, flowers, and buds by making mines and penetrating ovaries (Mamay et al., 2014). The wilting and vigor losses in leaves are the main symptoms of pest attack (Damos & Savopoulou-Soultani, 2010).

Per reports from Singh et al. (2002) and Gundappa & Kumar (2015), the pest is becoming more widespread and threatening not only India's export of mangoes and other commodities to neighboring countries like China and Pakistan, but also other fruit crops. Fig. 3 illustrates the mode of damage on various hosts, including *C. punctiferalis* major and minor host plants (Table 1). Fig. 4 details the yield losses inflicted by pests on various crops. The damage signs of *C. Punctiferalis* differ from *Anarsia lineatella* Zeller, also known as Peach Month (Lepidoptera: Gelechiidae), a common and dangerous pest in the Mediterranean. *Anarsia lineatella* enters ovaries through mines and assaults twigs, petals, flowers, and buds (Mamay et al., 2014). The primary signs of a pest infestation are the wilting and vigor losses in leaves (Damos & Savopoulou-Soultani, 2010).

PHYTOSANITARY MEASURES OF *CONOGETHES PUNCTIFERALIS*

Conogethes punctiferalis has been reported in several countries due to international trade. The International Standards for Phytosanitary Measures (ISPM) play a crucial role in creating a legal framework for countries involved in the import and export of fresh produce. To prevent the spread of this pest population, it is important to inspect imported and exported shipments for the presence of the pest. If infected goods are found, they must be destroyed immediately. Monitoring programs need to be implemented around these locations to ensure that the pest has not already invaded the area (Miniraj et al., 2000). In South

Table 1. The minor and major host plants of the *Conogethes punctiferalis*.

Common name	Scientific name	Family	Location	References
Peach	*Prunus persica*	Rosaceae	Japan, China	Abe & Sanari, 1992; Kimura & Honda, 1999
Corn	*Zea mays*	Poaceae	China	Wang et al., 2016; Jing et al., 2019
Durian	*Durio zibethinus*	Malvaceae	Philippines, Thailand, Australia	Evangelista, 1995; Astridge, 2001; Rojas-Sandoval, 2023
Pomegranate	*Punica granatum*	Lythraceae	China, India	Ma & Bai, 2004, Chakravarthy et al. 1997
Guava	*Pisidium guajava*	Myrtaceae	India, Vietnam	Pruthi & Batra, 1960; Shashank et al., 2018
Castor	*Ricinus communis*	Euphorbiaceae	India, Sri Lanka	Tandon, 1988; USDA, 1957
Cardamom	*Elettaria cardamomum*	Zingiberaceae	India, Sri Lanka	Atwal & Dhaliwal, 1997; Dharmadasa et al., 2008; Rashmi et al., 2021
Mango	*Mangifera indica*	Anacardiaceae	Bangladesh, Malaysia	Hussain et al., 1987; Shashank et al., 2015
Ginger	*Zingiber officinale*	Zingiberaceae	India, Sri Lanka, Malaysia	Balasuriya & Kelaniyangoda, 2010; Senthil Kumar et al., 2015
Turmeric	*Curcuma domestica*	Zingiberaceae	India, Sri Lanka	Devasahayam & Abdulla Koya, 2005; Senthil Kumar et al., 2015
Papaya	*Carica papaya*	Caricaceae	Australia	Chay-Prove et al., 2000
Mata Kuching	*Nephelium malaiense*	Sapindaceae	Australia	Astridge, 2006
Soursop	*Annona muricata*	Annonaceae	Vietnam	Shashank et al., 2018
Cotton	*Gossypium* spp.	Malvaceae	Malaysia	Shashank et al., 2015
Sorghum	*Sorghum bicolor*	Poaceae	Malaysia	Shashank et al., 2015
Cocoa	*Theobroma cacao*	Malvaceae	India, Malaysia, Sri Lanka	Devasahayam & Abdulla Koya, 2005; Alagar et al., 2013; Shashank et al., 2015
Loquat	*Eriobotrya japonica*	Rosaceae	Malaysia	Shashank et al., 2015
Longan	*Dimocarpus longan*	Sapindaceae	Malaysia, China, Vietnam	Huang et al., 2000; Shashank et al., 2018
Rambutan	*Nephelium lappaceum*	Sapindaceae	Bangladesh, Malaysia, Vietnam	Osman Mohd & Chettanachitara, 1987; Shashank et al., 2015
Jackfruit	*Artocarpus heterophyllus*	Moraceae	India, Malaysia	Atwal & Dhaliwal, 1997; Shashank et al., 2015
Tamarind	*Tamarindus indica*	Fabaceae	India	Atwal & Dhaliwal, 1997
Starfruit	*Averrhoa carambola*	Oxalidaceae	Vietnam	Shashank et al., 2018
Macadamia	*Macadamia ternifolia*	Proteaceae	Vietnam, Malaysia	Shashank et al., 2018
Carambola	*Averrhoa carambola*	Oxalidaceae	Malaysia	Nur Atiqah, 2014
Fig	*Ficus carica*	Moraceae	Malaysia, China	Shashank et al., 2015
Sunflower	*Helianthus annuus*	Asteraceae	China, Malaysia, Sri Lanka	Devasahayam & Abdulla Koya, 2005; Shashank et al., 2015
Soybean	*Glycine max*	Fabaceae	Malaysia	Shashank et al., 2015
Apple	*Malus pumila*	Rosaceae	Malaysia, China	Wang, 2009; Shashank et al., 2015
Avocado	*Persea americana*	Lauraceae	Malaysia, China	Wang, 2009; Shashank et al., 2015
Plum	*Prunus domestica*	Rosaceae	Malaysia	Shashank et al., 2015
Eggplant	*Solanum melongena*	Solanaceae	Malaysia	Shashank et al., 2015
Grapes	*Vitis vinifera*	Vitaceae	India, Malaysia	Ram et al., 1997
Lemon	*Citrus limon*	Rutaceae	Malaysia	Shashank et al., 2015
Kapok tree	*Ceiba pentandra*	Bombacaceae	Malaysia	Shashank et al., 2015
Flame tree	*Brachychiton acerifolius*	Fabaceae	Malaysia	Shashank et al., 2015
Teak	*Tectona grandis*	Lamiaceae	Sri Lanka	Mannakkara, 2006
Mulberry	*Morus alba*	Moraceae	Malaysia	Shashank et al., 2015
Litchi	*Litchi chinensis*	sapindaceae	India, China	Wang, 2009; Singh & Kaur, 2015b
Citrus	*Citrus sinensis*	Rutaceae	China	He, 1997
Hawthorn	*Crataegus pinnatifida*	Rosaceae	China	Chen et al., 2008; Lu et al., 2010
Cherry	*Cerasus pseudocerasus*	Rosaceae	China	Chen et al., 2008; Lu et al., 2010
Walnut	*Juglans regia*	Juglandaceae	China	Chen et al., 2008; Lu et al., 2010
Sugarcane	*Saccharum officinarum*	Poaceae	China	Chen et al., 2008; Lu et al., 2010
Haricot bean	*Lablab purpureus*	Fabaceae	China	Chen et al., 2008; Lu et al., 2010
Banana	*Musa paradisiaca*	Musaceae	India	Devasahayam & Abdulla Koya, 2007; Shashank et al., 2014
Walnut	*Juglans regia*	Juglandaceae	Korea	Lee, 2011
Chestnut	*Castanea mollissima*	Fagaceae	Korea, China	Ni, 1998; Jung et al., 2018
Persimmon	*Diospyros kaki*	Ebenaceae	Korea	Choi et al., 2004
Korean fir	*Abies koreana*	Pinaceae	Korea	Choi et al., 2004
Pine	*Pinus roxburghii*	Pinaceae	India	Inoue & Yamanaka, 2006
Larch	*Larix decidua*	Pinaceae	India	Inoue & Yamanaka, 2006
Cedar	*Cedrus deodara*	Pinaceae	India	Sondhi et al., 2022; Rojas-Sandoval, 2023
Firs	*Abies alba*	Pinaceae	India	Inoue & Yamanaka, 2006
Ber	*Ziziphus mauritiana*	Rhamnacea	India	Singh et al., 2016; Park et al., 1998
Oak	*Quercus virginiana*	Fagaceae	Malaysia	Sivapragasam et al., 2018
Yellow nicker	*Caesalpinia bonduc*	Fabaceae	Malaysia	Sivapragasam et al., 2018

