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# Population Trends of Sugarcane Moth Borers and Their Larval Parasitoid, *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) in Growing Sugarcane Plantations

**Tewee Maneerat* and Wiwat Suasa-ard**


## ABSTRACT

Sugarcane moth borers, *Chilo infuscatellus* Snellen, *Chilo sacchariphagus* (Bojer), *Chilo tumidicostalis* (Hampson), *Scirpophaga excerptalis* (Walker), and *Sesamia inferens* (Walker) are important and destructive insect pests attacking sugarcane crops in the sugarcane planting areas in central Thailand. In sugarcane fields, they are controlled by the endoparasitic wasp, *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) which is an effective larval parasitoid of the sugarcane moth borers. In the present investigation, population trends of the sugarcane moth borers and *C. flavipes* were analyzed in four districts of Thailand in three successive years (2009–2011 sugarcane planting seasons). Sugarcane moth borers occurred throughout the studied planting locations. The population trends of the insect pests and their parasitoid, *C. flavipes*, were synchronized early in each planting season when the sugarcane was in the sprout emergence stage, and throughout the end of each season. The sugarcane plants gave rise to fluctuations reminiscent of the parasitism of the parasitoid *C. flavipes*, indicating the phenology of the plant and insect host generating mechanisms, respectively.

**Keywords:** population trends, sugarcane moth borers, natural enemies, *Cotesia flavipes* Cameron

## INTRODUCTION

Planting technology is being applied to sugarcane cropping to increase yields. However, Thai sugarcane farmers are facing problems in cropping practices. One of these is insect pest damage which is a major burden causing yield loss; for example, in Thailand, during the 2007–2010 sugarcane planting seasons, sugarcane moth borers caused considerable economic damage to the Thai sugarcane industry (Suasa-ard *et al.*, 2010). More than 120 species of insect pests have been associated with sugarcane including sap feeding, leaf feeding and stem borers (Suasa-ard and Allsopp, 2000). Among these, sugarcane moth borers are considered to be the dominant insect pests both in damage level and distribution. They belong to five species—four are in the family Crambidae: *Chilo infuscatellus* Snellen, *C. sacchariphagus* (Bojer), *C. tumidicostalis* (Hampson), *Scirpophaga excerptalis* (Walker); and one is in the family Noctuidae: *Sesamia inferens* (Walker) (Lewanich, 1975; Suasa-ard, 1982; Suasa-ard, 2000; Suasa-ard, 2010). Generally sugarcane insect pests present in different phenological cycles of sugarcane (Suasa-ard *et al.*, 2009; Cheavegatti-Gianotto *et al.*, 2011). The larvae bore into either the shoots

Department of Entomology, Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, Kamphaeng Saen campus, Nakhon Pathom 73140, Thailand.
* Corresponding author, e-mail: teweem27@gmail.com
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or stalks of sugarcane depending on the borer species, producing severe economic loss to both the quantity and quality of the sugarcane (Sallam *et al*., 2010; Goebel *et al*., 2011). Effective control measures of these insect pests are being sought.

Nonetheless, most sugarcane farmers conventionally apply insecticides to control these insect pests. Although, adverse side effects usually exist and sustainable control of the insect pests cannot be achieved, the famers continuously and indiscriminately use this practice because of the convenience of application. Moreover, the target insect pests develop insecticide resistance to the chemicals. Chemical treatments, for long term use, are generally ineffective and expensive. Considering the longer term viewpoint with regard to environmental preservation and biodiversity conservation, biological control represents an acceptable preference (Goebel *et al*., 2010). Applications of parasitoids, insect predators and entomopathogenic microorganisms have been administered to control sugarcane insect pests in various countries, including Thailand (Fuchs *et al*., 1967; Gifford and Mann, 1979; Mohyuddin, 1991; Katrina *et al*., 2000; Sétamou *et al.,* 2002; Suasa-ard *et al*., 2008; Nadeem and Hamed, 2011).

