Journal of Biological Control, 38(2): 97-116, 2024, DOI: 10.18311/jbc/2024/43637

Review Article

A comprehensive review of *Chelonus* s. str. Panzer (Hymenoptera: Braconidae: Cheloninae) with a special reference to the species associated with fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae)

ORLANDO A. CALCETAS[1], RAVINDRA CHANDRA JOSHI[2*], GEORG GOERGEN[3], RICHA VARSHNEY[4] and M. S. VENUGOPAL[5]

[1]*Department of Agriculture, Regional Field Office-IVA-CALABARZON, Regional Crop Protection Center, Marawoy, Lipa City, Batangas, Philippines*

[2]*Philippine Rice Research Institute, Maligaya, Science City Muñoz, Nueva Ecija 3119, Philippines*

[3]*Biodiversity Centre/Biological Control Centre for Africa, International Institute of Tropical Agriculture (IITA-Benin), 08-01000 Cotonou, Benin*

[4]*ICAR-National Bureau of Agricultural Insect Resources, P.B. No. 2491, H.A. Farm Post, Bellary Road, Hebbal, Bengaluru – 560024, Karnataka, India*

[5]*Former Professor, Department of Entomology, Tamil Nadu Agricultural University, Coimbatore -641003, Tamil Nadu, India*

**Corresponding author E-mail:* rc.joshi@mail.philrice.gov.ph

---

ABSTRACT: The genus *Chelonus* s. str. (*Chelonus*) Panzer (Hymenoptera: Braconidae: Cheloninae) is reviewed with particular focus on species associated with fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae). Additionally, information on the biology and various mass-rearing techniques of the enumerated species are furnished, underlining their significance in biological control and integrated pest management strategies.

KEYWORDS: Fall armyworm, natural enemies, parasitoid, wasp

(Article chronicle: Received: 15-04-2024; Revised: 11-06-2024; Accepted: 14-06-2024)

INTRODUCTION

The fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), is a highly invasive and polyphagous insect pest capable of infesting over 353 plant species across 76 plant families. This widespread infestation significantly threatens various economically important crops, including essential staple and fibre crops (Early *et al.*, 2018; Montezano *et al.*, 2018; Casmuz *et al.*, 2010; Perier *et al.*, 2022). Since its introduction in continental Africa in early 2016, this pest, known for its migratory nature, has rapidly spread to more than 60 countries across the tropics and sub-tropics (Goergen *et al.*, 2016; Westbrook *et al.*, 2019). The recent incursion of *S. frugiperda* has resulted in profound environmental, economic, and social consequences, particularly affecting the food security and livelihoods of smallholder farmers in developing countries (Durocher-Granger *et al.*, 2021). The larval feeding behaviour of this invasive pest has led to significant crop yield losses and diminished crop quality, with reported losses of up to 20% on various crops in the United States and yield reductions ranging from 17% to 72% on maize in different global regions (Perier *et al.*, 2022; Mamahit & Kolondam, 2023). Recent occurrences in the Philippines underscore the recurring invasions of fall armyworms in rice nurseries and direct-seeded rice fields, including both previously affected areas and newly designated rice-production regions. This ongoing expansion highlights the persistent challenges posed by the increasing distribution of fall armyworm (Valdez *et al.*, 2023a; Valdez *et al.*, 2023b).

In the Western Hemisphere, the development and wide adoption of genetically modified maize against FAW and other insect pests (Bt maize) has contributed to increased productivity of the crop. However, its potential is continuously challenged by the development of field-evolved resistance, including new pyramided maize varieties that express multiple Bt toxins (Bernardi *et al.*, 2015). While GM maize has been widely adopted in some regions, its use is proscribed in many parts of the world due to a multitude of factors, including regulatory policies, economic pressures, public acceptance, and the ongoing need to address environmental and health concerns.

The extensive global use of synthetic insecticides to tackle *S. frugiperda* has developed resistance across diverse insecticide classes, including pyrethroids, organophosphates, and carbamates. In regions such as India, farmers initially relied on broad-spectrum synthetic insecticides such as lambda-cyhalothrin, emamectin benzoate, and thiamethoxam to address FAW outbreaks. However, the efficacy of chemical control proved to be short-lived and ultimately unsustainable (Prasanna *et al.*, 2018; Sharanabasappa *et al.*, 2019; Sagar *et al.*, 2022; Mamahit & Kolondam, 2023). Recognizing the limitations of synthetic chemical insecticides, Kenis *et al.* (2022) proposed an alternative approach. They identified 24 botanical insecticides sourced from 17 plant families and subjected them to rigorous testing against *S. frugiperda*. This exploration of botanical solutions presents a promising pathway for developing more sustainable and effective pest management strategies.

In economic entomology, employing environment friendly alternative measures, such as augmentative releases or the conservation of Natural Enemies (NE) like insect predators, parasitoids, and entomopathogens, represents a mutually beneficial solution for regulating pest populations at the farmers' field level. Biological pest control plays a crucial role in maintaining the natural balance, or homeostasis, of ecosystems, where certain organisms prey on others as part of their survival strategy (van Lenteren, 2000). Although sudden outbreaks of herbivorous species are common in natural environments, they typically return to their original levels due to the influence of natural regulatory mechanisms (DeBach, 1964). Various approaches have been proposed for conserving NE, including reducing reliance on synthetic pesticides (van Emden, 2002) and manipulating the environment through ecological engineering (Mitsch, 1998; 2012; Fiedler *et al.*, 2008). One widely accepted method involves the mass production and subsequent release of NE, known as "augmentative" or "inundated" biological control (Parrella *et al.*, 1992; Collier & van Steenwyk, 2004). The primary goal is significantly reducing pest populations below the Economic Threshold Level (ETL) (Parrella *et al.*, 1992). However, it is important to note that these NEs often have a broad range of hosts, such as Lepidoptera, in the field, which may distract the parasitoid from targeting the primary insect pest (Carrillo-Sánchez, 1985). Therefore, it is crucial to recognize that many NEs have diverse ranges of hosts and prey, underscoring the importance of conserving alternative hosts to maintain NE populations.

INSECT NATURAL ENEMIES OF *S. frugiperda*

The utilization of parasitoids presents a cost-effective, environment friendly, and comparatively long-term approach with minimal risk of inducing resistance (Molina-Ochoa *et al.*, 2003). A diverse array of approximately 172 parasitoid and parasite species targeting *S. frugiperda* has been documented in the American continents, including the Caribbean Islands (Molina-Ochoa *et al.,* 2003). Notably, trichogrammatids and braconids are prevalent, with 20 and 12 recorded species, respectively. For the latter, this includes one species of *Campoletis sonorensis* (Cameron) (Campopleginae), three species of *Cotesia* (Microgastrinae), and four species of *Coccygidium* (Agathinidae), Globally, 11 species of *Chelonus* associated with FAW have been recorded (Figure 1 and Table 1). Colmenarez *et al.* (2022) conducted a detailed review of the use of the egg parasitoid *Telenomus remus* Nixon (Hymenoptera: Scelionidae) in four Latin American countries (Venezuela, Honduras, Brazil, Colombia), encompassing the frequency of releases and the percentage of FAW egg parasitism. Recent findings by Kenis *et al.* (2022) extended the global understanding, documenting 37 parasitoid species, including four species of *Chelonus* in various African countries and 41 parasitoid species in Asia. In Ghana, Agboyi *et al.* (2020) reported larval parasitism by other parasitoids ranging from 18% to 42% during the maximum level of the rainy season but significantly lower in the minimum level of the rainy season. Additional insect groups acting as NE of *S. frugiperda* include two species of tachinid flies (Diptera: Tachinidae), *Drino quadrizonula* (Thomson), and an undetermined species, two species of minute pirate bugs *Orius insidiosus* (Say) and *Orius similis* Zheng (Hemiptera: Anthocoridae), and one pentatomid bug *Eocanthecona furcellata* (Wolff) (Hemiptera: Pentatomidae) (Bahena & Cortez 2015; Subramaniam, 2022). Noteworthy recent reports from the Philippines by Valdez *et al.* (2024) highlight two hymenopteran parasitoids, *Brachymeria lasus* Walker (Hymenoptera: Chalcididae), and *Copidosoma floridanum* (Ashmead) (Hymenoptera: Encyrtidae), while Calcetas *et al.* (2023) documented the egg-larval parasitoid *Chelonus formosanus* Sonan.

THE FAMILY BRACONIDAE AND SUBFAMILY CHELONINAE

The Braconidae is the second-most species-rich family of parasitoid wasps in the animal kingdom (Chen & van Achterberg, 2019). They are morphologically more diverse and better studied because a greater proportion of the species are important to agriculture and have been used in biological control (Huber, 2009). The parasitoid wasp family Braconidae is one of the most biodiversity-rich families of Hymenoptera and with more than 1,100 genera, and >21,220 valid described species it is also considered one of the largest families of Metazoan (Yu *et al.*, 2016; Chen & van Achterberg, 2019). It encompasses representatives in more than 40 accepted subfamilies, which are approximately 1–30 mm in length and are currently recognized as monophyletic

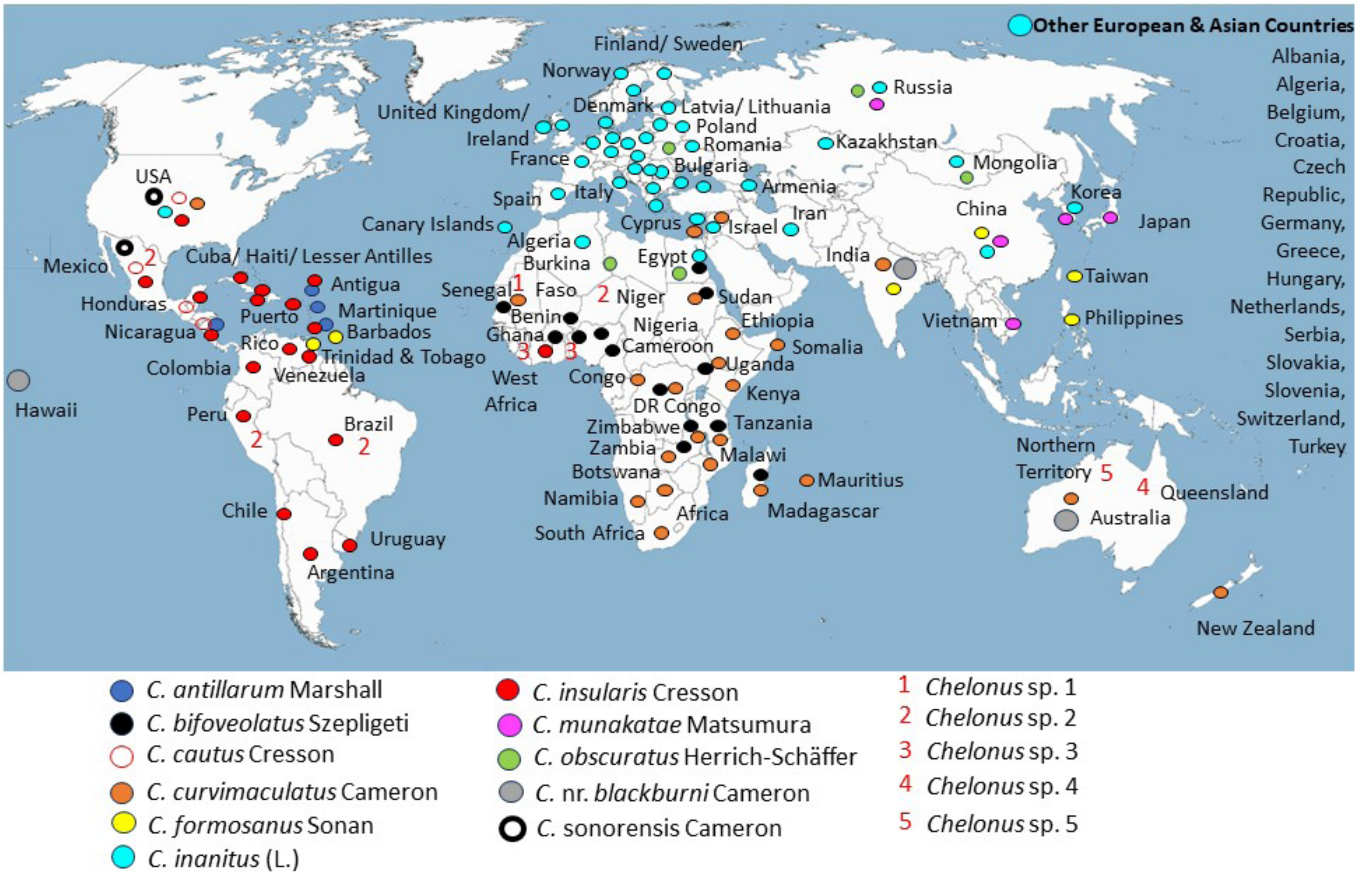

Figure 1. Geographic distribution of *Chelonus* s. str. Panzer associated with fall armyworm, *Spodoptera frugiperda* (JE Smith) (after Li *et al*., 2023) (Template of the map courtesy of Wikimedia, 2023).