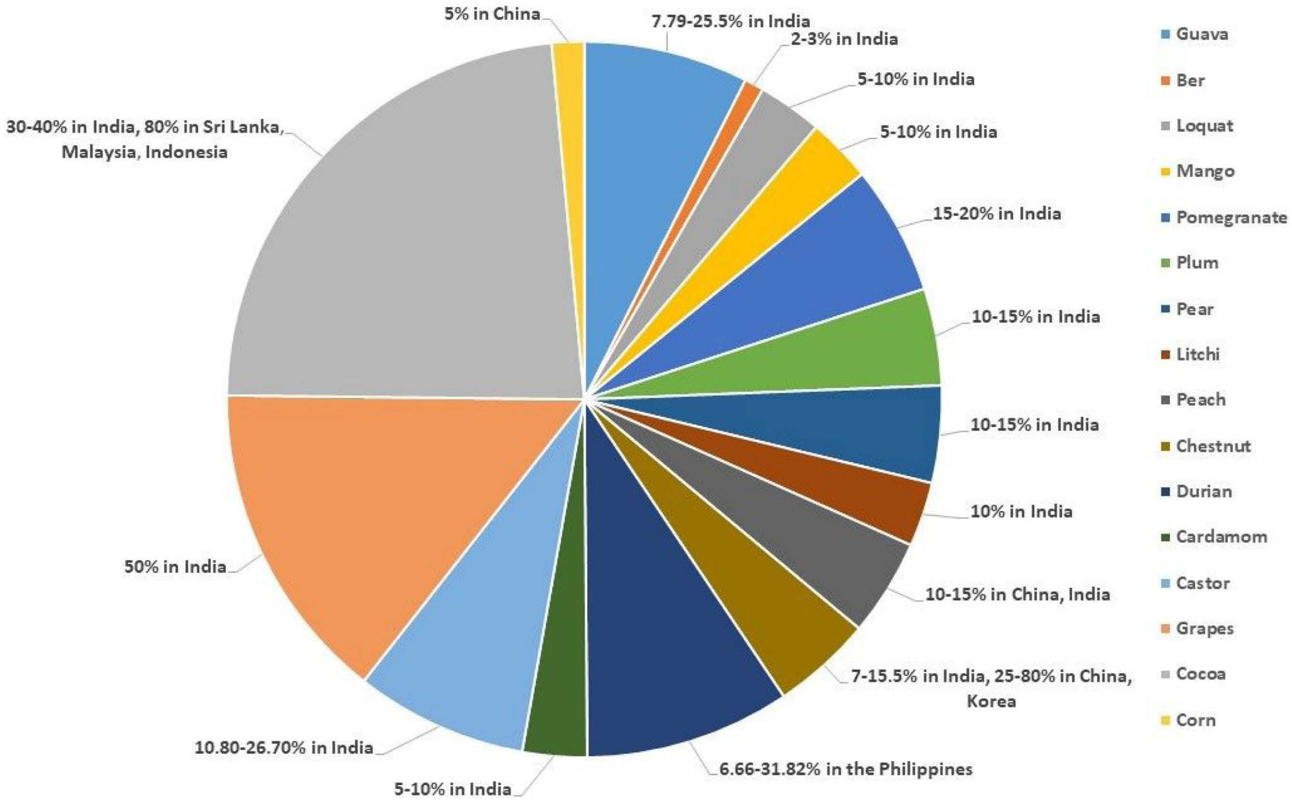

Fig. 4. Country specific fruit and crop losses caused by *Conogethes punctiferalis* (Entwistle, 1972; Evangelista, 1995; Xi et al., 1996; Ram et al., 1997; Suganthy, 2011; Alagar et al., 2013; Akashe et al., 2015; Shashank et al., 2015; Singh & Kaur, 2015b; Singh et al., 2016).