The koinobion larval parasitoid *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae) which attacks medium and large-sized larvae of gramineous stem borers in several countries in Asia (Overholt and Smith, 1990; Ngi-Song *et al*., 1995), has been used to accomplish biological control of sugarcane borers (Alam *et al.,* 1971; Mohyuddin, 1991; Suasa-ard and Charernsom, 1992) such as *C. partellus* (Swinhoe) (Lepidoptera: Crambidae) in Kenya (Jiang *et al*., 2004); *Diatraea saccharalis* Fabricius (Lepidoptera: Crambidae) in Florida, USA (Gifford and Mann, 1967), Texas, USA (Fuchs *et al*., 1979) and Mexico (Mahmoud *et al*., 2011); and *Diatraea* grandiosella Dyarand and Ostrinia nubilalis Hübner (Lepidoptera: Crambidae) in Illinois, USA (Alleyne and Wiedenmann, 2001). In Thailand, this parasitoid species is considered to be one of the most effective parasitoids for biological control of sugarcane moth borers (Suasa-ard and Charernsom, 1999; Suasa-ard and Permniyomkit, 2000; Suasa-ard *et al.*, 2006; Suasa-ard, 2010). For the standpoint of a biological control strategy, gaining a perspective of the ecology, in particular population trends of insect pests and their natural enemies, is a prerequisite.

In spite of the number of pesticide applications, the cryptic habit of the damaging larvae protects them from the toxic effect of insecticides. Further an understanding of the host plant, the insect host and parasitoid relationships is one of the key components for the augmentative biological control approach with regard to sugarcane moth borers. Additionally, there has been inadequate reporting in the Thai literature on this subject; all reports are from other countries (Botelho *et al*., 1980; Van Hamburg and Hassell, 1984; Tanwar and Varma, 2002; Khan *et al*., 2013; Muhammad *et al*., 2014). Hence, this research aimed to explore the population trends of sugarcane moth borers and their larval parasitoid *C. flavipes* in large scale sugarcane planting regions in three successive years (2009–2011 sugarcane planting seasons).

## MATERIALS AND METHODS

### Study sites

Sugarcane planting areas were sampled in four districts in four provinces from the central region of Thailand: Tha Muang district in Kanchanaburi (14º0′12″N 99º33′0″E), U-Thong district in Suphanburi (14º22′32″N 99º53′32″E), Kamphaeng Saen district in Nakhon Pathom (13º59′2″N 99º59′38″E) and Takhli district in Nakhon Sawan (15º42′48″N 100º08′07″E). Each study plot covered at least 1.6 ha. This study lasted over three years (2009–2011) covering three sugarcane planting seasons. The variety of sugarcane planted in the experimental trials was LK 92-11.

**Sampling scheme**

The incidence of sugarcane moth borer larvae and *C. flavipes*, was determined using systematic sampling with a random start. Initially, samples of populations of the sugarcane moth borers larvae were taken after bud sprouting and rooting (sugarcane seedlings aged 1 mth), with 100 samples per plot (1.6 ha), 10 stools per row and 10 rows per plot taken in each sampling. The sampling unit assigned was one stool per sample. Data on the number of sugarcane moth borer larvae and cocoons of *C. flavipes* were recorded monthly until the sugarcane was harvested at approximately 9 mth.

**Collections of samples of sugarcane moth borers and *C. flavipes***

Samples of infested sugarcane stalk were assembled from fields, placed in synthetic containers and later transferred to laboratory of the National Biological Control Research Center, Central Regional Center (NBCRC, CRC). The sample stalks were cut off with a sharp knife. The numbers of sugarcane moth borer larvae were recorded and were held in a cylindrical box, 21.5 cm in diameter and 10.5 cm in height; with a lid covered with polyester gauze for ventilation. The collected larvae were fed with pieces of young sugarcane stalk. Subsequently, the parasitoid larvae developed inside the sugarcane moth borer larvae, emerged and became cocoons, and were then gathered on a plate, 5.5 cm in diameter and 1 cm in height. The old stalks, provided as the food source for the developing larvae were replaced with new stalks every 3 d.

**Identification of specimens**

The specimen identification was carried out under the stereoscopic binocular microscope and the samples of the identified insects were deposited in the collection of the NBCRC, CRC, Kamphaeng Saen, Nakhon Pathom province, Thailand. The major characteristics applied to identify the larvae of sugarcane moth borers and the adults of *C. flavipes* followed the descriptions given by Butani (1956) and Suasa-ard (1982), respectively. Later confirmation of the insect species was carried out by Associate Professor Dr. Kosol Charernsom a taxonomic entomologist in the Department of Entomology, Kasetsart University.