Table 1. Updated geographic distribution of egg-larval parasitoid *Chelonus* s. str. Panzer associated with fall armyworm, *Spodoptera frugiperda* (JE Smith), and references (after Li *et al.,* 2023)

***Chelonus* Panzer spp.**	**Distribution**	**References**
C. antillarum Marshall	Antigua, Barbados, Martinique, Nicaragua	Ashley (1986); Molina-Ochoa *et al.* (2003); Yu *et al.* (2016); Zenner (2006)
C. bifoveolatus Szepligeti	Benin, Burkina Faso, Cameroon, DR Congo, Ghana, Madagascar, Nigeria, Senegal, Sudan, Tanzania, Uganda, Zambia, Zimbabwe	Madl and van Achterberg (2014); Yu *et al.* (2016); Tang *et al.* (2019); Tendeng *et al.* (2019); Agboyi *et al.* (2020); Koffi *et al.* (2020); Ngangambe and Mwatawala (2020); Ahissou *et al*. (2021); Durocher-Granger *et al.* (2021); Otim *et al.* (2021); Zang *et al.* (2022); Shen *et al.* (2023); Georgen (2024, personal communication)
C. cautus Cresson	Honduras; Mexico; Nicaragua; USA	Gutierres-Ramirez *et al.* (2015); Yu *et al.* (2016)
C. curvimaculatus Cameron	Australia, Botswana, Congo, DR Congo, Egypt, Ethiopia, India, Israel, Kenya, Madagascar, Malawi, Mauritius, Namibia, Senegal, Somalia, South Africa, Sudan, Tanzania, Uganda Zambia, Zimbabwe	Legner and Thompson (1977); Kittel (2014); Yu *et al.* (2016); Sisay *et al.* (2019); Koffi *et al.* (2020); Durocher-Granger *et al.* (2021)
C. formosanus Sonan	Barbados, China, India, Philippines, Trinidad and Tobago	Baringbing (1982); Baringbing and Baringbing (1984); Varshney (1999); Yu *et al.* (2016); Gupta *et al.* (2019); Firake and Behere (2020a, b); Gupta *et al.* (2020a); Tang *et al.* (2020); Jindal (2022); Liu *et al.* (2022); Sagar *et al.* (2022); Keerthi *et al.* (2023); Calcetas *et al.* (2023)

Table 1. Continued...

***Chelonus* Panzer spp.**	**Distribution**	**References**
C. inanitus (L.)	Albania, Algeria, Armenia, Belgium, Bulgaria, Canary Islands, China, Croatia, Cyprus, Czech Republic, Denmark, Egypt, Finland, France, Germany, Greece, Hungary, Iran, Ireland, Israel, Italy, Kazakhstan, Korea, Latvia, Lithuania, Mongolia, Netherlands, Norway, Poland, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, USA, United Kingdom	Rechav (1975, 1978); Rechav and Orion (1975); Hafez *et al.* (1980); Kaeslin *et al.* (1985)
C. insularis Cresson	Antigua, Argentina, Barbados, Brazil, Chile, Colombia, Cuba, Haiti, Honduras, Lesser Antilles, Mexico, Nicaragua, Peru, Puerto Rico, Trinidad and Tobago, USA, Uruguay, Venezuela	Zenner *et al*. (2006); Yu *et al*. (2016); Lopez *et al*. (2018); Prasanna *et al*. (2018); Tang *et al*. (2019); Garcia-Gonzales *et al*. (2020); Jaraleno-Teniente *et al*. (2020); Zang *et al*. (2022)
C. munakatae Matsumura	China, Japan, Korea, Russia, Vietnam	Yu *et al.* (2016); Li *et al.* (2019)
C. obscuratus Herrich-Schäffer	Egypt, Europe, Mongolia, North Africa, Russia (Central, East and South)	Goergen 2024, personal communication; Edmardash *et al.* (2011)
C. nr. *blackburni* Cameron	India	Nagarkatti and Singh (1989); Varshney (1999); Kittel (2014); Sagar *et al.* (2022); Keerthi *et al.* (2023); TNAU (2023)
C. sonorensis Cameron	Mexico, USA	Yu *et al.* (2016)
Chelonus sp. 1	West Africa (Senegal)	Tendeng *et al.* (2019)
Chelonus sp. 2	Brazil, Mexico, Peru, Niger	Molina-Ochoa *et al.* (2003); Amadou *et al.* (2018)
Chelonus sp. 3	Ghana, Benin	Shen *et al*. (2023)
Chelonus sp. 4	Queensland, Australia	Subramaniam (2022)
Chelonus sp. 5	Northern Territory, Australia	Subramaniam (2022)

(Huber, 2009; Chen & van Achterberg, 2019). Current records indicate that more than 2,600 species of braconids have been documented for the Afrotropical region, however, this number significantly underestimates the actual diversity of braconids in this region (Yu *et al*., 2013).

Braconids typically parasitize the immature stages of butterflies, moths, beetles, and flies, although they may infest other insect orders as well (Huber, 2009). They exhibit various lifestyles, being either solitary or gregarious, and can live externally on the surface of their host (ectoparasitoid) or internally within the host's body (endoparasitoid). Some species demonstrate polyembryony, a phenomenon where multiple individuals develop from a single egg, while a few are capable of parasitizing already parasitized insects or hyperparasitoids, and a handful are classified as phytophagous (Wharton, 1993). They constitute one of the primary groups of biological control agents of major plant pests and nearly all are major parasitoids of predominantly larval or adult forms belonging to over 120 insect families (Chen & van Achtenberg, 1997). The former subfamily Adeliinae is clustered (in-group) of the Cheloninae (Belshaw *et al*., 1998; Kittel *et al*., 2016) and is treated as a tribe. Notably, two genera of Cheloninae are represented in the fossil records (*Eobracon* Cockerell 1921 and *Diodontogaster* Brues 1933), while the remaining 15 extant genera include *Ascogaster* Wesmael 1835, *Austroascogaster* Kittel and Austin 2013, *Chelonus* Panzer 1806, *Dentigaster* Zettel 1990, *Huseyinia* Koçak and Kemal 2008, *Leptochelonus* Zettel 1990, *Megascogaster* Baker 1926, *Odontosphaeropyx* Cameron 1910, *Phanaustrotoma* Kittel and Austin 2013, *Phanerotoma* Wesmael 1838, *Phanerotomella* Szépligeti 1900, *Phanerotomoides* Zettel 1990, *Pseudo phanerotoma* Zettel 1990, *Siniphanerotomella* He, Chen and van Achterberg 1994, *Wushenia* Zettel 1990.

The subfamily Cheloninae Foerster, 1863, also known as chelonines, is widely distributed, comprising 23 genera, five tribes, and 1,523 described species worldwide, making it one of the largest lineages within the family Braconidae (Yu *et al.*, 2016; Kittel & Austin, 2014; Chen & van Achterberg, 1997). Divergence dating analyses and the reconstruction of ancestral ranges suggest that the Cheloninae originated in the Neotropics approximately 150 million years ago, indicating an older lineage than previously believed, which was estimated at 65-75 million years ago. The current biogeography of the Cheloninae is thought to be shaped by a dynamic process involving both vicariance and long-distance dispersal (Kittel & Austin, 2014). This subfamily is characterized by a large and homogeneous group of endoparasitoids targeting lepidopteran larvae, occupying a sub-basal position in the microgastroid lineage (Shi *et al.*, 2005; Sharanowski *et al.*, 2011). Chelonine parasitoids are frequently employed in biological control programs targeting lepidopterous insect pests worldwide (Legner & Thompson, 1977). They play a crucial role as biological control agents (BCAs) in regulating the population dynamics of phytophagous insects, particularly economically significant lepidopterous pests belonging to families such as Noctuidae, Geometridae, Tortricidae, Pyralidae, and Gelechiidae (Kaeslin *et al.*, 2005; Shaw & Huddleston, 1991; van Achterberg, 1990).

GENUS *Chelonus* s. str. PANZER, 1806

***Distribution*:** The genus *Chelonus* s. str. Panzer, 1806 has 973 described species worldwide and is one of the diverse genera of the subfamily Cheloninae (Yu *et al.,* 2016). Recently, the list was updated by Sharkey *et al.* (2021) to more than 1,000 species when he described 79 new species, which were mainly from Costa Rica, a global biodiversity hotspot. However, many more undescribed species of *Chelonus* and the hosts include a wide range of lepidopterous families (Sharkey *et al.*, 2021; Yu *et al.*, 2016). The type species of *Chelonus* is *Ichneumon oculator* Fabricius 1775, a species commonly occurring in the Palearctic region. The genus is also the most widespread and broadly distributed parasitoid of FAW in the American continent and Africa (Otim *et al.*, 2021). *Chelonus* species have received much importance globally as contender parasitoids for FAW control (Li *et al.*, 2023). Currently, an updated list of *Chelonus* spp. Li *et al.* (2023) showed that there are 11 species affiliated with FAW; five distributed in Central America, four in Africa, and five in Asia.

Diagnosis of the subfamily Cheloninae: Members of this subfamily are usually black, yellow, or orange, and they vary in size from 1.8 to 11 mm (Ghahari *et al.,* 2022). They can be easily distinguished from other braconid wasps by their wing venation (with three submarginal cells) and the presence of a complete postictal carina. These wasps are black, compact in appearance, and have a body length of 2–6 mm (Dudarenko, 1974). The carapace is the most prominent character and is formed by the fusion of the first three metasomal tergites covering the rest of the gaster; however, the rest of the parts of the metasoma are usually covered ventrally (Dudarenko, 1974; van Achterberg, 1976; Shaw, 1997). However, a carapace also appears convergently in several other braconid subfamilies (e.g. Brachistinae, Ichneutinae, Microgastrinae, and Sigalphinae), but it generally seldom occurs outside of the subfamily Cheloninae (Dudarenko, 1974). In layman's terms, the subfamily Cheloninae can be readily discerned by the shape of its abdomen or ventral side of the carapace, which looks similar to an inverted bathtub or a turtle shell. However, the last instar larvae have thin and cylindrical mandibles, usually with the presence of indeterminate hypostomal sutures (Kaeslin *et al.*, 2005).

***Higher classification of the genus Chelonus Panzer*:** The higher-level classification of the genus *Chelonus* s. l. is a subject of ongoing debate and lacks clarity. Several authors have questioned *Microchelonus Szépligeti,* 1908 and other experts classified *Microchelonus* as a subgenus of *Chelonus* (Zettel 1990; van Achterberg & Polaszek 1996; Zhang *et al.*, 2008). However, others recognized it as a valid genus (Papp, 1995; Tobias, 2000, 2011; Zhang *et al.*, 2008). Furthermore, the genus was split into six subgenera (*Carinichelonus* Tobias, 2000, *Microchelonus* s. str.*, Parachelonus* Tobias, 1995, *Rasnichelonus* Tobias, 2011, *Scabrichelonus* Chen and van Achterberg, 1997 and *Stylochelonus* Hellén, 1958) by Tobias (2000, 2011). However, Kittel *et al.* (2016) reached a different conclusion, suggesting that the subgenus *Microchelonus* should be synonymized with *Chelonus* based on molecular and morphological phylogenetic analyses, which also encompassed three other subgenera (*Baculonus*, *Carinichelonus*, and *Scabrichelonus*). Nonetheless, uncertainties persist regarding the status of other subgenera within *Chelonus* s. l. primarily due to limitations in sample size and the scope of conclusions drawn. Each of the three subgenera synonymized by Kittel *et al.* (2016) exhibits distinct apomorphic characteristics, and *Microchelonus* was recognized as a valid subgenus in the study conducted by Zhou *et al.* (2022).

Chelonus (Chelonus) Panzer, 1806: Currently, there are 12 subgenera under the genus *Chelonus*: *Areselonus* Braet, 1999; *Arichelonus* Viereck, 1913; *Baculonus* Braet and van Achterberg, 2001; *Carinichelonus* Tobias, 2000; *Chelonus* Panzer, 1806 s. str.; *Cubochelonus* Baker, 1926; *Megachelonus* Baker, 1926; *Microchelonus* Szépligeti, 1908 s. str.; *Mirachelonus* subgen. nov.; *Parachelonus* Tobias, 1995; *Scabrichelonus* He, Chen and van Acheterberg, 1997; and *Stylochelonus* Hellén, 1958 (Zhou *et al.* 2022).

Furthermore, a revisional work on the Cheloninae of China resulted in the establishment of a new subgenus, *Mirachelonus*, and the description of a new species *C. (M.) miraventris*, underscoring thereby the limitation of the generic concept and specific boundaries of the genus *Chelonus* s. l. (Zhou *et al.* 2022). Recently, Zhou *et al.* (2024) revised the genus *Chelonus* (*Chelonus)* Panzer, 1806 in China, adding 21 new species and bringing the total number of described species to 73.

Diagnosis of the genus Chelonus**:** *Chelonus* species can be easily compared to other genera of Cheloninae by the following distinguishing morphological characteristics: vein 1-SR+M of fore wing absent and vein SR1 nearly always completely sclerotized, metasomal carapace without distinct transverse sutures, eyes distinctly setose and usually vein R of fore wing emitted near middle from the pterostigma (van Achterberg & Polaszek, 1996). The head is transverse in dorsal view, and the temple is narrow. The mesoscutum is short and 0.7–0.8 as long as wide. The fore wing has 3 cubital cells present; cell 2 is small and more or less triangular and distinctly smaller than cell 3. Abscissa 1 of cubitus is absent, and the first cubital and first discoidal cells are confluent. The abdomen length is less than 3X the greatest width. The abdominal sutures are erased, and the tergites 1–3 are forming a solid carapace. Furthermore, at most 2 sutures are visible on the abdomen dorsally. Males can be distinguished from females by their thin and long bodies having somewhat setaceous antennae. Also, the female wasp has a short ovipositor, occasionally concealed inside the carapace (Yousuf & Ray, 2009). Furthermore, it has antennae thickened in the middle with depressions in the apical flagellar segments. In species of the subgenus *Microchelonus,* the apex of the male carapace bears an opening, the foramen. There are numerous keys to species covering specific world regions, among which the most important are Varshney (1999) for the oriental region, Papp (1995) for the western Palearctic, McComb (1968) for the Holarctic region, Tobias (2000) for the Russian far East, Zhang (2008) for S.E. Asia and De Saeger (1948) for the Afrotropical region.