Korea, gamma irradiation and methyl bromide (MeBr) fumigation were observed to result in 100% larval mortality of *C. punctiferalis* (Kwon et al., 2004). Irradiation with 0.5 kGy represents an alternative to MeBr fumigation and is considered suitable for combating quarantine pests. In Korea, a controlled atmosphere and heat treatment system (CATTS) was developed to suppress *C. punctiferalis* in apples before export to other countries (Hong et al., 2015). The older stages (5th instars) feed on the internal parts of fruits, making them difficult to control by CATTS. To kill the 5th instar, a prolonged heat treatment (2 h) at 46°C is required (Chakravarthy et al., 2015). According to USDA (2024), cold treatment at 1.11°C for 40 days is mandatory to kill *C. punctiferalis* in apples imported into the United States from Korea or Japan. Fumigation with methyl bromide for at least 0.5 h not only kills *C. punctiferalis* but is also harmful to fruits (USDA, 2024). For effective control of *C. punctiferalis* on lychee fruits from Thailand, Australia and China destined for New Zealand an irradiation dose in the range of 250–289 Gy is recommended (Luo et al., 2018). To suppress *C. punctiferalis*, papaya and lychee must be subjected to 250 Gy treatment before import from Australia to New Zealand (Butcher, 2019a, b). It is important to note that due to international trade in various crops, *C. punctiferalis* has the potential to spread to various other countries including Pakistan, Canada, New Zealand, the United Kingdom, South Africa, England, the Netherlands and the USA (FERA, 2012; Korycinska, 2012; Rojas-Sandoval, 2023). It is crucial to explore innovative methods to control pests and prevent their spread to other economically important crops. If left unchecked, this pest could become a serious problem and threaten the economies of agriculturally dependent countries (Sridhar et al., 2018). This could lead to serious disruptions in the import and export of goods, resulting in significant economic losses in combating the infestation.

MANAGEMENT STRATEGIES FOR *CONOGETHES PUNCTIFERALIS*

Integrated pest management includes changing cultural practices, focusing on biological control (predators, parasitoids and entomopathogens), and judicious use of plant extracts and chemicals. No single method is sufficient to combat *C. punctiferalis.* Instead, a combination of sustainable and economically significant approaches is required to effectively control this harmful pest. These strategies not only control pests and protect crops but also reduce reliance on insecticides (Bateman et al., 2018).

Prevention of *Conogethes punctiferalis*

Advisory services

The emergence of the highly polyphagous *C. punctiferalis* may result in economic losses due to a lack of knowledge about pest identification, life cycle, behavior, and host plants. The most affected crops in Asian, European and Australian countries include corn, cotton, sorghum, soybeans and fruits (Luo & Honda, 2015; Du et al., 2016). The first and most important step in stopping the spread of this devastating pest is to establish advisory services. These services should provide adequate information to farmers and policy-makers in areas where the pest is expected to spread soon. The Pest Management Advisory Council (PMAC) and the Pest Management Regulatory Agency (PMRA) should communicate with stakeholders about this destructive pest. This information could help farmers prepare to combat the pest in advance or control it at an earlier stage.

Agronomic and cultural control

Sanitation management and planting date. The infected parts of fruits and crops are the main source of the next generation of pests in certain regions. Destruction of these unviable host plants and pruning of infested parts can minimize pest damage (Anonymous 1913; Wang & Cai, 1997; Senthil Kumar et al., 2015; Singh & Kaur, 2015a). Cleanliness not only reduces pest infestation by disrupting the pest life cycle but also reduces the need for insecticides in orchards or crops (Sharma et al., 1995; Singh & Kaur, 2016). Pest recurrence can be suppressed by burying fallen or rotten fruits deep in the soil, packing them in plastic bags, exposing them to the sun, and crushing them in a grinder (Reddy, 2020). The sowing dates of crops play a key role in the establishment of pest populations in specific regions. The incidence of *C. punctiferalis* was recorded highest in castor bean sown early than late sown (Ranga et al., 2022). Castor bean sown in July can reduce pest infestation, resulting in maximum yield. Early ripening varieties should be avoided to protect the crop from pest attacks, as *C. punctiferalis* attacks ripen fruits and ears. The spacing between plants can also impact pest populations. The lowest incidence of the pest was recorded in castor bean crops planted with large spacing between plants (Sarma et al., 1992; Sridharan et al., 1990). Due to the lack of published work on the commercial impact of planting dates on *C. punctiferalis* response in corn, the plants should be sown taking into account the previous year's pest incidence to protect the plants from pest attack. Temjentoshi (2008) and Lalruatsangi & Ao (2022) recorded the highest *C. punctiferalis* infestation on ginger planting on April 15th than in April 30th planting.