**Statistical analysis**

The collected data on sugarcane moth borer larvae and the cocoons of the larval parasitoid, *C. flavipes* covered a wide range and so data transformation using log (N+1) was undertaken (Fletcher *et al.*, 2005) before implementation of the graphical work to determine the population trends.

## RESULTS

**Population trends of sugarcane moth borers and the larval parasitoid, *C. flavipes***

Population trend data in the first crop (new stalk crop, 2009) and the second crop (first ratoon crop, 2010) were recorded during February to September 2009 and 2010. However, data on the third crop (second ratoon crop, 2011) were initially recorded in March 2011, rather than in February as in 2009 and 2010, because of the delayed harvest due primarily to the mega flooding that occurred from November 2011 to January 2012 on the central plain of Thailand including the experimental areas.

In the 2009 cropping season, at the sampling site in Kamphaeng Saen district, Nakhon Pathom province (Figure 1), after the emergence of sprout sugarcane, the population of the sugarcane borers surged abruptly in March (tillering initiation stage). Afterwards, the population oscillated slightly throughout the cropping season. Similarly the population of *C. flavipes,* at the beginning of the planting season also increased considerably in parallel with its host populations. Nevertheless, the peaks of the population of the parasitoids were bimodal. The first peak was in April–May and the second peak was in July–August.

Analyses of the data of both the borers and the parasitoids in the 2010 and 2011 cropping seasons at the Kamphaeng Saen district, Nakhon Pathom province sampling site indicated similar results to the 2009 cropping season.

Interestingly, the other cropping seasons (2009–2011) and sampling site locations—U-Thong district, Suphanburi province (Figure 2a); Tha Muang district, Kanchanaburi province (Figure 2b); and Takhli district, Nakhon Sawan province (Figure 2c)—exhibited similar outcomes. Additionally the average populations of both the borers and the larval parasitoid at the four sampling locations in the 3 yr period also were comparable (Figure 2d) with the 2009–2011cropping seasons at the Kamphaeng Saen district, Nakhon Pathom province sampling sites (Figures 1 and 2).

## DISCUSSION

The fact that all the cropping seasons and locations studied presented similar population trends of sugarcane moth borers and their parasitoid might have been due to the availability of oviposition and food sources for the hatching larvae (Figures 1 and 2). The adults moths started to lay their eggs as soon as bud sprouting and rooting commenced on the sugarcane plants. Generally the eggs of the moths took 7–9 d to hatch. This simply synchronized with the phenology of the plant. The effects of host plant phenology impact the development and dissemination of insect species (Bale *et al.*, 2002; Karuppaiah and Sujayanad, 2012). The findings of the current study revealed that the fluctuations in the population density of these borers was dependent upon the phenology of the sugarcane which were similar to those reported on *C. flavipes* that had parasitized *C. infuscatellus* (Khan *et al.*, 2013; Muhammad *et al.*, 2014), and *D. saccharalis* (Rossi and Fowler, 2002). The population of *C. flavipes* developed as a numerical response to the population of sugarcane moth borers in the field (Price, 1975). To some extent, the larval parasitoid, *C. flavipes,* was able to regulate the moth borer population.

The up-down cycle in the population of the insect host (the sugarcane moth borer) was reliant upon the phenology of the host plant (the sugarcane) being damaged and the insect host influenced the number of parasitoids (*C. flavipes*), unmasking the tritrophic level of plant-insect-parasitoid interactions (Leutourneau, 1988).

A number of studies have addressed the attraction of the parasitoid to its insect host in a tritrophic system (for example, Dicke, 1994; De Moraes *et al*., 1998; Prütz *et al*., 2004; Colazz *et al*., 2004; Gross *et al.,* 2005; Cappuccino, 2008; Erb *et al*., 2010; Büchel *et al*., 2011). One of the main factors was the volatile compounds that arouse the parasitoids. Examining plant-insect and host-parasitoid interactions in tritrophic interactions has been of considerable interest (Dicke, 1994; De Moraes *et al*., 1998). The presence of the larval parasitoid, *C. flavipes* in this study might be due to the volatile compounds released by the sugarcane plant (after the emergence of the stalk in the bud sprouting and rooting stage and it being damaged by the moth borers) which incited the oviposition of the larval parasitoid, *C. flavipes*.