BIOLOGY, ECOLOGY AND PARASITISM

Bio-ecology of Cheloninae**:** Oviposition in host eggs is a common behaviour among chelonines. Members of the genus *Ascogaster* are typically found in shrubby areas, while *Chelonus* species inhabit steppes, prairies, and grasslands, showing a high tolerance to heat and drought. *Phanerotoma* species are often encountered in arid and seasonally dry habitats (Shaw, 1997; Beyarslan, 2021). Certain species exhibit nocturnal behaviour and are frequently captured in light traps, such as *Phanerotoma* and *Phanerotomella*, while females of various species forage in vegetation during the daytime and can be collected using sweep nets on foliage (Shaw, 1997).

Bio-ecology of Chelonus Panzer**:** Adults of *Chelonus* are free-living, contrasting with the larvae that parasitize host larvae (Yousuf & Ray, 2009). They are predominantly solitary, and the mode of development is egg-larval concerning the host stage and koinobiont concerning its effect on the host insect. Upon hatching, the larva becomes an internal parasitoid, and the host's development continues even after parasitization (Baltazar, 1962; Khajeh *et al.*, 2020). Members of *Chelonus* spp. display arrhenotoky, a reproductive mode common among aculeate and parasitic Hymenoptera, in which unfertilized eggs produce male offspring and fertilized eggs yield female offspring (Yu *et al.*, 2016). Nearly all koinobionts are endoparasitic, laying their eggs directly inside the host insect. Larval development of the parasitoid typically occurs when the host larva is nearing maturity (Baltazar, 1962). Additionally, eggs are deposited into the host egg, delaying larval development at the first instar until the host larva matures (Tang & Marsh, 1994). FAW larvae parasitized by *Chelonus* experience a gradual reduction in food intake, consuming less than 10% of the biomass ingested by healthy larvae (Prasanna *et al.*, 2018).

Life history and parasitism of *Chelonus formosanus* Sonan

Gupta *et al.* (2020a) investigated the life history and parasitism of *C. formosanus* in Karnataka, India, finding that adult longevity ranged from 2 to 7 days, and the developmental period on *S. frugiperda* was 20 to 25 days in the BOD incubator (KCS/BI-50) set at 27±2°C and 65± 2% RH. The per cent parasitism varied from 10.0% to 19.4%, with 45.0% to 57.5% of *C. formosanus* adults successfully emerging from cocoons. In a concurrent study in the same region, Jindal *et al.* (2022) observed a parasitism rate of 6.67% to 32% by *C. formosanus*, with a peak in the second and third week of November 2020 and an overall mean parasitism rate of 16.33%. Firake and Behere (2020b) reported a parasitism rate of 5% by *C. formosanus* on *S. frugiperda* in northern India, while Keerthi *et al.* (2023) identified *C. formosanus* as the most active parasitoid contributing to the highest total parasitism in India. In Hainan, China, Kenis *et al.* (2022) reported parasitism rates of 12%, 7%, and 4% by *C. formosanus*, the larval parasitoid *Microplitis pallidipes*, and the pupal parasitoid *Tetrastichus howardi*, respectively.

In Flores Island, Indonesia, Baringbing and Baringbing (1984) conducted mass rearing of the introduced parasitoid *C. formosanus* in the laboratory conditions, utilizing the potato tuber moth *Phthorimaea operculella* as the host to control the coconut moth *Batrachedra arenosella*. Each female parasitoid in the laboratory produced an average of 14 offspring, with a male-biased sex ratio favouring 2.27. Males exhibited an incubation period of 26 days, while females had a slightly longer incubation period of 27 days within the host body of *P. operculella*. In contrast, the sex ratio of the same parasitoid in the field, parasitizing *B. arenosella*, was 1:1, while the sex ratio of the pest in the field was 1:1.26. A 10% honey solution served as suitable food for both the parasitoid and adult *P. operculella*. Laboratory observations suggested that achieving a sex ratio close to 1:1 for the parasitoid is preferable for effective biological control of *B. arenosella*, indicating that the observed increase in the proportion of males to females in the laboratory may be due to deficient fertilization.

Rao and Patel (1974) investigated the biology of *C. formosanus* using *Spodoptera litura* (F.) and *Spodoptera exigua* (Hübner) in India. Their findings revealed that at a temperature of 26.7 ± 1.5°C, females exhibited an average pre-oviposition period of 3.7 ± 0.77 days and an oviposition period of 6.6 ± 1.06 days. Mated females had an average egg-laying capacity of 299 ± 71 eggs, with a parasitoid egg incubation period of 23.9 hours. The parasitoid larva underwent five instars, and the entire egg-larval duration, including cocoon formation, was 14.16 days. After the 11th day of parasitization, the parasitized host larvae exhibited smaller lengths than larvae that were not parasitized. Male cocoons were smaller than female cocoons in the soil. Pupal duration in cocoons averaged 5.57 ± 0.97 days for males and 6.12 ± 0.79 days for females.

Life history and parasitism of *Chelonus insularis* Cresson

The average incubation period of *Chelonus insularis* is approximately 1.8 days, with no pre-oviposition period for adults. The larval stage typically lasts between 17 and 23 days at a temperature of 25 ± 2 °C, with an average duration of 20.4 days. Pupal development averages 6.2 days, resulting in a total cycle duration of 28.6 days. Mated females exhibit an average longevity of 11.6 days, ranging from a maximum of 18 days to a minimum of 5 days. The number of parasitized eggs and the longevity of individual female wasps vary considerably, decreasing notably towards the end of their lifespan. Females of *C. insularis* deposit their eggs within the egg masses of their host, emerging from *S. frugiperda* larvae during the 4th instar, ultimately leading to the host's death (Zenner *et al.*, 2006). The peak parasitism rate occurs in females aged three days, ranging from a maximum of 92.2 to a minimum of 48.1 eggs parasitized during this period. Between the 3rd and 6th days, females maintain a parasitism rate of 72% to 80% (Prasanna *et al.*, 2018). However, under natural conditions, the parasitism of *C. insularis* on *S. frugiperda* ranges from 6.63% to 21.96% (Tang *et al.*, 2019). Notably, *Chelonus* species, including *C. insularis* and *C. bifoveolatus* exhibit larger body sizes and greater egg-carrying capacity compared to other egg parasitoids such as *Telenomus remus* and *Trichogramma* spp. (Tang *et al.*, 2019; Zang *et al.*, 2022).

Life history and parasitism of *Chelonus bifoveolatus* Szépligeti

The wasp *C. bifoveolatus* parasitized 0-to-2-day-old *S. frugiperda* eggs and it successfully parasitized and developed on eggs in all tested samples (Shen *et al.*, 2023). Notably, 1-day-old eggs of FAW eggs exhibited a higher parasitism rate, pupation rate, and emergence rate compared to 2-day-old FAW eggs, albeit with a shorter development time. The sex ratio of females-to-males sex was nearly 1:1 across all stages examined (Shen *et al.*, 2023). Under laboratory conditions, *C. bifoveolatus* required an average of 40.2 ± 3.88 days at 25°C and 33.3 ± 2.47 days at 30 ± 1°C (n=35) to develop from egg to adult when feeding on *S. frugiperda* (C.E.F. Kassa, unpublished data). Moreover, at these same temperatures and with the same host, female *C. bifoveolatus* produced an average of 117 and 98 offspring, respectively, with a sex ratio ranging from 0.27 to 0.45. The adult lifespan ranged between 10.2 days at 25°C and 6.2 days at 30°C. In a survey conducted across 54 maize fields in central and southern Benin, the average rate of parasitism of *S. frugiperda* by *C. bifoveolatus* ranged from 12.3% to 2.4%, respectively (Personal communication, Goergen, unpublished data), indicating that the parasitoid is better adapted to conditions prevalent in the dry savannas.

Parasitism of *Chelonus blackburni* Cameron

In India, Keerthi *et al.* (2023) conducted a study documenting the overall parasitism rates of *S. frugiperda* by various parasitoids, ranging from 28.37% to 42.44%. Notably, *Chelonus* nr. *blackburni* emerged as the predominant species, contributing significantly with 18.57% parasitism during July 2021.

Parasitism of *Chelonus oculator* Panzer

Özmen (2004) investigated the biological interactions between the egg-larval parasitoid *C. oculator* and two different hosts under laboratory conditions. The study also assessed the impact of Aldicarb on the parasitoid using radioisotope tracer techniques. The optimal host age for successful parasitization was determined to be eggs older than 24 hours of the Mediterranean flour moth *Ephestia kuehniella* Zeller. Female *C. oculator* exhibited a maximum longevity of 16.3 ± 2.3 days, with a mean development time of 58.6 ± 0.09 days, while males had a longevity of 14.1 ± 2.3 days and a mean development time of 55.9 ± 0.09 days both at optimum temperature. The parasitoid demonstrated high fecundity, with a mean of 2,344 ± 222.5 parasitoids, a sex ratio of 2.5:1 (male: female), and a net reproduction rate of 668.8 female/female. The presence of a mating partner more than doubled the number of produced females. Additionally, the development time of *C. oculator* on its natural host, the Egyptian cotton leafworm *Spodoptera littoralis*, was 18.4 ± 0.3 days. Parasitization significantly reduced the food consumption of *S. littoralis*, with parasitized larvae consuming 32.9 ± 0.6 sq. cm leaf area compared to 143.3 ± 6.5 sq. cm in unparasitized larvae. The study also revealed that C^{14} Aldicarb residues applied to parasitized *S. littoralis* larvae were retained at 75.4 ± 3.2% sq. cm of the initially applied radioactivity, indicating that the parasitoid was not adversely affected by Aldicarb residues. Overall, the research highlighted the high fecundity of the parasitoid when reared on *E. kuehniella*, its ability to reduce the food consumption of harmful hosts like *S. littoralis*, and its resilience to Aldicarb residues in the context of cotton field protection.

Biology and parasitism of *Chelonus* sp. 1 in West Africa

Tendeng *et al.* (2019) provided a concise account of the biology and parasitism of an unidentified *Chelonus* species. Parasitized *S. frugiperda* larvae completed their development until the parasitoid's emergence. Upon emergence, the host larvae became moribund, losing mobility and feeding capability. Although positioned externally, the parasitoid remained attached to the larval track, continuously extracting hemolymph. After the larval contents were emptied, the parasitoid larvae detached and proceeded with pupal development, secreting a silk cocoon for protection until adulthood. The resulting larvae were pearly white, ranging in size from 8 to 10 mm, with emergence occurring 8 to 9 days later. There were 28 individuals of *Chelonus* sp. 1 emerged from FAW larvae, resulting in a calculated parasitism rate of 10.9% (n=255). The adult parasitoids' size ranged from 8 to 9 mm. The undetermined species has two white spots in the anterior part of the abdomen. The relationship between antenna length and the body length and that of the wing and body were 0.8 mm and 0.75 mm, respectively.

Parasitism of *Chelonus* spp. on other *Spodoptera* spp.

In Africa and Asian continents, various *Chelonus* species, originally parasitoids of local *Spodoptera* spp. (Lepidoptera: Noctuidae) have been observed and reported as significant parasitoids that have adapted to *S. frugiperda* (Agboyi *et al.*, 2020; Durocher-Granger *et al.*, 2021; Firake & Behere, 2020a, 2020b; Gupta *et al.*, 2020a).

ALTERNATE HOSTS

Chelonus has numerous associations with various lepidopterous species, including some significant agricultural pests worldwide (Baltazar, 1962; Jones, 1985). Notably, it can target insect pests from the superfamily Tortricoidea and Pyraloidea (Yousuf & Ray, 2009). This genus of wasps has been successful in controlling economically important agricultural pests such as the common cutworm *S. litura* Fabricius, beet armyworm *S. exigua* (Hübner), and corn earworm or cotton bollworm *Helicoverpa armigera* (Hübner). *Chelonus* spp., reared in laboratories using factitious hosts, have effectively contributed to the control of various lepidopteran pests, including *Batrachedra arenosella* (Walker) (Lepidoptera: Batrachedridae), *Earias villa* (F.) (Lepidoptera: Noctuidae), *H. armigera* (Hübner) (Lepidoptera: Noctuidae), *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), *Prays oleae* Bernard (Lepidoptera: Praydidae), and *S. littoralis* (Boisduval) (Lepidoptera: Noctuidae) (Pawar *et al.*, 1983; Baringbing & Baringbing, 1984; Hafez *et al.*, 1980; Legner & Thomson, 1977; Arambourg *et al.*, 1970).

The wasp *C. formosanus* has demonstrated effective control of various noctuid pests, including *H. armigera* (Hübner) (Yadav, 1980; Liu, 2022), *Leucania (Mythimna) loreyi* (Duponchel) (Sonan, 1932; Chou, 1981), *S. exigua* (Chou, 1981; Liu, 2022), *S. frugiperda* (Molina-Ochoa *et al.*, 2003; Liu, 2022), and *S. litura* (Sonan, 1932; Sonan, 1937; Rao & Patel, 1974; Chou, 1981; Liu, 2022). In addition to *S. frugiperda*, a comprehensive list of other lepidopterous insect pests, along with moths utilized in the rearing of *Chelonus* spp., is provided and summarized in Table 2. The utilization of alternative hosts by all currently recorded *Chelonus* species plays a pivotal role in sustaining populations of these parasitoids during periods when FAW availability is reduced, such as the maize off-season. This ecological strategy and adaptability are paramount for Integrated Pest Management (IPM) systems, ensuring the resilience of *Chelonus* spp. populations, which are crucial for regulating FAW populations upon the resumption of the maize growing season.