Trap crops, intercropping and crop rotation. Trap cropping is an effective approach to keep pests away from the main crop (Atwal & Dhaliwal, 1997). Intercropping, also known as the New Green Revolution (Martin-Guay et al., 2018), not only increases crop production and improves soil fertility, but also increases the diversity of biological fauna, resulting in a reduction in the occurrence of pests and diseases (Brooker et al., 2015; Ememwa et al., 2017). Intercropping corn with legumes is a traditional practice in several countries to reduce the presence of corn borers (He et al., 2019; Beaumelle et al., 2021; Pierre et al., 2021). Intercropping of cowpea, cluster bean, black chickpeas and peanuts can reduce the occurrence of *C. punctiferalis* (Sathiyaseelan & Balaji, 2023). The companion crops emit volatile compounds that attract natural enemies and help keep pest populations on the main crop below the economic threshold. Polyculture practices canreduce the need for pesticides, lower the risk of eco-toxicity, and contribute to agricultural sustainability (Pierre et al., 2023). For example, the prevalence of *Ostrinia furnacalis* was lower in polycultures compared to monoculture corn plants and there were higher number of natural enemies. *Conogethes punctiferalis* hasan attraction to the volatile components of sunflower i.e. β-phellandrene and α-pinene (Zhou et al., 2023), which can be used to divert the attention of *C. punctiferalis* resulting in reduction to corn. Nutrient content increased significantly in corn-soybean and corn-peanut intercropping systems (Li et al., 2022). Corn-legume intercropping is a practical and profitable option for maximizing crop production and improving soil fertility for both small and large farmers. Intercropping may not be suitable in developing countries where machinery is expensive but labor is readily available for agronomic management (Pieree et al., 2023). The effects of corn-soybean and corn-peanut intercropping on *C. punctiferalis* should be studied and may prove successful in pest control. Crop rotation, a traditional method of controlling pest damage in agriculture, involves alternating host and non-host crops annually and should be promoted to reduce pest infestation.

Nutrient management, tillage and land preparation. Plant nutrients can help maintain pest populations to a large extent and increase plant tolerance to insect pests. However, excessive use of nitrogenous fertilizers can increase pest populations on crops and lead to yield loss (Thyagaraj & Chakravarthy, 1999). It is recommended to replace nitrogen containing fertilizers with micronutrients, especially silicon and phosphorus, as these can reduce host suitability and increase plant resistance to insect pests (Bala et al., 2018). Physical factors such as cuticle thickness as well as chemical barriers such as repellent or toxic scents, can prevent or reduce pest damage to crops. Tolerance traits can also limit pest damage by altering plant phenology (Cook et al., 2006). Promoting these resistance traits in plants is crucial to keeping pest populations below economic damage levels. Soil, crop and nutrient management play a key role in integrated plant nutrition, which is an important part of plant resistance to insect pests. The effects of nutrient management on corn for *C. punctiferalis* are still unknown and require further verification. *C. punctiferalis* pupates in the soil or fallen leaves, making it vulnerable to control by deep tillage. It has been observed that the reproductive potential of pests decreases with increasing mortality due to soil conservation practices in various crops (Alyokhin et al., 2020). Conservation tillage can effectively reduce various pest stages, promote crop diversification, and create a favorable habitat for natural enemies such as predators and parasitoids.

Bagging and pest monitoring. One month before harvest, ripe fruits are wrapped in paper bags to protect them from *C. punctiferalis* oviposition (Verhagen et al., 2009; Sushil et al., 2015). Although it is difficult to bag the fruits, this method effectively prevents *C. punctiferalis* females from laying eggs on the surface of ripe fruits, resulting in higher production (Badii et al., 2015). In the Philippines, bagging reduced pest infestation of durians by 9.2% (Evangelista, 1995). Light traps are effective pest population monitoring tools and are installed in various regions such as Australia and Japan to monitor or trap the *C. punctiferalis* population. However, they were not considered effective in suppressing the pest population (Konno et al., 1982; Korycinska, 2012). Kim et al. (2014) reported that among the installed light traps (A, B and C), type C light traps with a Dulux EL white lamp captured the highest number of adult *C. punctiferalis* (73%) in chestnut trees. Installing one light trap per hectare of guava and pomegranate orchard can help monitor the pest population (Anonymous, 2004). The spread of pests can be minimized in certain regions if pest prediction and early warning systems are used. These systems are an integral part of IPM approaches that predict damage based on weather conditions and prepare farmers to take timely preventive measures, resulting in more efficient pest control with minimal use of chemical pesticides and reduced environmental impact of agriculture. Since *C. punctiferalis* is a new major pest that is not yet established in several countries, climate models predict its imminent spread in these locations if appropriate control measures are not taken (Sridhar et al., 2018). To control the spread or establishment of this harmful pest, a monitoring system is required. The FAO (2020) has developed a monitoring and early warning system for recently established *Spodoptera frugiperda*; A similar surveillance system is required to control the spread or establishment of *C. punctiferalis*. The Economic Threshold Value (ETL) is a practical tool and an important part of IPM strategies aimed at balanced pest management. ETL can vary depending on the type of crop affected. Different crops have different tolerances to pest infestation, and what may be economically viable for one crop may not be the case for another. However, the ETL for *C. punctiferalis* has not been determined. Studies should be conducted to accurately determine the ETL of *C. punctiferalis*. This will benefit agricultural producers, improve the quality of crops and reduce environmental pollution.

Biological control

Biological pest control uses natural enemies to reduce pest populations on valuable crops, promoting an environmentally friendly, sustainable and beneficial approach to crop production (FAO, 2018). This method minimizes the need for insecticide applications by improving plant vigor and supporting environmentally responsible agricultural systems. It serves as an effective tool to ensure both food security and environmental sustainability. Biological pest control is divided into classical biological pest control, biological pest control and conservation biological pest control, each offering unique strategies for using natural enemies to control pest populations in agriculture and ecosystems.