Some experiments have been conducted to scrutinize these relationships. The egg parasitoid, *Trissolcus basalis* (Wollaston) (Hymenoptera: Scelionidae) responded to the volatiles emitted by leguminous plants induced by the feeding and oviposition activity of the green stink bug, *Nezara viridula* (L.) (Heteroptera: Pentatomidae) (Colazz *et al*., 2004). Erb *et al.* (2010) pointed out that herbivore-infested plants emitted volatile compounds that were very attractive to parasitoids; their findings also revealed that the parasitoid *Cotesia margniventris* (Cresson) (Hymenoptera: Braconidae) strongly preferred the volatiles of plants infested with its host *Spodoptera littoralis* (Boisduval). Furthermore, the study of Büchel *et al*. (2011) indicated that not only the feeding injury on elm made by the insect herbivore, the elm leaf beetle *Xanthogaleruca luteola* (Müller)

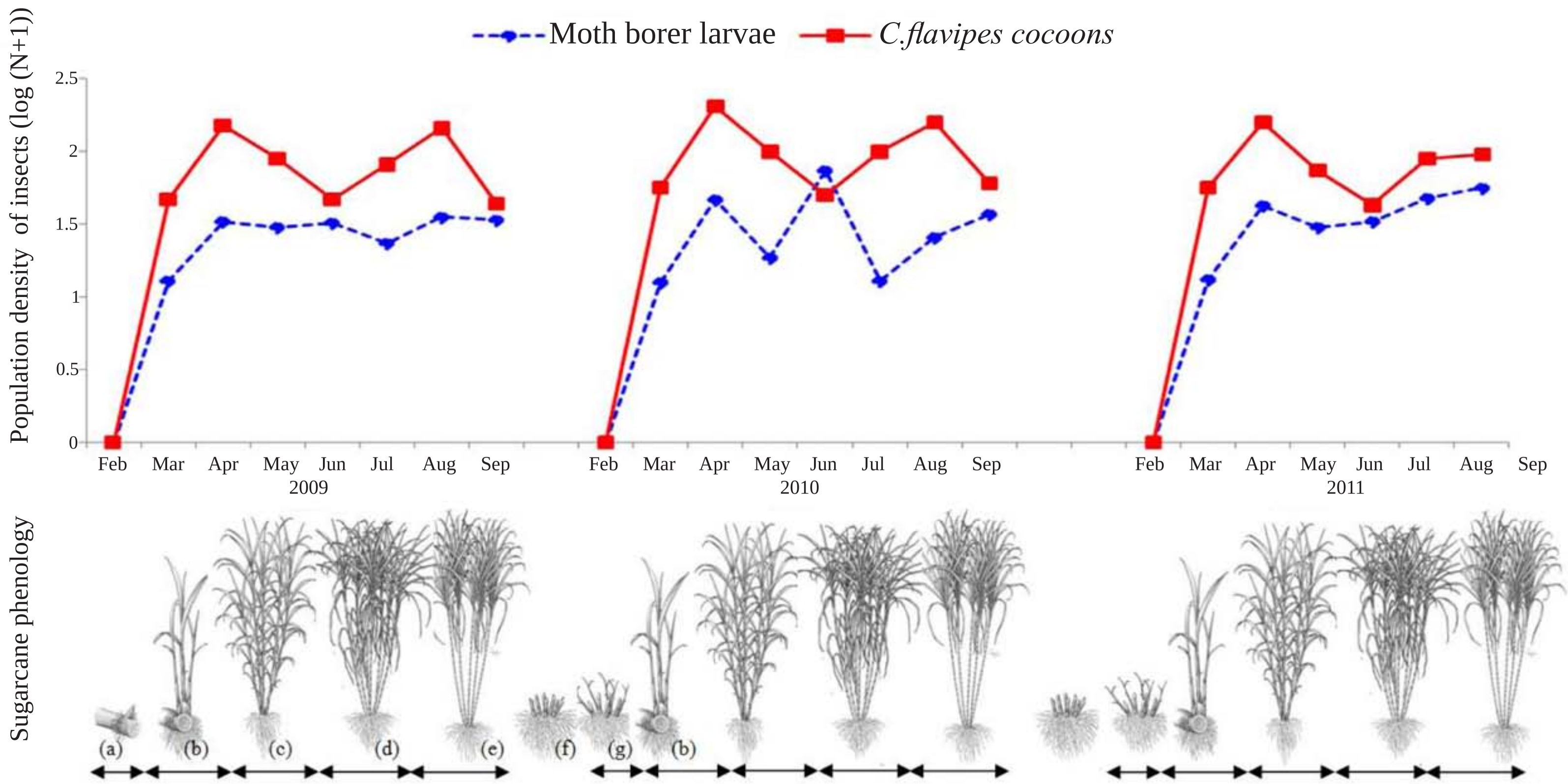


**Figure 1** Population densities of sugarcane moth borers and the larval parasitoid, *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) in sugarcane fields in Kamphaeng Saen district, Nakhon Pathom province during February 2009 to September 2011: (a) Beginning of bud sprouting and rooting; (b) Tillering initiation; (c) Intense tillering; (d) Beginning of maturation; (e) Manufacturable stalks with optimal sucrose concentration; (f) Harvesting; (g) Ratoon sprouting. (Modified from: Cheavegatti-Gianotto *et al.*, 2011).