GEOGRAPHIC DISTRIBUTION OF *CHELONUS* SPP. PANZER

North and South America

The presence and impact of Fall armyworm, *S. frugiperda* have been documented since its initial observation on grains and grasses in Georgia, USA, dating back to 1797 (Westbrook *et al.*, 2019). In the Caribbean Islands, *Chelonus* spp., particularly *Chelonus antillarum* Marshall, is among the earliest recorded parasitoids of *S. frugiperda*, targeting its eggs (Ashley, 1986; Zenner *et al.,* 2006). Notably, *S. frugiperda* larvae exhibit increased susceptibility to chlorpyriphos, methomyl, and cypermethrin upon infestation by the egg-larval parasitoid of *S. frugiperda*.

In Nicaragua, key parasitoids of *S. frugiperda* in maize include braconids, with up to 30% parasitism of collected larvae, predominantly *Aleiodes* (= *Rogas*) *laphygmae* (Viereck) and *C. insularis* (van Huis, 1981). Another ectoparasitoid of *S. frugiperda*, *Diapetimorpha introita*

Table 2. Lepidopterous insect hosts and rearing hosts of egg-larval parasitoid *Chelonus* s. str. Panzer

***Chelonus* spp.**	**Insect Hosts / Factitious Hosts**	**References**
C. antillarum Marshall	*Spodoptera frugiperda* (JE Smith)	Ashley (1986); Molina-Ochoa *et al.* 2003); Zenner *et al.* (2006)
C. bifoveolatus Szepligeti	*Spodoptera frugiperda* (JE Smith); *S. exigua* (Hübner), *S. littoralis* (Boisduval), *S. litura* (Fab.), *Helicoverpa armigera* Hübner (Noctuidae); *Haritalodes derogata* (Fab.) (Crambidae)	Van den Berg (1988); Madl and van Achterberg (2014); Tang *et al.* (2019); Ngangambe and Mwatawala (2020); Yu *et al.* (2016); Zang *et al.* (2022)
C. cautus Cresson	*Spodoptera frugiperda* (JE Smith); *Herpetogramma phaeopteralis* (Guenée) (Crambidae); *Pectinophora gossypiella* (Saunders) (Gelechiidae)	Shenefelt (1973); Gutierrez-Ramirez *et al*. (2015)
C. curvimaculatus Cameron	*Spodoptera frugiperda* (JE Smith); *S. exigua* (Hübner), *Busseola fusca* (Fuller), *Helicoverpa armigera* (Hübner), *Helicoverpa assulta* (Guenée), *Heliothis peltigera* Denis and Schiffermüller, *Sesamia calamistis* Hampson, *Trichoplusia ni* (Hübner), *Thysanoplusia oricalcea* (Fab.) (Noctuidae); *Piezotrachelus varium* (Wagner) (Apionidae); *Chilo orichalcociliellus* Pinhey, *Chilo partellus* (Swinhoe), *Chilo zacconius* Błeszyński (Crambidae), *Loxostege frustalis* (Zeller) (Crambidae); *Pectinophora gossypiella* (Saunders), *Phthorimaea operculella* (Zeller), *Platyedra cunctatrix* Meyrick, *Scrobipalpa aptatella* (Walker), *Scrobipalpa ergasima* (Meyrick) (Gelechiidae); *Earias insulana* (Boisduval), *Nola pumila* Snellen (Nolidae); *Plutella xylostella* (L.) (Plutellidae); *Phycita diaphana* (Staudinger) (Pyralidae)	Legner and Thompson (1977); Kittel (2014); Yu *et al.* (2016); Sisay *et al.* (2019)
C. formosanus Sonan	*Spodoptera frugiperda* (JE Smith); *S. exigua* (Hübner) and *S. litura* (Fab.) (Noctuidae); *Helicoverpa armigera* (Hübner) (Noctuidae); *Leucania* (*Mythimna*) *loreyi* Duponchel (Noctuidae); *Batrachedra arenosella* Walker (Bathrachedridae); *Phthorimaea operculella* (Zeller) (Gelechiidae)	Sonan (1932); Sonan (1937); Morghan and Crumb, 1941; Rao and Patel (1974); Yadav (1980); Chou (1981); Baringbing (1982); Baringbing and Baringbing (1984); Molina-Ochoa *et al.* (2003); Wang and Chen (2009); Yousuf and Ray, 2009; Ramani and Ballal, 1994; Varshney (1999); Liu (2022)
C. inanitus (L.)	*Spodoptera frugiperda* (JE Smith), *S. exigua* (Hübner), *S. littoralis* (Boisduval), *Agrotis segetum* (Denis and Schiffermüller), *Longalatedes elymi* (Treitschke), *Leucania* (*Mythimna*) *loreyi* Duponchel, *Mesoligia literosa* (Haworth), *Mythimna unipuncta* (Haworth), *Oligia strigilis* (L.), *Peridroma saucia* (Hübner) (Noctuidae); *Haritalodes derogata* (Fab.), *Ostrinia nubilalis* (Hübner) (Crambidae); *Phthorimaea operculella* (Zeller) (Gelechiidae); *Etiella zinckenella* (Treitschke) (Pyralidae); *Aethes francillana* (Fab.), *Eucosma aemulana* (Schläger) (Tortricidae)	Hafez *et al.* (1980); Khanjani, 2006; Yu *et al.* (2016)
C. insularis Cresson	*Spodoptera frugiperda* (JE Smith); *S. eridania* (Cramer), *S. exempta* (Walker), *S. exigua* (Hübner), *S. mauritia* (Boisduval), *S. ornithogalli* (Guenée), *S. praefica* (Grote), *Agrotis ipsilon* (Hufnagel), *Anomis flava* Fab., *Autographa californica* (Speyer), *Feltia subterranean* (Fab.), *Helicoverpa zea* (Boddie), *Chloridea virescens* (Fab.), *Lycophotia porphyria* (Denis and Schiffermüller), *Peridroma saucia* (Hübner), *Mythimna unipuncta* (Haworth), *Trichoplusia ni* (Hübner) (Noctuidae); *Achyra rantalis* (Guenée), *Loxostege sticticalis* (L.) (Crambidae); *Elasmopalpus lignosellus* (Zeller), *Ephestia elutella* (Hübner) (Pyralidae)	van Huis (1981); Wheeler *et al.* (1989); Molina-Ochoa *et al.* (2003); Zenner (2006); Yu *et al*. (2016); Tang *et al.* (2019); Jaraleno-Teniente *et al*., 2020; Zang *et al.* (2022)

Table 2. Continued...

***Chelonus* spp.**	**Insect Hosts / Factitious Hosts**	**References**
C. munakatae Matsumura	*Spodoptera frugiperda* (JE Smith); *Chilo suppressalis* (Walker), *Cnaphalocrocis medinalis* (Guenée), *Diatraea* sp., *Omiodes indicata* (Fab.) (Crambidae)	Yu *et al*. (2016); Li *et al.* (2019)
C. obscuratus Herrich-Schäffer	*Spodoptera frugiperda* (JE Smith)	Goergen 2024, personal communication; Edmardash *et al.* (2011)
C. nr. *blackburni* Cameron	*Spodoptera frugiperda* (JE Smith); *Helicoverpa armigera* (Hübner) (Noctuidae); *Pectinophora gossypiella* (Saunders), *Phthorimaea operculella* (Zeller) (Gelechiidae); *Earias* spp. (Nolidae); *Corcyra cephalonica* (Stainton) (Pyralidae)	Pawar *et al.* (1983); Nagarkatti and Singh (1989); Varshney (1999); Kittel (2014); Keerthi *et al.* (2023); TNAU (2023)
C. sonorensis Cameron	*Spodoptera frugiperda* (JE Smith) (Noctuidae); *Eoreuma loftini* (Dyar) (Crambidae)	Yu *et al.* (2016)
Chelonus sp. 1	*Spodoptera frugiperda* (JE Smith)	Tendeng *et al.* (2019)
Chelonus sp. 2	*Spodoptera frugiperda* (JE Smith)	Molina-Ochoa *et al.* (2003); Amadou *et al.* (2018)
Chelonus sp. 3	*Spodoptera frugiperda* (JE Smith)	Shen *et al.* (2023)
Chelonus sp. 4	*Spodoptera frugiperda* (JE Smith)	Subramaniam (2022)
Chelonus sp. 5	*Spodoptera frugiperda* (JE Smith)	Subramaniam (2022)

(Cresson) (Hymenoptera: Ichneumonidae), has been reported in Georgia, USA (Pair & Gross, 1984). *Chelonus insularis* emerges as the predominant parasitoid of *S. frugiperda* in Central America, while *C. antillarum* is also documented in Barbados (Molina-Ochoa *et al.*, 2003). Together with *Chelonus* sp. 2 from Brazil, Mexico, Peru, and Niger, they represent some of the earliest *Chelonus* spp. parasitoids reported on *S. frugiperda* (Molina-Ochoa *et al.*, 2003; Amadou *et al.,* 2018).

In Colombia, *C. insularis* has been observed parasitizing *S. frugiperda*, though it exhibits high susceptibility to insecticides like chlorpyriphos, methomyl, and cypermethrin, except for *Bacillus thuringiensis* Berliner (Bt) toxin (Zenner, 2006). Wheeler *et al.* (1989) reported in Honduras that the parasitoid complex accounted for 42% of mortality in *S. frugiperda*, with *C. insularis* being the most common, contributing to 15.5% mortality. This suggests insecticide exposure through *S. frugiperda* larvae may diminish the likelihood of successful parasitoid survival.

Research on the non-target effects of spinosad, including its impact on FAW parasitoids, revealed multiple side effects for most tested parasitoids (Biondi *et al.*, 2012). In Mexico, Gutierrez-Ramirez *et al.* (2015) documented the parasitism of *Chelonus cautus* Cresson on *S. frugiperda*, marking it as the fourth *Chelonus* species identified for this invasive pest. Additionally, from May to October of 2017 and 2018 in Guanajuato, Mexico, a survey involving 4,323 sentinel egg masses of *S. frugiperda* exposed at 12 field sites revealed the recovery of *Trichogramma atopovirilia* Oatman and Platner (Hymenoptera: Trichogrammatidae) from three locations and *C. insularis* from two sites (Jaraleno-Teniente *et al.*, 2020).

Africa

Four species of *Chelonus* have been documented in Africa following their introduction to the continent. The first is *Chelonus bifoveolatus* Szépligeti, with a parasitism rate ranging between 1.04 and 12.3%, has been identified in Benin, Burkina Faso, Cameroon, DR Congo, Ghana, Kenya, Madagascar, Nigeria, Tanzania, Senegal, Uganda, and Zambia, covering sub-Saharan Africa (Nonveiller, 1984; van den Berg (1988); Madl & van Achterberg, 2014; Tendeng *et al.*, 2019; Agboyi *et al.*, 2020; Koffi *et al.*, 2020; Ahissou *et al.*, 2021; Durocher-Granger *et al.*, 2021; Otim *et al.*, 2021; Shen *et al.*, 2023). Notably, *C. bifoveolatus* is recognized as one of the predominant *S. frugiperda* parasitoids throughout tropical Africa (Agboyi *et al.*, 2020; Ahissou *et al.*, 2021). However, a molecular study by Shen *et al.* (2023) revealed that, although *Chelonus* sp. 3 shares >99% similarity with specimens from Ghana and Benin, it also exhibits >99% similarity to *C. formosanus* found in Guangdong, Taiwan, Hainan, Zhejiang (China), and certain regions of India (Gupta, 2020a). Furthermore, the blast results indicated that *Chelonus* sp. 3 and *C. bifoveolatus* in Benin, Burkina Faso, Ghana, Senegal, Uganda, and Zambia are situated in the same branch, with a 99.99% similarity between them. Additionally, they display >99.69% similarity to *C. formosanus* (Shen *et al.*, 2023).

Chelonus bifoveolatus Szépligeti (sic) was observed in Kenya and Zambia, demonstrating a parasitism rate of 4.8% (Sisay *et al.*, 2019). Unfortunately, in Tanzania, the use of Flubendiamide, an anthranilic diamide insecticide, led to a reduction in *S. frugiperda* parasitism by *C. bifoveolatus* and *Coccygidium luteum* (Brulle) (Ngangambe & Mwatawala, 2020). Recently, *C. bifoveolatus* was identified in Zimbabwe from a specimen submitted for identification (Georgen 2024, unpublished report). Furthermore, according to Goergen (2024, personal communication), the species *Chelonus intermedius* in Egypt is a synonym of *Chelonus obscuratus* Herrich-Schäffer. *Chelonus obscuratus* is also recorded in Mongolia, Russia (Central, East, and South), Northern Africa, and Europe (Ermardash *et al.* 2011).