Predators and parasitoids

It is critical to maintain a record of the local parasitoids and predators that naturally regulate pest populations in the field. This information allows us to consider strategies for their conservation and population increase on site. The primary predators of *C. punctiferalis* may include larval predator springtails *Euborellia annulata*, dermapteran (*Euborellia stali*), insectivorous birds, assassin flies, earwigs, and spiders (Chakravarthy, 1988; Ballal et al., 2018). In additiona, certain beneficial insects such as ladybirds and lacewings can also prey on its eggs or larvae. The specific mix of predators can vary depending on the local ecosystem and environmental conditions. Several parasitoids affecting parasitize different life stages of *C. punctiferalis* on infested host plants have been observed in different countries and are listed in Table 2. Stanley et al. (2009) recorded 47.3%, 14.8%, and 11.5% parasitism by *T. flavo-orbitalis*, *B. atteviae*, and phorid flies, respectively. In India, *A. taragamae* and *Glyptapanteles* sp. proved to be good larval parasitoids of *C. punctiferalis* infecting castor bean plants, while *Bassus* sp. was found to be the least effective (Ali et al., 2014; Shashank et al., 2018). Pena et al. (2002) documented that *Argyrophylax proclinata* CrossKey (Diptera: Tachinidae) parasitizes *C. punctiferalis* larvae with a 40% parasitism rate of 40% in Australia, *Suallonius* sp. parasitizing larvae and pupae of *C. punctiferalis* in the Philippines (Evangelista, 1995). In China, *Trichogramma dendrolimi* Matsumura (Hymenoptera: Trichogrammatidae) has shown higher parasitism rates on *C. punctiferalis* eggs in chestnut orchards (Li, 2007). He et al. (2008) observed a parasitism rate of 28.8% of *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae) on *C. punctiferalis*. The use of natural enemies, with particular emphasis on parasitoids, to attack the egg and larval-pupal stages is essential for the effective control of C. punctiferalis populations in agricultural and horticultural crops, as previously reported by Chakravarthy et al. (2015). In particular, parasitoid species such as *Bracon* spp., *T. pretiosum*, *T. chilonis* and *Chelonus blackburni* (Cameron) (Hymenoptera: Braconidae) have been identified as promising candidates for the control of *C. punctiferalis*. *Trichogramma* spp. and *Bracon* spp., as adaptable parasitoids that can thrive in different climatic conditions, deserve funding for crop pest control (Stanley et al., 2009; Ali et al., 2014; Ballal et al., 2018; Chen et al., 2021). This proactive approach is particularly important in regions where the pest has not yet established itself.

Microorganisms

Biopesticides, derived from natural sources offer numerous benefits for pest control, particularly in the context of *C. punctiferalis* control. These are environmentally friendly, leave minimal chemical residues and pose less risk to non-target organisms (Devasahayam, 2000). Importantly, biopesticides can help curb the development of pesticide resistance, thereby improving the long-term effectiveness of pest control. They also ensure safer conditions for farmers, farmworkers, and consumers through shorter pre-harvest intervals. However, although various commercially available biopesticides show effectiveness against *C. punctiferalis*, they have limitations. Factors such as susceptibility to sunlight, low endurance and delayed action under field conditions can affect their performance (Kavitha et al., 2015). Frequent applications may be required, particularly in areas of high pest infestation, and their effectiveness is influenced by several variables, making them less

Table 2. Main parasitoids of *Conogethes punctiferalis* found in different countries.

Species	Order	Family	Biological stage parasitized	Countries	References
Apanteles sp.	Hymenoptera	Ichneumonidae	Larvae	India, Malaysia	Vasantharaj David et al., 1964; Mohamed et al., 1999
Apanteles taragamae Viereck	Hymenoptera	Braconidae	Larvae	India	Thiyagarajan et al., 2019
Agrypon sp.	Hymenoptera	Ichneumonidae	Larvae, pupae	India	Thiyagarajan et al., 2019
Glyptapanteles sp.	Hymenoptera	Braconidae	Larvae	India	Ali et al., 2014
Phanerotoma hendecasiella Cameron	Hymenoptera	Braconidae	Larvae	Sri Lanka	Rodrigo, 1941; Devasahayam & Abdulla Koya, 2007
Dolichurus sp.	Hymenoptera	Ampulicidae	Larvae	Sri Lanka	Rodrigo, 1941; Devasahayam & Abdulla Koya, 2007
Angita trochanterata Thomson	Hymenoptera	Ichneumonidae	Larvae	India	Vasantharaj David et al., 1964
Theronia inareolata Westwood	Hymenoptera	Ichneumonidae	Larvae	India	Vasantharaj David et al., 1964
Bracon brevicornis Wesmael	Hymenoptera	Braconidae	Larvae	India	Vasantharaj David et al., 1964
Microbracon hebetor Say	Hymenoptera	Braconidae	Larvae	India	Patel & Gangrade, 1971
Brachymeria nosatoi Habu	Hymenoptera	Chalcididae	Larvae	India	Joseph et al., 1973
B. lasus Walker	Hymenoptera	Chalcididae	Larvae	India	Joseph et al., 1973
B. euploeae Westwood	Hymenoptera	Chalcididae	Pupae	India	David et al., 1964
B. obscurata Walker	Hymenoptera	Chalcididae	Larvae	China, Japan	Charles & McGillivray, 2006
B. atteviae JNJ	Hymenoptera	Chalcididae	Larvae	India	Stanley et al., 2009
Myosoma sp.	Hymenoptera	Braconidae	Larvae	India	Jacob, 1981
Xanthopimpla sp.	Hymenoptera	Ichneumonidae	Larvae	Sri Lanka	Rodrigo, 1941; Devasahayam & Abdulla Koya, 2007
X. australis Saussure	Hymenoptera	Ichneumonidae	Larvae, pupae	India	Jacob, 1981
X. stemmator Thunberg	Hymenoptera	Braconidae	Larvae	Malaysia	Mohamed et al., 1999
Suallonius sp.	Hymenoptera	Braconidae	Larvae, pupae	Philippines, Vietnam	Evangelista, 1995
Friona sp.	Hymenoptera	Ichneumonidae	Larvae, pupae	India	Stanley et al., 2009
Epitranus erythrogaster Cameron	Hymenoptera	Chalcididae	Larvae	India	Stanley et al., 2009
Trichogramma pretiosum Riley	Hymenoptera	Trichogrammatidae	Eggs	India	Krishnamurthy et al., 1989
Brassus sp.	Hymenoptera	Braconidae	Larvae	India	Stanley et al., 2009
Myosoma sp.	Hymenoptera	Braconidae	Larvae	India	Stanley et al., 2009
Trathala flavoorbitalis Cameron	Hymenoptera	Ichneumonidae	Larvae	India, Malaysia	Stanley et al., 2009; Mohamed et al., 1999
Chelonus blackburni Cameron	Hymenoptera	Braconidae	Larvae	India	Stanley et al., 2009
Argyrophylax proclinata Crosskey	Diptera	Tachinidae	Larva	Australia	Pena et al., 2002
Temelucha sp.	Hymenoptera	Ichneumonidae	Larvae	China	Huang et al., 2000; Devasahayam & Abdulla Koya, 2007
Apechthis capulifera Kriechbaumer	Hymenoptera	Ichneumonidae	Larvae	Japan	Charles & McGillivray, 2006
Scambus persimilis Iwata	Hymenoptera	Ichneumonidae	Larvae	Japan	Charles & McGillivray, 2006
Anthocephalus decipiens (Masi)	Hymenoptera	Chalcididae	Larvae	Philippines, Vietnam	Stanley et al., 2009