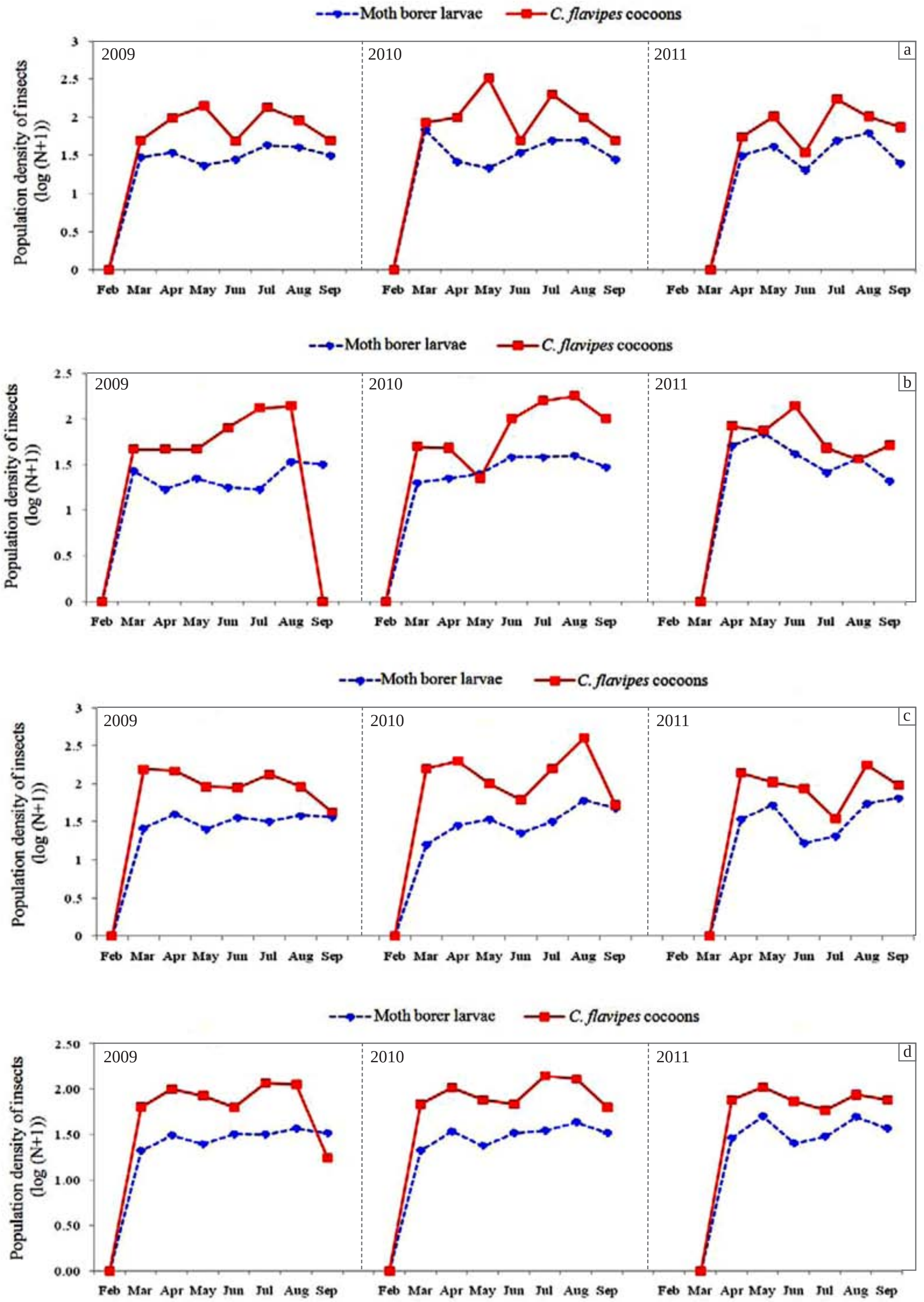


**Figure 2** Population densities of sugarcane moth borers and the larval parasitoid, *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) in sugarcane fields at: (a) U-Thong district in Suphanburi province (b) Tha Muang district in Kanchanaburi province (c) Takhli district in Nakhon Sawan province and (d) Average population of insects at all four locations from February 2009 to September 2011. (See sugarcane phenology in Figure 1.)

(Coleoptera: Chrysomelidae), but also the leaf beetle egg deposition which also made a wound, were able to release volatile compounds that attracted the eulophid parasitoid, *Oomyzus gallerucae* (Fonscolombe) (Hymenoptera: Eulophidae). Hence, it is possible that after the sugarcane borers laid their eggs on the sugarcane which also caused some wounding, this may have emitted some volatile compounds to attract the larval parasitoid *C. flavipes* to lay eggs on the larvae of its host as soon as they emerged on the sugarcane plants.

## CONCLUSION

The results of the research highlighted the field population trends of sugarcane moth borer larvae and their natural enemy, *C. flavipes*, in four provinces and three consecutive planting seasons (consisting of the new stalk crop in 2009, the first ratoon crop in 2010 and the second ratoon crop in 2011). Plant phenology might be a crucial factor affecting the populations of sugarcane moth borers and the parasite. The larval parasitoid *C. flavipes* appeared to regulate the sugarcane moth borer population in the field, which suggested there is good scope for it to augment the biological control of sugarcane moth borers.