Asia and Oceania

In Israel, *Chelonus inanitus* (L.) is recognized as a parasitoid of *S. littoralis*, *S. exigua*, and *S. frugiperda* (Rechav, 1975; Rechav & Orion, 1975; Rechav, 1978). The parasitoid *C. formosanus* was initially identified from a survey conducted in corn areas infested with FAW, cotton, and other host plants in Karnataka in 2018 and in Uttar Pradesh in 2019, India (Gupta *et al.*, 2019; Jindal *et al.*, 2022). *Chelonus* spp. and *Coccygidium* spp. (Gupta *et al.*, 2020b) were identified as more abundant and widely distributed parasitoids in India. Collectively, these parasitoids provided an average of 9.2% *S. frugiperda* larval mortality in various locations. Furthermore, two braconid parasitoids of *S. frugiperda* were documented on corn in India, *Coccygidium transcaspicum* (Kokujev) (Gupta *et al.*, 2020b), and *Cotesia ruficrus* (Haliday) (Gupta *et al.*, 2019). The latter parasitoid was also reported in Trinidad and Tobago, with Gupta *et al.* (2019) providing detailed morphological and molecular identification, along with host data, cocoon characters, and geographical distribution. These promising species can potentially be harnessed for the biological control of key forest insect pests, contributing to the effective balance of ecosystems (Yousuf & Ray, 2009).

In ginger (*Zingiber officinale* Roscoe) fields in Meghalaya State of India, Firake and Behere (2020b) documented a 74% larval mortality, primarily attributed to the egg-larval parasitoid *C. formosanus* (5%), mermithid nematodes (10%), *Metarhizium rileyi* (Farl.) Kepler, Rehner, and Humber (38.01%), and SfMNPV (21%). A recent survey of *S. frugiperda* parasitoids in India by Sagar *et al.* (2022) revealed an 80.46% larval mortality due to the natural enemy complex.

Eight species of *Chelonus* have been documented in India, with Varshney (1999) providing a taxonomic key for these chelonine species. The most prevalent parasitoid attacking *S. frugiperda* in India is *C.* nr. *blackburni* Cameron, causing a larval mortality rate of 49.24%, followed by *C. formosanus*. *Chelonus blackburni* is a notable example of an introduced parasitoid in India, imported from Hawaii, USA, in 1976 by the Indian Station of the Commonwealth Institute of Biological Control, Bangalore, and subsequently released near Bangalore against *H. armigera* Hübner (Nagarkatti & Singh, 1989). Subsequent records indicate its efficacy against *Earias* spp. (Lepidoptera: Nolidae), *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), and *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae), providing significant management to these pests (Morgan & Crumb, 1914; Yousuf & Ray, 2009). *Mythimna (Cirphis) loreyi* (Duponchel) (Lepidoptera: Noctuidae) and *S. (Prodenia) litura* (Fabricius) (Lepidoptera: Noctuidae) have also been identified as hosts for *C. formosanus* (Varshney, 1999).

In organic corn areas in New Delhi, India, *C. formosanus* emerged as the dominant parasitoid at 12.55%, followed by *C.* nr. *blackburni* at 10.98%, and *Coccygydium* sp. (Hymenoptera: Braconidae) at 4.85% (Keerthi *et al.*, 2023). Additionally, *C. formosanus* was recorded as the most abundant egg-larval parasitoid of *S. frugiperda* in the northern part of India (Sagar *et al.,* 2022) and India as a whole (Firake & Behere 2020a; Gupta *et al.,* 2020a).

In Middle Eastern countries, Ghahari *et al.* (2022) reported a total of 219 species within the subfamily Cheloninae, constituting 14.3% of the world species, distributed across five genera and three tribes (Adeliini, Cheloninae, Phanerotomini). The genus *Chelonus* stands out as the most abundant, with 137 recorded species.

In China, a survey conducted in corn plantations infested with *S. frugiperda* in the Hainan Province identified the presence of *Chelonus munakatae* Matsumura. Following its discovery, artificial propagation and field application were initiated (Li *et al.*, 2019). *Spodoptera frugiperda* infestations have also been observed in ginger plants in China (Shankar & Adachi, 2019). The distribution of the parasitoid *C. formosanus* spans Taiwan, Guangdong, Zhejiang, and Hainan provinces (Liu *et al.*, 2022). Notably, a study presenting the chromosome-level genome assembly of *C. formosanus*, sequenced using PacBio®, Illumina®, and Hi-C technologies® by Liu *et al.* (2022), could prove to be a valuable resource for the biological control of lepidopterous pests.

In Southeast Asia, throughout 2019, *S. frugiperda* occurrences were reported in Indonesia (Trisyono *et al.*, 2019), Laos, Malaysia, Vietnam, the Philippines, Cambodia (personal observation by Khay), and in Eastern Asia from the Republic of Korea and Japan in July 2019 (Australian Aid, 2020). The moth's high potential for contaminating specific agricultural trade products (Early *et al.,* 2018) contributed to its success as a pest and facilitated its spread to different countries. The larvae and pupae of *S. frugiperda* can unintentionally contaminate traded commodities, especially plant parts. They have been frequently intercepted on vegetables in Europe, fruits from the Americas, and occasionally on herbaceous ornamentals (Seymour *et al.*, 1985; Cock *et al.*, 2017). Similarly, Taiwan, located just

1,205 km from the northern tip of Luzon, Philippines, as per Watanabe (1937), boasts ten species of *Chelonus*, including *C. formosanus*. However, it is worth noting that *C. formosanus* exhibits a Neotropical and Oriental distribution (Yu *et al.*, 2016).

In the Philippines, the endemic species *Chelonus semihyalinus* Ashmead has yet no recorded host information (Ashmead, 1904; Baltazar, 1962). Recently, Calcetas *et al.* (2023) reported the presence of *C. formosanus,* a well-known parasitoid of FAW in the Philippines, and its association with FAW has been an important aspect of the enhancement of the biological control program in the country. This marks it as the second species of *Chelonus* Panzer, following *C. semihyalinus* Ashmead, in 1904, to be recorded in the country. The global geographic distribution of the *Chelonus* species, including the new record from the Philippines, is presented in Figure 1. Another chelonine species, *Megachelonus* Baker, was recorded in the Philippines.

The first report of *S. frugiperda* in Australia emerged in February 2020, and the moth pest swiftly established itself across various regions in Northern Australia, including northern Queensland, the Northern Territory, and northern parts of Western Australia (Sisay *et al.*, 2019; Plant Health Australia, 2020). In Australia, the pest was also identified in sorghum, chickpea, melons, green beans, and pasture seed crops, with some instances of larvae reported on Rhodes grass in Western Australia. More recently, *S. frugiperda* was detected in Papua New Guinea (Australian Aid, 2020), the Solomon Islands in 2021, and New Zealand in March 2022. Australia records 45 species of Cheloninae, along with several introduced for biocontrol: *Ascogaster quadridentata* Wesmael, *C. blackburni* Cameron, *Chelonus phthorimaeae* Gahan, *Chelonus curvimaculatus* Cameron, and *Phanerotoma hendecasisella* Cameron (Kittel & Austin, 2014). Comprehensive field surveys carried out between 2021 and 2022, aimed at investigating *S. frugiperda* across two Australian states and two territories spanning 65 locations, resulted in the collection of two *Chelonus* species yet identified at a generic level only (Subramaniam, 2022). Also, a field survey in Queensland, particularly in Bowen and Burdekin locations, *Chelonus* sp. 4 along with *C. ruficrus* strain B and *Coccygidium* spp. as the commonly recorded larval parasitoids (Subramaniam, 2022). However, a survey in the Northern Territory, Australia, showed that the most plentiful larval parasitoids found in the majority of sampling sites were the Tachinid fly *Exorista xanthaspis* and the *Chelonus* sp. 5, exhibiting an average parasitism rate ranging between 12.38% and 25% (Subramaniam, 2022).

The global geographic distribution map of the sixteen (16) different species of *Chelonus* spp. associated with *S. frugiperda* and corresponding references are presented in Figure 1 and Table 1. Currently, there are eight (8) species of *Chelonus* associated with *S. frugiperda* in the North and South American continents, where the invasive pest originates (*C. insularis, C. antillarum, C. cautus, C. formosanus, C. sonorensis, C.* nr. *blackburni* (Hawaii), *C. inanitus, Chelonus* sp. 2), eight (8) species in Africa (*C. curvimaculatus, C. bifoveolatus, C. inanitus, C. insularis, C. obscuratus, Chelonus* sp. 1, *Chelonus* sp. 2, *Chelonus* sp. 3), and six (6) in Asia (*C. inanitus, C. formosanus, C. munakatae, C.* nr. *blackburni, C. obscuratus, C. curvimaculatus*), with two (2) in Europe (*C. inanitus, C. obscuratus*) and four (4) in Oceania (*C. curvimaculatus, C.* nr. *blackburni*, *Chelonus* sp. 4, *Chelonus* sp. 5). However, the report of *C. intermedius* in Egypt is excluded, as it is no longer considered a valid taxon, being a synonym of *C. obscuratus* Herrich-Schäffer, and its identity is questionable (Goergen 2024, personal communication).

Mass rearing of *Chelonus* spp.

The mass rearing, quality management, and release methods of parasitoids play pivotal roles in augmentative biocontrol strategies (Agboyi *et al.*, 2020). This approach stands out as the most sustainable pest management strategy, leveraging over a century of global agricultural research and application (Heimpel & Mills, 2017). However, the success of an augmentative biological control program hinges significantly on the quality of natural enemies' production (van Lenteren *et al.*, 2003).

The initiation of the biological control campaign in West Africa involving the importation of the parasitoid *C. insularis* originated from the Americas. Due to the cannibalistic habit of the caterpillars, the mass rearing of *C. marginiventris* utilizing *S. frugiperda* as a host presents significant challenges. Successful reproduction is only achievable within compartmentalized rearing units that maintain relatively low larval densities. Presently, production rates have reached approximately 5 to 6 thousand individuals per week, with its introduction primarily conducted through inoculative field releases, exemplifying classical biological control methods (Goergen 2024, personal communication).

In Karnataka, India, the parasitoid *C. formosanus* is produced on a large scale using the rearing methods outlined by Gupta *et al.* (2020a). Field-collected eggs and larvae infested by the parasitoid are reared to obtain adult parasitoids. They undergo growth in the laboratory through a combination of fresh corn leaves and an artificial diet. Parasitized *S. frugiperda* larvae are collected and allowed to pupate, and the cocoons are subsequently harvested. To achieve mass production, emerging adult parasitoids are encouraged to parasitize *S. frugiperda* eggs and larvae that are reared in the laboratory. The parasitized *S. frugiperda* eggs and newly emerged adult parasitoids are released into the field while maintaining a cohort of parasitoid individuals that are continuously mass reared in the laboratory. This process ensures a sustainable and scalable production of *C. formosanus* in the laboratory.

On Flores Island, Indonesia, Baringbing and Baringbing (1984) outlined three crucial steps for laboratory production of *C. formosanus* to control the coconut moth *B. arenosella*. The first step involves collecting *B. arenosella* moths. Coconut palm spathes from infested areas are carefully cut and opened in the laboratory. *B. arenosella,* in the pupal stage, are placed in 1 L plastic containers, where adult parasitoids emerge from the parasitized pupae. The second step is the rearing of the host, *B. arenosella*. Adults of *P. operculella* (Zeller) (Lepidoptera: Gelechiidae) are collected from potato plantations and housed in plastic containers with cotton wool soaked in 10% honey as a food source. Eggs are deposited on the undersurface of the cotton fabric used to cover the container. The third step involves the rearing of the parasitoid, *C. formosanus*. Adults of *C. formosanus* emerging from host pupae in the first step are paired in test tubes to facilitate mating. Gravid females are then transferred to new plastic containers, accommodating up to 21 individuals, and provided with cotton wool soaked in 10% honey as food. Container lids from the second step (containing *P. operculella* eggs) are transferred to the container with *C. formosanus* females for parasitization. After two days, the cotton fabric containing parasitized eggs is removed, and the potato (*Solanum tuberosum*) tubers are wrapped around and placed in an empty container. The tuber serves as food for developing parasitized and non-parasitized *P. operculella* larvae. After approximately six days, the cotton fabric is opened, and adults of both *P. operculella* (from non-parasitized eggs) and *C. formosanus* emerge from the pupae, typically around four weeks later.

The parasitoid *C. blackburni*, introduced from Hawaii, is reared on the common rice meal moth *Corcyra cephalonica* (Stainton) (Lepidoptera: Pyralidae) and potato tuber moth *Phthorimaea operculella* (Zeller) in Tamil Nadu Agricultural University (TNAU, 2023). The production procedures for both hosts are outlined below:

Rearing procedure of *Corcyra cephalonica* (Rice Meal Moth)

Start by affixing 24-hour-old *Corcyra* eggs (a set of 100, not exposed to UV) onto a 5 x 5 cm card. Place this card, containing the host eggs, into a 1.5-liter plastic container with 30 *C. blackburni* adults. Inside the container, insert two cotton swabs: one soaked in a 10% honey solution and the other for drinking water. Seal the side opening tightly with a cotton plug covered with cloth. Expose the card to the *C. blackburni* adults for 24 hours, then remove it and transfer it onto 500 g of sterilized stubble medium. After 30 days, adult parasitoids begin emerging from cocoons, indicating the completion of development on *Corcyra* larvae. These adult parasitoids have a lifespan of 25 days, during which they can produce approximately 400 eggs.

Mass production procedure using *Phthorimaea operculella* (Potato Tuber Moth) (PTM)

The mass production of the parasitoid on the Potato Tuber Moth (PTM) involves utilizing a set of 1,500 PTM eggs laid on a cloth and stapled to a card, which is then exposed to 30 adult parasitoids of *C. blackburni* for 24 hours in a plastic rearing container with windows and plastic mesh for aeration. Inside the container, a 50% honey solution and drinking water are provided, covered with a cotton plug wrapped in cloth. After this exposure, the PTM eggs are transferred onto punctured potatoes in a similar plastic container lined with sterilized sand at the bottom. Following a period of 25–27 days, adult parasitoids start emerging from the cocoons. They are formed either in the sand at the cage bottom or occasionally inside the punctured potatoes. These adult parasitoids have a lifespan of 23–31 days, during which their fecundity ranges from 288 to 390 eggs. It is essential to maintain a parasitoid-host ratio of 1:50, and fresh eggs are provided daily to ensure successful rearing.