predictable than synthetic pesticides. In addition, the cost of biopesticides and their narrower spectrum of activity can pose challenges for farmers and require complementary pest control methods. Therefore, farmers must carefully consider their individual circumstances and goals when considering integrating biopesticides into their pest management strategies (Lalruatsangi, 2022). Below are some biopesticides that have been tested in different countries to combat *C. punctiferalis*.

Entomopathogenic fungi and baculoviruses. The indigenous strains of entomopathogenic fungi (EPF), including *Metarhizium anisopliae* and *Beauveria bassiana*, effectively caused infections in laboratory-grown *C. punctiferalis* larvae. *Nomuraea rileyi* and *M. anisopliae* have shown the highest effectiveness against *C. punctiferalis* under field conditions (Ingle et al., 2016). Murphy et al. (1995) recommended the combination of nuclear polyhedrosis virus (NPV) applications and other IPM strategies to control *C. punctiferalis*. Strategic application of fungi to early-stage flowers and fruits attracts *Conogethes* moths to lay eggs, leading to subsequent capitulation to fungal activity. EPFs show potential when the canopy is thoroughly covered with microbial preparations, but their application in plant pest control is limited by specific targeting as they require ingestion to be effective and comprehensive coverage for effective control of *C. punctiferalis* (Kavitha et al., 2015). Their use should be considered as part of an integrated pest management strategy, taking into account local conditions and crop-specific factors. Ongoing research and field trials will help refine their use and effectiveness in controlling this pest.

Entomopathogenic bacteria and nematode. Entomopathogenic bacteria (EPB) are microorganisms that produce toxic proteins, infecting insect pests, especially butterflies, and causing death. *Bacillus thuringiensis* (Bt) is one of the most well-known EPBs and can control a wide range of economically important pests in agriculture, horticulture and forestry, including *C. punctiferalis*. Bt has shown 73.8–79.1% effectiveness in controlling *C. punctiferalis* infestation on chestnut trees in China (Xu et al., 2002). Bt should be promoted against this pest because its effectiveness is higher and cheaper than traditional chemical control methods. The cry1 gene was identified in six indigenous Bt isolates, with Bt strain T27 exhibiting 100% mortality of *C. punctiferalis* larvae (Manikandan et al., 2016). Various Bt proteins (Cry1Ab, Cry1Ac, Cry1Ah, Cry2Aa, Cry1Fa, Cry1Ie and Vip3Aa19) were tested individually and in combination against *C. punctiferalis*. Combinations such as Cry2Aa with Cry1Ac, Cry1Ie and Cry1Ab showed antagonistic effects, while Cry2Aa with Cry1Fa and Cry1Ah showed synergistic effects (Shwe et al., 2021a, b). Cry1Ab, Cry1Ac, and Vip3Aa19 have demonstrated effective control over *C. punctiferalis* populations due to their high toxic activity. Bt proteins can be an alternative to chemical insecticides and can be incorporated into IPM programs to improve their overall effectiveness in controlling *C. punctiferalis*. Although Bt has shown promise in China, its application to control *C. punctiferalis* is limited in other infested countries, highlighting the need for further research on the effectiveness of EPBs against *C. punctiferalis* worldwide. Entomopathogenic nematodes (EPN) are also considered effective and pathogenic biological controls of *C. punctiferalis* (Bandaru et al., 2020). Older stages are difficult to control with other strategies, but *Heterorhabditis bacteriophora* and *H. indica* have shown the highest pathogenicity in killing them (Gayatri et al., 2020). Pervez et al. (2012) recorded 100 larval deaths with *Steinernema* sp. (IISR 02), *Heterorhabditis* sp. (IISR 01) and *Oscheius* sp. (IISR 07 and 08), with *Oscheius* sp. (IISR 07) is the most toxic with a pupal mortality of 100%. The percentage of mortality of the pest increased with higher doses and longer exposure times (Pervez et al., 2014a, b). *Steinernema glaseri* and *Heterorhabditis indica* are also considered to be the most effective nematodes against *C. punctiferalis*, but their pathogenicity percentage has not been reported and needs further study (Choo et al., 2001; Xu et al., 2002; Charles & McGillivray, 2006; Stanley et al., 2009). The effectiveness of nematodes is influenced by temperature, with the most suitable temperature for optimal effectiveness being 30°C (Pervez et al., 2015). Understanding the spread of beneficial properties such as temperature tolerance, within EPN species can assist in selecting the most suitable candidate for use in a particular geographic region or microclimate in biocontrol efforts.

Botanicals

Plant-based chemicals are considered environmentally friendly and part of sustainable pest control, but very few plant extracts are most effective in controlling pest populations. In Korea, a combination of wormstop and wood vinegar was tested to combat *C. punctiferalis* on late and early-ripening chestnut varieties. The extracts showed the highest effectiveness on early ripening varieties compared to late ripening varieties. This difference in effectiveness may be due to the presence of susceptible *C. punctiferalis* stages (1st–3rd) in early ripening varieties and older instars (4–5th) on late-ripening cultivars. Controlling older instars is difficult because 5th instars bore into the fruit and are inaccessible to chemicals (Lee, 2009). In many countries, herbal extracts (tobacco and neem based) have been tested on different hosts for control of *C. punctiferalis* but were not satisfactory (Eapan, 1994; Varadarasan, 2001; Joseph Rajkumar et al., 2002; Thyagaraj et al., 2002; Thyagaraj, 2003; Rajabaskar & Regupathy, 2013). Plant extracts could be better utilized to control pest populations if used in conjunction with other management strategies.