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## LITERATURE CITED

Alam, M.M., F.D. Bennett and K.P. Carl. 1971. Biological control of *Diatraea saccharalis* (F.) in Barbados by *Apanteles flavipes* Cam. and *Lixophaga diatraeae*. **Entomophaga** 16: 151–158.

Alleyne, M. and R.N. Wiedenmann. 2001. Encapsulation and hemocyte numbers in three lepidopteran stemborers parasitized by *Cotesia flavipes* complex endoparasitoids. **Entomol. Exp. Appl.** 100: 279–293.

Bale, J., G. Masters, I. Hodkinson, C. Awmack, T.M. Jnbezemer, V.K. Brown, J. Butterfield, A. Buse, J.C. Coulson, J. Farrar, J.G. Good, R. Harrington, S. Hartley, T.H. Jones, L. Lindroth, M.C. Press, I. Mrnioudis, A. Wall and A. Whittaker. 2002. Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. **J. Glob. Change Biol.** 8: 1–16.

Botelho, P.S.M., N. Macedo and A.C. Mendes. 1980. Aspects of the population dynamics of *Apanteles flavipes* (Cameron) and support capacity of its host *Diatraea saccharalis* (Fabr). *In* **Proceedings of the Congress of the International Society of Sugarcane Technology**, 1–11 February 1980. Manila, the Philippines.

Büchel, K., S. Malskies, M. Mayer, T.M. Fenning, J. Gershenzon, M. Hilker and T. Meiners. 2011. How plants give early herbivore alert: Volatile terpenoids attract parasitoids to egg-infested elms. **Basic Appl. Ecol.** 12: 403–412.