In France, Arambourg *et al.* (1970) conducted large-scale breeding of *Chelonus elaeaphilus* (Silvestri) in a laboratory environment. They utilized the Mediterranean flour moth, *Ephestia (Anagasta) kuehniella* (Zeller) (Lepidoptera: Pyralidae), as the host with the aim of controlling the olive moth, *Prays oleae* Bernard (Lepidoptera: Praydidae).

In conclusion, the mass rearing of *Chelonus* spp. stands out as a pivotal component of augmentative biocontrol strategies, offering a sustainable and effective approach to *S. frugiperda* management. The success hinges on precise quality management and release methods for parasitoids. Historical instances, like the importation of *C. insularis* and the mass production of *C. formosanus*, underscore the method's adaptability and significance globally. The versatility of mass rearing, demonstrated with *C. blackburni* on different hosts, highlights its practical application across diverse agricultural landscapes. Overall, mass rearing of *Chelonus* spp. proves to be an essential tool for ecologically friendly and economically viable pest control against *S. frugiperda*.

ACKNOWLEDGEMENTS

We extend our gratitude to the following for their support and facilities: Department of Agriculture, Regional Field Office-IVA and the Regional Crop Protection-IVA

(DA-RCPC-IVA), Philippines; Department of Agriculture-Philippine Rice Research Institute (DA-PhilRice), Philippines; and the Fall Armyworm research at the International Institute of Tropical Agriculture (IITA), financially supported by the Federal Ministry for Economic Cooperation and Development (BMZ/GIZ) through project Grant 81235252 GA. RCJ acknowledges the invaluable contributions of Dr. Sivapragasam Annamalai and Dr. Muhammad Faheem from the Centre for Agriculture and Biosciences International – South East Asia, Serdang, Selangor, Malaysia; Dr. S.N. Sushil and Dr. Ankita Gupta from the Indian Council of Agricultural Research-National Bureau of Agricultural Insect Resources, India; Dr. Avinjikkattu Parambil Ranjith from the Insect Biosystematics and Conservation Laboratory, Ashoka Trust for Research in Ecology and the Environment, India; and Dr. Lekhnath Kafle from the National Pingtung University of Science and Technology, Taiwan, for their valuable insights on *Chelonus* spp. and for sharing access to relevant publications.

REFERENCES

Arambourg, Y., Pralavorio, R., and Chabot, B. 1970. The possibility of rearing *Ageniaspis fuscicollis praysincola* Silv. a parasite of *Prays oleae* Bern. (Lep. Hyponomeutidae) in a substitute host. *Ann Zoo Ecol Anim*, **2**: 657-658. https://www.cabdirect.org/cabdirect/abstract/19730503073

Agboyi, L. K., Goergen, G., Beseh, P., Mensah, S. A., Clottey, V. A., Glikpo, R., … Day, R. 2020. Parasitoid complex of fall armyworm, Spodoptera frugiperda, in Ghana and Benin. *Insects*, **11**(2): 68. https://doi.org/10.3390/insects11020068

Ahissou, B. R., Sawadogo, W.M., Bokonon-Ganta, A., Somda, I., and Verheggen, F. 2021. Integrated pest management options for the fall armyworm *Spodoptera frugiperda* in West Africa: Challenges and opportunities. A review. *Biotechnol Agron Soc Environ*, **25**(3): 192-207. https://doi.org/10.25518/1780-4507.19125

Amadou, L., Baoua, I., Ba, M. N., Karimoune, L., and Muniappan, R. 2018. Native parasitoids recruited by the invaded fall armyworm in Niger. *Indian J Entomol*, **80**(4): 1253-1255. https://doi.org/10.5958/0974-8172.2018.00338.3

Ashley, T. R. 1986. Geographical distributions and parasitization levels for parasitoids of the fall armyworm, *Spodoptera frugiperda*. *Fla Entomol*, **69**(3): 516-524. https://doi.org/10.2307/3495384

Ashmead, W. H. 1904. Descriptions of new genera and species of Hymenoptera from the Philippines Islands. *Proc US Nat Mus*, **28**(1387): 127-158. https://doi.org/10.5479/si.00963801.28-1387.127

Bahena, J. F., and Cortez, M. E. 2015. Gusano cogollero del maíz, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). In: Arredondo BHC (ed), Casos de Control Biológico en México 2. Guadalajara, Jalisco, México: Biblioteca Básica de Agricultura, p. 181-250.

Baltazar, C. R. 1962. The genera of parasitic Hymenoptera in the Philippines, Part 1. *Pac Insects*, **4**(4): 737-771. http://hbs.bishopmuseum.org/pi/pdf/4(4)-737.pdf

Baringbing, W.A. 1982. Laporan perjalanan dinas ke Nusa Tenggara Timur. Balai Penelitian Tanaman Industry, Bogor, Indonesia, Unpublished.

Baringbing, W. A., and Baringbing, B. 1984. Studies on Chelonus sp. a parasite of the coconut moth *Batrachedra arenosella*. *Trop Pest Manag*, **30**(2): 207 p. https://doi.org/10.1080/09670878409370877

Belshaw, R., Fitton, M., Herniou, E., Gimeno, C., and Quicke, D. L. J. 1998. A phylogenetic reconstruction of the Ichneumonoidea (Hymenoptera) based on the D2 variable region of 28S ribosomal RNA. *Syst Entomol*, **23**(2): 109-23. https://doi.org/10.1046/j.1365-3113.1998.00046.x

Bernardi, D., Salmeron, E., Horikoshi, R. J., Bernardi, O., Dourado, P.M., Carvaletho, R. A. … Omoto, C. 2015. Cross-resistance between Cry1 proteins in fall armyworm (*Spodoptera frugiperda*) may affect the durability of current pyramided Bt maize hybrids in Brazil. *PLoS ONE*, **10**(10): 140-130. https://doi.org/10.1371/journal.pone.0140130

Beyarslan, A. 2021. Taxonomic studies on Cheloninae (Hymenoptera, Braconidae) fauna of Northeastern Anatolia region (Ardahan, Erzurum, Iğdır, and Kars) of Turkey. *Nat Somogy*, **36**: 111-124. https://doi.org/10.24394/natsom.2021.36.111

Biondi, A., Desneux, N., Siscaro, G., and Zappalà, L. 2012. Using organic-certified rather than synthetic pesticides may not be safer for biological control agents: Selectivity and side effects of 14 pesticides on the predator *Orius laevigatus*. *Chemosphere*, **87**(7): 803-812. https://doi.org/10.1016/j. chemosphere.2011.12.082

Calcetas, O. A., Joshi, R. C., Gupta, A., Ranjith, A. P., Madrid, M. A., and Fameronag, J. 2023. New record of the egg-larval parasitoid, *Chelonus formosanus* Sonan of Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith) in the Philippines. *J Plant Prot*, **7**(2): 103-114.

Carrillo-Sánchez, J. L. 1985. Evolution of biological control in Mexico. *Folia Entomol Mex*, **65**: 139-146.

Casmuz, A., Juarez, M. L., Socias, M. G., Murua, M. G., Prieto, S., Medina, S., … Gastaminzaet, G. 2010. Review of the host plants of fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Rev Soc Entomol Arg*, **69**(3-4): 209-231. https://www.biotaxa.org/RSEA/article/view/28610

Chen, X. X., and van Achterberg, C. 1997. Revision of the subfamily Euphorinae (excluding the tribe Meteorini Cresson) (Hymenoptera: Braconidae) from China. *Zool Verh*, **313**(1): 1-217. https://repository.naturalis.nl/pub/317826

Chen, X. X., and van Achterberg, C. 2019. Systematics, phylogeny, and evolution of Braconid Wasps: 30 years of progress. *Annu Rev Entomol*, **64**: 335-358

Chou, L. Y. 1981. A preliminary list of Braconidae (Hymenoptera) of Taiwan. *J Agric Res China*, **30**(1): 71-88. (In Chinese)

Cock, M. J. W., Beseh, P. K., Buddie, A. G., Cafá, G., and Crozier, J. 2017. Molecular methods to detect *Spodoptera frugiperda* in Ghana, and implications for monitoring the spread of invasive species in developing countries. *Sci Rep*, **7**(1): 4103. https://doi.org/10.1038/s41598-017-04238-y

Collier, T., and van Steenwyk, R. 2004. A critical evaluation of augmentative biological control. *Biol Control*, **31**(2): 245-256. https://www.cdfa.ca.gov/is/pdfs/Study/BiologicalControl.pdf

Colmenarez, Y. Z., Babendreier, D., Wurst, F. R. F., Vásquez-Freytez, C. L., and Bueno, A. D. F. 2022. The use of *Telenomus remus* (Nixon, 1937) (Hymenoptera: Scelionidae) in the management of *Spodoptera* spp.: potential, challenges and major benefits. *CABI Agric Biosci*, **3**(5): 1-13. https://doi.org/10.1186/s43170-021-00071-6

DeBach, P. 1964. Biological control of insect pests and weeds. Chapman and Hall Ltd, London 844 p.

De Saeger, H. 1948. Cardiochilinae et Sigalphinae (Hymenoptera Apocrita Fam. Braconidae). Exploration du Parc National Albert. Mission G.F. de Witte (1933-1935). Fasc. 53. https://cd.chm-cbd.net/archives_rdc/archives/publications/exploration-national-park-albert/exploration-national-park-albert-first-series/mission-g.-f.-de-witte-1933-1935/1948-fascicule-53-cardiochilinae-et-sigalphinae-hymenoptera-apocrita-fam./copy-of-de-saeger_1948_complet.pdf

Dudarenko, G. P. 1974. Formation of the abdominal carapace in braconids (Hymenoptera, Braconidae). *Entomol Rev*, **53**: 80-90.

Durocher-Granger, L., Mfune, T., Musesha, M., Lowry, A., Reynolds, K., Buddie, A., Kenis, M. 2021. Factors influencing the occurrence of fall armyworm parasitoids in Zambia. *J Pest Sci*, **94**: 1133-1146. https://doi.org/10.1007/s10340-020-01320-9

Early, R., González-Moreno, P., Murphy, S. T., and Day, R. 2018. Forecasting the global extent of invasion of the cereal pest *Spodoptera frugiperda*, the fall armyworm. *NeoBiota*, **40**: 25-50. https://neobiota.pensoft.net/articles.php?id=28165

Fiedler, A. K., Landis, D. A., and Wratten, S. D. 2008. Maximizing ecosystem services from conservation biological control: The role of habitat management. *Biol Control*, **45**(2): 254-271. https://doi.org/10.1016/j.biocontrol.2007.12.009

Firake, D. M., and Behere, G. T. 2020a. Natural mortality of invasive fall armyworm, *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) in maize agroecosystems of northeast India. *Biol Control*, **148**: 104-303. https://doi.org/10.1016/j.biocontrol.2020.104303

Firake, D. M., and Behere, G. T. 2020b. Bioecological attributes and physiological indices of invasive fall armyworm, *Spodoptera frugiperda* (J. E. Smith) infesting ginger (*Zingiber officinale* Roscoe) plants in India. *Crop Prot*, **137**: 105-233. https://doi.org/10.1016/j.cropro.2020.105233

Ghahari, N. S., Gadallah, N. S., Kittel, R. N., Shaw, S. R., and Quicke, D. L. J. 2022. Subfamily Cheloninae Foerster, 1863. 256-287. In: Gadallah NS, Ghahari H, SR Shaw (eds), Braconidae of the Middle East (Hymenoptera) Taxonomy, Distribution, Biology, and Biocontrol Benefits of Parasitoid Wasps. Academic Press, Elsevier Inc., United Kingdom.

Goergen, G., Kumar, P. L., Sankung, S. B., Togola, A., and Tamò, M. 2016. First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae), a new alien invasive pest in West and Central Africa. *PLoS ONE*, **11**(10). https://doi.org/10.1371/journal.pone.0165632

Gupta, A., Babu, S. R., and Kumar, M. S. 2019. Cotesia ruficrus (Haliday, 1834) (Hymenoptera: Braconidae) emerging as a common natural parasitoid of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) in Indian maize fields. *J Biol Control*, **33**(3): 193-196. https://doi.org/10.18311/jbc/2019/24118

Gupta, A., Babu, S.R., and Kumar, M.S. 2019. *Cotesia ruficrus* (Haliday, 1834) (Hymenoptera: Braconidae) emerging as a common natural parasitoid of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) in Indian maize fields. *Journal of Biological Control,* **33**(3): 193-196. https://doi.org/10.18311/jbc/2019/24118

Gupta, A., Lalitha, Y., Varshney, R., Shylesha, A.N., and van Achterberg, C. 2020a. *Chelonus formosanus* Sonan (Hymenoptera: Braconidae) an egg-larval parasitoid of the invasive pest *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) amenable to laboratory mass production in India. *J Entomol Zool Stud*, **8**(1): 1521-1524.

Gupta, A., Soujanya, P. L., van Achterberg, C., and Sekhar, J. C. 2020b. *Coccygidium transcaspicum* (Kokujev) (Hymenoptera: Braconidae) parasitizing larvae of invasive pest *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) in India. *Zootaxa*, **4750**(2): 293-297.