Chemical / Insecticides

Insecticides have long been considered the main weapon in the relentless fight against borers (Stanley et al., 2010). However, their effectiveness is clouded by the demanding need for repeated applications at increased doses, inadvertently creating a favorable environment for pest adaptation and resistance (Chakravarthy et al., 2012). Similar to borers, controlling *C. punctiferalis proves* to be a daunting task due to its complicated feeding habits and ability to remain hidden within the plant's tissues. Thiacloprid is used in China to control the pest population of various crops. 2% thiacloprid significantly reduced the *C. punctiferalis* population in chestnut orchards (Yuan et al., 2011). In Vietnam, insecticides are widely used at intervals of 10 to 15 to control *C. punctiferalis* during the flowering and fruiting stages of fruits. Excessive use of insecticides during the flowering and fruiting phases not only leads to resistance in *C. punctiferalis*, but also shortens pollinator visit times. The damage of the pest to crops was reduced by the combined application of abamectin and *Bacillus thuringiensis* var. kurstaki (Thoa et al., 2009). In Sri Lanka, no insecticide has yet been recommended to control this harmful pest due to its feeding nature and to prevent exposure of natural enemies and the environment to the toxic effects of pesticides (Mannakkara et al., 2018). To combat them, they rely mainly on plant extracts and biological agents such as microorganisms, parasitoids and predators. Control of *C. punctiferalis* on fruits and crops can be challenging due to various complexities and obstacles. Insecticide access to *C. punctiferalis* larvae is difficult because the larvae bore into the stems, branches, and fruits of the host plant, making them difficult to detect and attack. A major obstacle to combating pest infestations is the tall stature of fruit trees. Therefore, it is a difficult task to apply pesticide directly to the specific or infested fruits without the helo of a motorized sprayer with an extended lance capable of

Table 3. Country wise list of insecticides used to control *C. punctiferalis* on various crops.

Insecticide	Crop	Country	References
Diafenthiuron	Cardamom	India	Rajabaskar & Regupathy, 2013
Profenofos	Cardamom	India	Rajabaskar & Regupathy, 2013
Fenthion	Cardamom	India	Rajabaskar, 2003
Monocrotophos	Cardamom	India	Rajabaskar, 2003
Chlorpyrifos	Cardamom	India	Rajabaskar, 2003
Malathion	Ginger	India	Rajabaskar, 2003; Kumar et al., 2017b
Triazophos	Cardamom	India	Rajabaskar, 2003
Dimethoate	Cardamom	India	Rajabaskar, 2003
Flubendiamide	Ginger	India	Kumar et al., 2017b
Cyantraniliprole	Ginger	India	Kumar et al., 2017b
Thiamethoxam	Ginger	India	Kumar et al., 2017b
Quinalphos	Cardamom	India	Rajabaskar, 2003
Endosulfan	Cardamom	India	Rajabaskar, 2003
Lambda cyhalothrin	Turmeric	India, Vietnam	Rajabaskar, 2003; Loc et al., 2006; Kumar et al., 2019
Chlorantraniliprole	Ginger, turmeric	India	Kumar et al., 2017b, 2019
Spinosad	Ginger, turmeric	India, Vietnam	Loc et al., 2006, 2018; Kumar et al., 2017b, 2019
Acephate	Guava	India	Gundappa et al., 2018
Monocrotophos	Cardamom	India	Devasahayam & Abdulla Koya, 1998; Thyagaraj, 2003
Phosalone	Cardamom	India	Devasahayam & Abdulla Koya, 1998; Thyagaraj, 2003
Fenitrothion	Castor	India	Patel et al., 1988
Carbaryl	Castor	India	Patel et al., 1988
Quinalphos	Castor	India	Patel et al., 1988
Abamectin	Durian	Vietnam	Loc et al., 2006, 2018
Emamectin benzoate	Durian	Vietnam	Loc et al., 2006, 2018
Diazinon	Durian	Vietnam	Loc et al., 2018
Fipronil	Durian	Vietnam	Loc et al., 2018
Deltamethrin	Durian	Malaysia	Masdek et al., 1991; Shamsudin, 1994
Dimethoate	Durian	Malaysia	Masdek et al., 1991; Shamsudin, 1994
Fenthion	Durian	Malaysia	Masdek et al., 1991; Shamsudin, 1994
Thiacloprid	Chestnut	China	Yuan et al., 2011
Chlorfluazuron	Chestnut, wulnut	Korea	Kim et al., 2022

reaching these high heights (Měsić et al., 2008; Michael et al., 2022). It is very difficult to protect the natural enemies on trees with a motorized sprayer. As mentioned above, *C. punctiferalis* populations can develop resistance to commonly used insecticides. The country-wise list of insecticides commonly used to control this pest is shown in Table 3. Integrated pest management (IPM) techniques that combine multiple control methods, such as biological control, cultural practices, and chemical control, are often required. To effectively control *C. punctiferalis* in horticultural and fruit crops, it is important to apply integrated pest management (IPM) techniques that combine various control methods such as biological control, pheromone-based monitoring, selective pesticide use, and cultural practices.