Butani, D.K. 1956. A key for the identification of sugarcane borers. **Indian J. Entomol.** 18: 303–304.

Cappuccino, N. 2008. Adjacent trophic-level effects on spatial density dependence in a herbivore-predator-parasitoid system. **Ecol. Entomol.** 17: 105–108.

Cheavegatti-Gianotto, A., H.M. Couto de Abreu, P. Arruda, J.C.B. Filho, W.L. Burnquist,

S. Creste, L. di Ciero, J.A. Ferro, A.V. de Oliveira Figueira, T. de Sousa Filgueiras, M. de Fatima, E.C. Guzzo, H.P. Hoffmann, M.G. de Andrade Landell, N. Macedo, S. Matsuoka, F. de Castro Reinach, E. Romano, W.J. da Silva, M. de Castro Silva Filho and E.C. Ulian. 2011. Sugarcane (*Saccharum officinarum*): A reference study for the regulation of genetically modified cultivars in Brazil. **Trop. Plant Biol.** 4: 62–89.

Colazz, S., A. Fucarino, E. Peri1, G. Salerno, E. Conti and F. Bin. 2004. Insect oviposition induces volatile emission in herbaceous plants that attracts egg parasitoids. **J. Exp. Biol.** 207: 47–53.

De Moraes, C.M., W.J. Lewis, P.W. Pare, H.T. Alborn and J.H. Tumlinson. 1998. Herbivore-infested plants selectively attract parasitoids. **Nature** 393: 570–573.

Dicke, M. 1994. Local and systemic production of volatile herbivore-induced terpenoids: Their role in plant carnivore mutualism. **J. Plant Physiol.** 143: 465–472.

Erb, M., N. Foresti and T.C. Turlings. 2010. A tritrophic signal that attracts parasitoids to host damaged plants withstands disruption by non-host herbivore. **BMC Plant Biology** 10: 247.

Fletcher, D., D. Mackenzie and E. Villouta. 2005. Modelling skewed data with many zeros: A simple approach combining ordinary and logistic regression. **Environ. Ecol. Stat.** 12: 45–54.

Fuchs, T.W., F.R. Huffman and J.W. Jr. Smith. 1979. Introduction and establishment of *Apanteles flavipes* (Hym.: Braconidae) on *Diatraea saccharalis* (Lep.: Pyralidae) in Texas. **Entomophaga** 24: 109–114.

Gifford, J.R., and G.A. Mann. 1967. Biology, rearing and a trial release of *Apanteles flavipes* in the Florida everglades to control the sugarcane borer. **J. Econ. Entomol.** 60: 44–47.

Goebel, F.R., E. Achadian, A. Kristini, M. Sochib, and H. Adi. 2011. Investigation of crop losses due to moth borers in Indonesia. **Proc. Aus. Soc. Sugar Cane Technol.** 33: 9.

Goebel, F.R., E. Roux, M. Marquier, J. Frandon, H. Do ThiKhanh and E. Tabone. 2010. Biocontrol of *Chilo sacchariphagus* (Lepidoptera: Crambidae) a key pest of sugarcane: Lessons from the past and future prospects. **Sugar Cane International** 28: 128–132.

Gross, P., B.A. Hawkins, H.V. Cornell and B. Hosmane. 2005. Using lower trophic level factors to predict outcomes in classical biological control of insect pests. **Basic Appl. Ecol.** 6: 571–578.

Jiang, N., M. Sétamou, A.J. Ngi-Song and C.O. Omwega. 2004. Performance of *Cotesia flavipes* (Hymenoptera: Braconidae) in parasitizing *Chilo partellus* (Lepidoptera: Crambidae) as affected by temperature and host stage. **Biol. Control** 3: 155–164.

Karuppaiah V. and G.K. Sujayanad. 2012. Impact of climate change on population dynamics of insect pests. **World J. Agric. Sci.** 8: 240–246.

Katrina J.D.,G. Leslieand, J.A. Thomson. 2000. Biocontrol of the sugarcane borer *Eldana saccharina* by expression of the *Bacillus thuringiensis cry1Ac7* and *Serratia marcescenschi A* genes in sugarcane-associated bacteria. **Appl. Environ. Microbiol.** 66: 2804–2810.