Gutiérrez-Ramírez, A., Robles-Bermúdez, A., Cambero-Campos, J., Santillán-Ortega, C., Ortíz-Catón, M., Coronado-Blanco, J.M., and Campos-Figueroa, M. 2015. Parasitoides de *Spodoptera frugiperda* (Lepidoptera: Noctuidae) Encontrados en Nayarit, México, *Southwest Entomol,* **40**(3): 555-564. https://doi.org/10.3958/059.040.0314

Hafez, M., Tawfik, M. F. S., and Ibrahim, A. A. 1980. The immature stages of *Chelonus inanitus* (L.), a parasite of the cotton leafworm, *Spodoptera littoralis* (Boisduval) in Egypt (Hymenoptera: Braconidae). *Dtsch Entomol Z*, **27**(1-3): 29-38. https://doi.org/10.1002/mmnd.19800270104

Heimpel, G. E., and Mills, N. J. 2017. Biological control - ecology and applications. Cambridge University Press, Cambridge. https://doi.org/10.1017/9781139029117

Huber, J. T. 2009. Biodiversity of Hymenoptera 303-323. In: Footit RG, Adler PH (eds), Insect Biodiversity: Science and Society. Wiley-Blackwell, Blackwell Publishing Limited. https://doi.org/10.1002/9781444308211.ch12

Jaraleño-Teniente, J., Lomeli-Flores, J. R., and Rodríguez-Leyva, E. 2020. Egg parasitoids survey of *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) in maize and sorghum in Central Mexico. *Insects*, **11**(3). https://doi.org/10.3390/insects11030157

Jindal, J., Sharma, K. P., Shera, P. S., and Cheema, H. K. 2022. Native parasitoids of fall armyworm *Spodoptera frugiperda* (J.E. Smith) in maize. *Ind J Ent*, **84**(4): 865-867. https://doi.org/10.55446/IJE.2021.72

Jones, D. 1985. Endocrine interaction between host (Lepidoptera) and parasite (Cheloninae: Hymenoptera): Is the host or the parasite in control? *Ann Entomol Soc Am*, **78**(2): 141-148. https://doi.org/10.1093/aesa/78.2.141

Kaeslin, M., Wehrle, I., Grossniklaus-Bürgin, C., Wyler, T., Guggisberg, D., Sehittny, J. C., and Lanzrein, B. 2005. Stage-dependent strategies of host invasion in the egg-larval parasitoid *Chelonus inanitus*. *J Insect Physiol,* **51**(3): 287-296. https://doi.org/10.1016/j.jinsphys.2004.11.015

Keerthi, M. C., Suroshe, S. S., Doddachowdappa, S., Shivakumara, K. T., Mahesha, H. S., Rana, V. S., ... Shakil, N. A. 2023. Bio-intensive tactics for the management of invasive fall armyworm for organic maize production. *Plants,* **12**(3). https://www.mdpi.com/2223-7747/12/3/685

Kenis, M., Benelli, G., Biondi, A., Calatayud, P. A., Day, R., Desneux, N., … Wu, K. 2022. Invasiveness, biology, ecology, and management of the fall armyworm, *Spodoptera frugiperda*. *Entomol Gen*, **43**(2): 187-241. https://doi.org/10.1127/entomologia/2022/1659

Khajeh, N., Rakhshani, E., Barahoel, H., and Armjomandinejad, A. 2020. Taxonomic study of the genus *Chelonus* Panzer (Hymenoptera, Braconidae, Cheloninae) in Sistan region. 21st Iranian Plant Protection Congress.

Kittel, R. N., and Austin, A. D. 2014. Synopsis of Australian chelonine wasps (Hymenoptera: Braconidae: Cheloninae) with description of two new genera. *Aust J Entomol.,* **53**(2): 183-202. http://dx.doi.org/10.1111/aen.12070

Kittel, R. N., Austin, A. D., and Klopfstein, S. 2016. Molecular and morphological phylogenetics of chelonine parasitoid wasps (Hymenoptera: Braconidae), with a critical assessment of divergence time estimations. *Mol Phylogenetics Evol,* **101**: 224-41. https://doi.org/10.1016/j.ympev.2016.05.016

Koffi, D., Kyerematen, R., Eziah, V. Y., Agboka, K., Adom, M., Goergen, G., and Meagher Jr., R. L. 2020. Natural enemies of the fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) in Ghana. *Fla Entomol,* **103**(1): 85-90. https://doi.org/10.1653/024.103.0414

Legner, E. F., and Thompson, S. N. 1977. Effects of the parental host on host selection, reproductive potential, survival, and fecundity of the egg-larval parasitoid, *Chelonus* sp. near *curvimaculatus*, reared on *Pectinophora gossypiella* and *Phthorimaea operculella*. *Entomophaga*, **22**: 75-84. https://doi.org/10.1007/BF02372992

Li, F., Wang, L., Lü, B., Cao, F., Pan, X., Yuan, L., and Wu, S. 2019. The report of *Chelonus munakatae* parasitizing fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in Hainan, China. *Chinese J Biol Control*, **35**(6): 992-996. https://doi.org/10.16409/j.cnki.2095-039x.2019.06.003

Li, T. H., Bueno, A. D. F., Desneux, N., Zhang, L., Wang, Z., Dong, H., Zang, L. S. 2023. Current status of the biological control of the fall armyworm *Spodoptera frugiperda* by egg parasitoids. *J Pest Sci*, **96**: 1345-1363. https://doi.org/10.1007/s10340-023-01639-z

Liu, J. F., Zhao, H. Y., Song, Y. F., Yu, Y. C., and Yang, M. F. 2022. A chromosome-level genome assembly of the parasitic wasp *Chelonus formosanus* Sonan, 1932 (Hymenoptera: Braconidae). *Genome Biol Evol,* **14**(1): 1-6. https://doi.org/10.1093/gbe/evac006

Madl, M., and van Achterberg, C. 2014. A catalogue of the Braconidae (Hymenoptera: Ichneumonoidea) of the Malagasy subregion. Linzer Biologische Beitraege, 46(1): 5-220. https://zenodo.org/records/4507364

McComb, C. W., 1968. A revision of the *Chelonus* subgenus *Microchelonus* in North America, North of Mexico: (Hymenoptera: Braconidae). *Uni Maryland, Agri Experi Stat, Bull,* **A-149**(1967): 1-148.

Mamahit, J. M. E., and Kolondam, B. J. 2023. A review on fall armyworm (*Spodoptera frugiperda*) insecticide resistance. *Int J Res Rev,* **10**(5): 146-151. http://dx.doi.org/10.52403/ijrr.20230519

Mitsch, W. J. 1998. Ecological engineering — The 7-year itch. *Ecol Eng,* **10**(2): 119-138. http://dx.doi.org/10.1016/S0925-8574(98)00009-3

Mitsch, W. J. 2012. What is ecological engineering? *Ecol Eng,* **45**: 5-12. https://doi.org/10.1016/j.ecoleng.2012.04.013

Molina-Ochoa, J., Carpenter, J. E., Heinrichs, E. A., and Foster, J. E. 2003. Parasitoids and parasites of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas and Caribbean Basin: an Inventory. *Fla Entomol,* **86**(3): 254-289. https://doi.org/10.1653/0015-4040(2003)086[0254:PAPOSF]2.0.CO;2

Montezano, D. G., Specht, A., Sosa-Gómez, D. R., Roque-Specht, V. F., Sousa-Silva, J. C., Paula-Moraes, S. V., … Hunt, T. E. 2018. Host plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas. *Afr Ent,* **26**(2): 286-300. https://doi.org/10.4001/003.026.0286

Morgan, A. C., and Crumb, S. E. 1914. The tobacco split worm. Series: *Bull U.S. Depart Agri Washington*, D. C., USA. **59**: 1-7. https://doi.org/10.5962/bhl.title.64426

Nagarkatti, S., and Singh, S. P. 1989. Importation and establishment of new natural enemies of *Heliothis* spp. (Lepidoptera: Noctuidae) into India, In: King EG, Jackson RD (eds), *Proc Workshop on Biol Control Heliothis: Increasing the Effectiveness of Natural Enemies*, Far Eastern Regional Research Office, United States Department of Agriculture, New Delhi, India, 375-385.

Nonveiller, G. 1984. Catalogue des insectes du Cameroun d'intérêt agricole, Belgrad, 1984. *Bull Société Entomol France*, **91**(3-4).

Ngangambe, M. H., and Mwatawala, M. 2020. Effects of Entomopathogenic Fungi (EPFs) and cropping systems on parasitoids of fall armyworm (*Spodoptera frugiperda*) on maize in eastern central, Tanzania. *Bio Sci Tech*, **30**(5): 418-430. https://doi.org/10.1080/09583157.2020.1726878

Otim, M. H., Aropet, S. A., Opio, M., Kanyesigye, D., Opolot, H. N., and Tay, T. W. 2021. Parasitoid distribution and parasitism of the fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in different maize producing regions of Uganda. *Insects*, **12**(2). https://doi.org/10.3390/insects12020121

Özmen, D. 2004. Biological relations between *Chelonus oculator* Panzer (Hymenoptera: Braconidae) and its host *Spodoptera littoralis* (Boisduval) and *Ephestia kuehniella* Zeller and investigation of the effects of Aldicarb on the parasitoid by radioisotope tracer technique [Unpublished doctoral dissertation] Ankara University, Graduate School of Natural and Applied Sciences Department of Plant Protection.

Papp, J. 1995. Revision of C. Wesmael's Chelonus species (Hymenoptera Braconidae Cheloninae). Bull l'Institut Royal Sci Naturelles Belgique, 65: 115-134.

Pair, S. D., and Gross Jr., H. R. 1984. Field mortality of pupae of the fall armyworm, *Spodoptera frugiperda* (J.E. Smith), by predators and a newly discovered parasitoid, *Diapetimorpha introita*. *J Georgia Entomol Soc,* **19**(1): 22-26. https://agris.fao.org/search/en/records/6473620e08fd68d5460483ac

Parrella, M. P., Heinz, K. M., and Nunney, L. 1992. Biological control through augmentative releases of natural enemies: A strategy whose time has come. *Amer Ento,* **38**(3): 172-180. https://doi.org/10.1093/ae/38.3.172

Pawar, A. D., Prasad, J., Asre, R., and Singh, R. 1983. Introduction of exotic parasitoid, *Chelonus blackburni* Cameron in India for the control of cotton bollworms. *Ind J Ent*, **45**: 436-439.

Perier, J. D., Haseeb, M., Kanga, L. H. B., Meagher, R. L., and Legaspi, J. C. 2022. Intraguild Interactions of three biological control agents of the fall armyworm *Spodoptera frugiperda* (JE Smith) in Florida. *Insects*, **13**(9). https://doi.org/10.3390/insects13090815

Plant Health Australia. 2020. Fall armyworm continuity plan for the Australian Grains Industry, Version 1 (November 2020). https://www.planthealthaustralia.com.au/wp-content/uploads/2020/11/Fall-Armwork-Continuity-Plan-2.pdf

Prasanna, B. M., Huesing, J. E., Eddy, R., and Peschke, V. M. 2018. Fall armyworm in Africa: A guide for integrated pest management. CIMMYT, Mexico.

Rao, B. N., and Patel, R. C. 1974. Bionomics of *Chelonus formosanus* Sonan, an egg larval parasite of *Spodoptera litura* (F). *Ind J Ent,* **36**(2): 103-109.

Rechav, Y. 1975. Biological and ecological studies of the parasitoid *Chelonus inanitus* (L.) (Hym.: Braconidae) in Israel. I. Distribution, abundance and parasitism in natural host populations. *Entomoph,* **20**(4): 365-371.

Rechav, Y., and Orion, T. 1975. The development of the immature stages of *Chelonus inanitus*. *Ann Entomol Soc Am,* **68**(3): 457-462. https://doi.org/10.1093/aesa/68.3.457

Rechav. Y. 1978. Biological and ecological studies of the parasitoid *Chelonus inanitus* (L.) (Hym.: Braconidae) in Israel. IV. Oviposition, host preferences, and sex ratio. *Entomoph*, **23**(1): 95-102. https://link.springer.com/article/10.1007/BF02371997

Sagar, D., Suroshe, S. S., Keerthi, M. C., Poorani, J., Gupta, A., and Chandel, R. K. 2022. Native parasitoid complex of the invasive fall armyworm, *Spodoptera frugiperda* (JE Smith) from Northern India. *Int J Trop Insect Sci*, **42**: 2773-2778. https://doi.org/10.1007/s42690-022-00743-4

Seymour, P. R., Roberts, H., and Davis, M. E. 1985. Insects and other invertebrates found in plant material imported into England and Wales, 1984. *Reference Book, Ministry of Agriculture, Fisheries and Food, UK* No. 442/84.

Shankar, G., and Adachi, Y. 2019. First report of the occurrence of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on Ginger (*Zingiber officinale*) in Haveri district, Karnataka. *India J Entomol Zool Stud*, **7**(5): 78-80.

Sharkey, M. J., Janzen, D. H., Hallwachs, W., Chapman, E. G., Smith, M. A., Dapkey, T., … Burns, J. M. 2021. Minimalist revision and description of 403 new species in 11 subfamilies of Costa Rican braconid parasitoid wasps, including host records for 219 species. *ZooKeys,* **1013**: 1-665. https://doi.org/10.3897/zookeys.1013.55600

Sharanabasappa, K. C. M., Poorani, J., Maruthi, M. S., Pavithra, H. B., and Diraviam, J. 2019. Natural enemies of *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), a recent invasive pest on maize in South India. *Fla Entomol*, **102**(3): 619-623. https://doi.org10.1653/024.102.0335

Sharanowski, B. J., Dowling, A. P. G., and Sharkey, M. J. 2011. Molecular phylogenetics of Braconidae (Hymenoptera: Ichneumonoidea), based on multiple nuclear genes, and implications for classification. *Systematic Entomology*, **36**(3): 549-572.