Pheromones

Pheromones play an important role in the communication and reproduction of many insect pests, including *C. punctiferalis*. The pheromone of *C. punctiferalis*, (E)-10-hexadecenal, was first reported by Konno et al. (1980) in Japan. The pheromones of this harmful pest have been extensively studied. Female moths release pheromones to attract males to mate. Pheromones provide a practical way to control borers when other strategies have not been successful in controlling them due to their feeding habits (Breth & Tee, 2007). Agricultural experts and entomologists understand the utility of these chemical signals in developing of effective control strategies to monitor and control this pest. Cai & Mu (1993) reported that the pest population was reduced by installing traps containing 250 µg of (Z)-10-hexadecenal and (E)-10-hexadecenal in citrus orchards in China. These pheromones were later confirmed by Liu et al. (1994) to show greater attraction than the synthetic pheromones (E)-10-hexadecenol and (Z)-10-hexadecenal (Xiao & Honda, 2010). Jung et al. (2000) identified three compounds, (Z)-10-hexadecenal (Z10-16:Ald), (E)-10-hexadecenal (E10-16:Ald), and hexadecanal (16:Ald) in the female of *C. punctiferalis*. A male pheromone, acetophenone, has been identified that can attract females for courtship (Stanley et al., 2018; Aoshima et al., 2020) and can be used in an IPM program. The emission of male pheromones can disrupt the activity of other males. Mating disruptions and pheromone traps should be developed to capture the moths and provide valuable information for timing control measures. Disrupting mating disrupts the reproductive cycle of the pest population and reduces damage to crops. The use of pheromones is a sustainable pest control method that can minimize the need for chemical pesticides and has helped reduce economic losses and environmental impacts associated with pest infestations in fruits and crops.

Biotechnological approach

Host plant resistance

Conogethes punctiferalis is a notorious polyvoltine pest that causes significant damage to crops and leads to economic yield loss. Infestation with this pest can be minimized by plant-resistant varieties. These varieties not only protect crops from pest attacks, but also reduce the need for chemical insecticides, ensure food security, improve farmers' economic profitability, and promote more sustainable and environmentally friendly agricultural practices. Selecting or growing resistant varieties is crucial to increasing crop production as pest infestations as well as diseases such as stem rot and Phytophthora root, which can be introduced by pests such as *C. punctiferalis*, contribute significantly to yield reduction. In India, certain castor bean genotypes such as JI-130, SKI-126, SKI-129, SHB-392, SHB-556, JHB-705 and 48-1 have been reported as resistant varieties to *C. punctiferalis* (Sharma et al., 1995; Jayalaxmi, 1996). On the other hand, genotypes with compact ears and large capsules should be discouraged due to their susceptibility to *C. punctiferalis* (Lakshminarayana, 2005). Cultivation of loose ear genotypes could be a useful strategy for pest control. Certain varieties of crops such as Dehradun litchi, Florida prince peach, Satluj purple plum, Pathar Nakh pear, Allahabad safeda guava, Shilong-1 guava (Singh & Kaur, 2016) and Huaijiu chestnut (Du et al., 2016) were used. It is reported to be the most susceptible to *C. punctiferalis* and should be avoided in cultivation. Genetically modified crops (GMOs), particularly maize, have been developed to control lepidopteran pests (Devasahayam et al., 2010; Li et al., 2015). Cultivation of genetically modified plants in key host species could prove to be an effective management strategy for *C. punctiferalis*. Research by Manikandan et al. (2016) showed that Bt T27 had 100% larval mortality under laboratory conditions, which needs to be verified under field conditions. The incorporation of protease inhibitors into transgenic plants could make them resistant to *C. punctiferalis*. Developing host plant varieties with morphological traits that limit egg laying in the future could lead to pest reduction. Commercialization of Bt maize in several countries may help in sustainable pest control if combined with the application of indigenous genetic resistance.

Gene editing approach (CRISPR-Cas system)

The field of gene editing, particularly using techniques such as CRISPR-Cas9 and RNAi, has gained importance in the study of various insect pests, particularly butterflies, for pest control. However, no comprehensive study on gene editing in *C. punctiferalis* has been published to date. The functional studies of chemosensory genes identified in previously published antenna transcriptomic data of *C. punctiferalis* may be helpful in identifying pheromone receptors, elucidating host plant recognition, avoiding natural enemies, and developing pest control strategies (attractants or repellents). be. Several CRISPR/Cas9 transgenic methods have already been developed to enable advanced functional genomic studies in other insect pests (Chen & Palli, 2022), which could help silence genes in *C. punctiferalis* (Zhu et al., 2020). There is a need to explore RNAi technology to develop a sustainable and environmentally friendly method to combat this pest.

CONCLUSION, FUTURE OUTBREAK, RESEARCH, STORIES, AND ROADMAP FOR SUCCESSFUL INTEGRATED PEST MANAGEMENT

Despite extensive historical documentation of *C. punctiferalis* damage on various hosts in India and China, a significant knowledge gap remains regarding several aspects of its ecological dynamics and management strategies. Eliminating these gaps is crucial to mitigating the negative consequences of its presence in invaded regions. The predominant approach to control *C. punctiferalis* relies predominantly relies on the use of chemical insecticides. However, the use of such measures is often viewed as unsustainable and undesirable in many regions where this pest has established itself. Therefore, the main goal is to develop and implement ecologically sound IPM strategies that can be adopted in any infested region. In this context, we outline concrete research recommendations aimed at achieving this goal. Identification and removal of resistance genes in *C. punctiferalis* through Bt technologies could help control the pest population. Combining RNAi and CRISPR technologies with Bt technology could extend the overall shelf life of GMO crops through more effective pest control. The chemical communication system, including region-specific pheromones, should be identified and utilized in IPM programs for the most effective pest control. Understanding the mechanisms involved in mate attraction and host outcomes can lead to the development of pest control strategies. Pheromone-based mating disruption products are still unclear in several invaded regions and should be developed and approved. Inductive (propagation) and inoculative (preservation) biological control methods should be promoted in pest-infested areas. Agroecological approaches should be maintained to improve existing biological agents. The use of insecticides to control *C. punctiferalis* should be discouraged and the impact of other control methods on the environment and biological agents should be evaluated to improve IPM strategies for *C. punctiferalis*. Quarantine protocols must be implemented to prevent the spread.

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