Shaw, M. R., and Huddleston, T. 1991. Classification and biology of braconid wasps (Hymenoptera: Braconidae). *Royal Ent Soc London*, British Museum (Natural History) at The Natural History Museum, London 1-130.

Shaw, S. R. 1997. Subfamily Cheloninae. In: Wharton RA, Marsh PM, Sharkey MJ (eds), Identification Manual of the New World Genera of the Family Braconidae Hymenoptera vol. **1**: 192-201. Washington, DC, USA.

Shen, Z., Zang, Z. -Y., Dai, P., Xu, W., Nkunika, P. O. Y., and Zang, L. S. 2023. Identification of *Chelonus* sp. from Zambia and its performance on different aged eggs of *Spodoptera frugiperda*. *Insects*, **14**(1): 61. https://doi.org/10.3390/insects14010061

Shenefelt, R. D. 1973. Braconidae 6. Cheloninae. In: van Der VJ and Shenefelt RD (eds), *Hymenopterorum Catalogus (nova editio) Pars,* **10**: 813-936.

Shi, M., Chen, X. X., and van Achterberg, C. 2005. Phylogenetic relationships among the Braconidae (Hymenoptera: Ichneumonoidea) inferred from partial 16S rDNA, 28S rDNA D2, 18S rDNA gene sequences, and morphological characters. *Mol Phylogenetics Evol,* **37**(1): 104-116. https://doi.org/10.1016/j.ympev.2005.03.035

Sisay, B., Simiyu, J., Mendesil, E., Likhayo, P., Ayalew, G., Mohamed, S., and Tefera, T. 2019. Fall armyworm, *Spodoptera frugiperda* infestations in East Africa: Assessment of damage and parasitism. *Insects,* **10**(7). https://doi.org/10.3390/insects10070195

Sonan, J. 1932. Notes on some Braconidae and Ichneumonidae from Formosa, with descriptions of 18 new species. *Trans Nat Hist Soc Formosa*, **22**: 66-87.

Sonan, J. 1937. Studies on the tobacco caterpillar, *Prodenia litura* FAB., in Formosa. Gov. Formosa, Centr. Inst., Div. *Agri Bull,* **70**. (In Japanese)

Subramaniam, S. 2022. Identifying potential parasitoids of the fall armyworm, Spodoptera frugiperda, and the risk to Australian horticulture. Final Report to Queensland Department of Agriculture and Fisheries.

Tamil Nadu Agricultural University (TNAU). 2023. Mass production of *Chelonus blackburni.* https://agritech.tnau.ac.in/crop_protection/crop_prot_bio_mass_parasitoids5.html

Tang, Y., and Marsh, P. M. 1994. A taxonomic study of the genus *Ascogaster* in China" (Hymenoptera: Braconidae: Cheloninae). *J Hymenopt Res*, **3**: 279-302.

Tang, P., Wang, Z., …Wu, Q.. 2019. The natural enemies of the fall armyworm *Spodoptera frugiperda* and their application in biological control programs. *Chinese Journal of Applied Entomology,* **56**: 370-381.

Tang, Y., Guo, J., Wang, Q., Tai, H., Cao, Z., He, K. and Wang, Z. 2020. Three larval parasitic wasps of *Spodoptera frugiperda* were found in Dehong prefecture of Yunnan province. *Plant Protection*, **46**: 254–259.

Tendeng, E., Labou, B., Diatte, M., Djiba, S., and Diarra, K. 2019. The fall armyworm *Spodoptera frugiperda* (JE Smith), a new pest of maize in Africa: Biology and first native natural enemies detected. *Internat J Biol Chem Sci*, **13**(2): 1011-1026. https://doi.org/10.4314/ijbcs.v13i2.35

Trisyono, Y. A., Suputa-Aryuwandari. V. E. F., Hartaman, M., and Jumari, J. 2019. Occurrence of heavy infestation by the fall armyworm *Spodoptera frugiperda*, a new alien invasive pest, in corn in Lampung Indonesia. *J Perlindun Tanam Indonesia,* **23**(1): 156-160.

Jaraleño-Teniente, J., Lomeli-Flores, J. R., Rodríguez-Leyva, E., Bujanos-Muñiz, R., and Rodríguez-Rodríguez, S. E. 2020. Egg parasitoids survey of *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) in maize and sorghum in Central Mexico. *Insects,* **11**(3). https://doi.org/10.3390/insects11030157

Tobias, V. I. 2000. Subfamily Cheloninae. In: Lehr PA. (ed.), Key to the insects of the Russian Far East, Vol. IV. Neuropteroidea, Mecoptera, Hymenoptera, Vol. IV (pp. 426-571), Dal'nauka, Vladivostok.

Tobias, V. I. 2011. A new subgenus of the genus *Microchelonus* Szépligeti and a new species of the genus *Chelonus* Panzer (Hymenoptera: Braconidae) from Central Asia. *Russ Entomol J,* **20**(3): 327-330.

Valdez, E. M., Joshi, R. C., Rillon, G. S., Donayre, D. K. M., Martin, E. C., dela Cruz, K. B., … Annamalai, S. 2023a. Rice: A new host of fall armyworm *Spodoptera frugiperda* (J.E. Smith) and its strains in the Philippines. *Insect Environ*, **26**(2): 129-36.

Valdez, E. M., Rillon, G. S., Joshi, R. C., dela Cruz, K. B., Donayre, D. K. M., Martin, E. C., … Annamalai, S. 2023b. Fall armyworm, *Spodoptera frugiperda* (J.E. Smith) damage on rice in the Philippines. *Asia Pacific J Sustain Agri, Food Energy,* **11**(2): 37-46.

Valdez, E. M., Joshi, R. C., Rillon, G. S., dela Cruz, K. B., Donayre, D. K. M., Martin, E. C., … Annamalai, S. 2024. Novel records of parasitoids targeting fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), in rice-corn-based cropping systems in the Philippines. *J Biol Control*, **38**(1): 82-86. https://doi.org/10.18311/jbc/2024/36513

van Achterberg, C. 1976. A preliminary key to the subfamilies of the subfamilies of the Braconidae (Hymenoptera). Tijdschrift voor *Entomologie,* **119**: 33-78. https://www.biodiversitylibrary.org/part/66809

van Achterberg, C., and Polaszek, A. 1996. The parasites of cereal stemborers (Lepidoptera: Cossidae, Crambidae, Noctuidae, Pyralidae) in Africa, belong to the family Braconidae (Hymenoptera: Ichneumonoidea). *Zoolog Verhand,* **304**(1): 1-123. https://repository.naturalis.nl/pub/317822

Van den Berg, H., Waage, J. K., and Cock, M. J. W. 1988. Natural enemies of *Helicoverpa armigera* in Africa: A review. CAB Internat.

van Huis, A. 1981. Integrated pest management in the small farmers' maize crop in Nicaragua. Veenman and Zonen, Wageningen, The Netherlands. https://library.wur.nl/WebQuery/wurpubs/74659

van Emden, H. F. 2002. Conservation biological control: From theory to practice. In: Van Driesche R (ed) *Proc 1st Internat Symp Biol Control Arthropods*, United States Depart Agricult Forest Service, Hawaii. USDA Forest Service, Morgantown, WV. 199-208.

van Lenteren, J. C. 2000. A greenhouse without pesticides: Fact or fantasy? *Crop Prot*, **19**: 375-384. https://doi.org/10.1016/S0261-2194(00)00038-7

van Lenteren, J. C., Hale, A., Klapwijk, J. N., van Schelt, J., Steinberg, S. 2003. Guidelines for quality control of commercially produced natural enemies. Quality control and production of biological control agents: theory and testing procedures. CABI Publishing, Wallingford, p. 1-8. https://doi.org/10.1079/9780851996882.0265

Varshney, K. 1999. Taxonomic studies on Indian Cheloninae (Hymenoptera: Braconidae). [Unpublished doctoral dissertation]. Aligarh Muslim University, Aligarh, India.

Watanabe, C. 1937. A contribution to the knowledge of the braconid fauna of the empire of Japan (Hymenoptera). *J Facul Agricul, Hokkaido Imperial University*, **42**(1): 1-188.

Westbrook, J., Fleischer, S., Jairam, S., Meagher, R., and Nagoshi, R. 2019. Multigenerational migration of fall armyworm, a pest insect. *Ecosph*, **10**(11): 12 p. https://doi.org/10.1002/ecs2.2919

Wheeler, G. S., Ashley, T. R., and Andrews, K. L. 1989. Larval parasitoids and pathogens of the fall armyworm in Honduran maize. *Entomoph*, **34**(3): 331-340. https://doi.org/10.1007/bf02372472

Wharton, R. A. 1993. Bionomics of the Braconidae. *Ann Rev Entomol*, **38**: 121-143. https://doi.org/10.1146/annurev.en.38.010193.001005

Wyckhuys, K. A. G., Akutse, K. S., Amalin, D. M., Araj, S. E., Barrera, G., Beltran, M. J. B., Ben Fekih, I., Calatayud, P. A., Cicero, L., Cokola, M. C., Colmenarez, Y. C., Dessauvages, K., Dubois, T., Durocher-Granger, L., Espinel, C., Fallet, P., Fernández-Triana, J. L., Francis, F., Gómez, J., Haddi, K., Harrison, R. D., Haseeb, M., Iwanicki, N. S. A., Jaber, L. R., Khamis, F. M., Legaspi, J. C., Lomeli-Flores, R. J., Lopes, R. B., Lyu, B., Montoya-Lerma, J., Montecalvo, M. P., Polaszek, A., Nguyen, T. D., Nurkomar, I., O'Hara, J. E., Perier, J. D., Ramírez-Romero, R., Sanchez-Garcia, F. J., Robinson-Baker, A. M., Silveira, L. C., Simeon, L., Solter, L. F., Santos-Amaya, O. F., Talamas, E. J., de Souza Tavares, W., Trabanino, R., Turlings, T. C. J., Valicente, F. H., Vásquez, C., Wang, Z., Wengrat, A. P. G. S., Zang, L. S., Zhang, W., Zimba, K. J., Wu, K., Elkahky, M. and Hadi, B. A. R. 2024. Global scientific progress and shortfalls in biological control of the fall armyworm *Spodoptera frugiperda*. *Biol Control*, **191**: 105-460. https://doi.org/10.1016/j.biocontrol.2024.105460

Yadav, D. N. 1980. Studies on the natural enemies of *Heliothis armigera* (Hübner) and its biological control using an egg-parasite, *Trichogramma australicum* Girault (Hymenoptera: Trichogrammatidae). *Gujarat Agricult University Res J,* **6**(1): 62-63. https://eurekamag.com/research/000/991/000991435.php

Yousuf, M. and Ray, P. 2009. Record of *Chelonus* Panzer (Braconidae: Cheloninae) from Central India. *J Biopest*, **2**(2): 145-149. http://www.jbiopest.com/users/lw8/efiles/mohd_yousuf.pdf

Yu, D. S., van Achterberg, C., and Horstmann, K. 2013. Biological and taxonomical information: Ichneumonoidea 2012. *Ottawa (Taxapad Interactive Catalogue),* **304**.

Yu, D. S., van Achterberg, C., and Horstmann, K. 2016. Taxapad 2016. Ichneumonoidea 2015. Database on flash-drive. **304**. https://www.scienceopen.com/document?vid=55b95bf4-66fd-4cea-8b9b-27b4dbefc056

Zang, L. -S., Shen, Z., and Li, T. H. 2022. A method of using rice moth eggs as a factious host for the production of *Chelonus bifoveolatus*. China patent 202210918583.0. Chinese.

Zenner, I., Álvarez, A., and Barreto, S. 2006. Influence of parasitism by *Chelonus insularis* Cresson (Hymenoptera: Braconidae) on the susceptibility of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) to insecticides. *Neotro Entomol,* **35**(6): 818-822.

Zettel, H. 1990. Neue *Phanerotoma* - Arten von pazifischen Inseln (Hym. Braconidae). *Dtsch Entomol Zt*, **37**(1-3) 45-69. https://doi.org/10.1002/mmnd.19900370116

Zhang, H. Y. 2008. Taxonomic study on genus Chelonus Panzer, 1806 (Hymenoptera: Braconidae: Cheloninae) from China [Doctoral dissertation, Zhejiang University].

Zhang, H. Y., Shi, M., He, J. -H., and Chen, X. -X. 2008. New species and records of the subgenus *Microchelonus Szépligeti* (Braconidae: Cheloninae) from China. *Biologia*, **63**(1): 107-112. https://doi.org/10.2478/s11756-008-0001-7

Zhou, J. -J., van Achterberg, K., Tang, P., and Chen, X. -X. 2022. A new subgenus of *Chelonus* Panzer, 1806 (Braconidae: Cheloninae) from China. *Zootaxa*, **5115**(2): 288-294. https://doi.org/10.11646/zootaxa.5115.2.8

Zhou, J. -J., van Achterberg, K., Tang, P., Chen, X. -X.. 2024. A review of the subgenera *Carinichelonus*, *Microchelonus*, *Parachelonus* and *Stylochelonus* of the genus *Chelonus* Panzer (Braconidae: Cheloninae) with descriptions of twenty-one new species from China. *Zootaxa,* **5412**(1): 1-127. https://doi.org/10.11646/zootaxa.5412.1.1