Khan, M., R. Sultana, B. A. Bughio, A. Ali, B. K. Solangi and S. Kumar. 2013. Studies on the population dynamics of sugarcane stem borer, *Chilo infuscatellus* (Lepidoptera: Pyralidae) and its parasitoid *Cotesia flavipes* (Hymenoptera: Braconidae) in sugarcane in Hyderabad Region of Sindh. **Sindh Univ. Res. J. (Science Series).** 45: 542–545.

Leutourneau, D.K. 1988. Part III Theory and mechanisms: Plant effects via allelochemicals on the third trophic level. **Novel Aspects of Insect-Plant Interactions.** A Wiley-

Interscience Publication. Hoboken, NJ, USA.

Lewanich, A. 1975. The study on taxonomy of lepidopterous pest of sugarcane insect pest. **The Reported Study Assessment Analysis of Sugarcane.** Division of Entomology and Zoology. Bangkok, Thailand. p. 159–200.

Mahmoud, A.M.A., E.J de Luna-Santillana and M.A. Rodríguez-Perez. 2011. Parasitism by the endoparasitoid, *Cotesia flavipes* induces cellular immune suppression and enhances susceptibility of the sugar cane borer, *Diatraea saccharalis* to *Bacillus thuringiensis*. **J. Insect Sci.** 11: 119 (available online: insectscience.org/11.119).

Mohyuddin, A.I. 1991. Utilization of natural enemies for the control of insect pests of sugarcane. **Insect Sci. Appl. J.** 12: 19–26.

Muhammad, R., Q. Ahmed, N. Ahmad, M.M. Shah and N. Depar. 2014. Varietal responses on the population dynamics of sugarcane stem borer and its parasitoids. **Acc. J. Agric. Res.** 2: 087–092.

Nadeem, S. and M. Hamed. 2011. Biological control of sugarcane borers with inundative release of *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae) in farmer fields. **J. Agri. Sci. Technol.** 48: 71–74.

Ngi-Song, A.J., W.A. Overholt, and J. N. Ayertey, 1995. Suitability of African graminaceous stemborers for the development of *Cotesia flavipes* and *Cotesia sessamiae* (Hymenoptera: Braconidae). **Environ. Entomol.** 24: 972–984.

Overholt, W.A. and J.W. Smith. 1990. Comparative evaluation of three exotic insect parasites (Hymenoptera: Braconidae) against the southwestern corn borer (Lepidoptera: Pyralidae) in corn. **Environ. Entomol.** 19: 1155–1162.

Price, P.W. 1975. **Insect Ecology.** A Wiley-Interscience Publication. Hoboken, NJ, USA.

Prütz, G., A. Brink and K. Dettner. 2004. Transgenic insect-resistant corn effects the fourth trophic level: effects of *Bacillus thuringiensis*-corn on the facultative hyperparasitoid *Tetrastichus howardi*. **Naturwissenschaften** 91: 451–454.

Rossi, M.N. and H.G. Fowler. 2002. Manipulation of fire ant density, *Solenopsis* spp., for short-term reduction of *Diatraea saccharalis* larval densities in Brazil. **Sci. Agric.** 59: 389–392.

Sallam, N., E. Achadian, A. Kristini, M. Sochib and H. Adi. 2010. Monitoring sugarcane moth borers in Indonesia: Towards better preparedness for exotic incursions. **Proc. Aus. Soc. Sugar Cane Technol.** 32: 181–192, 11–14 May 2010. Bundaberg, QLD, Australia.

Sétamou, M., J.S. Bernal, J.C. Legaspi and T.E. Mirkov. 2002. Parasitism and location of sugarcane borer (Lepidoptera: Pyralidae) by *Cotesia flavipes* (Hymenoptera: Braconidae) on transgenic and conventional sugarcane. **Environ. Entomol.** 31: 1219-1225.

Suasa-ard, W. 1982. **Ecology of Sugarcane Moth Borers and Their Parasites in Thailand.** Ph.D. dissertation, Kasetsart University. Bangkok, Thailand.

Suasa-ard, W. 2000. *Chilo tumidicostalis* (Hampson) (Lepidoptera: Pyralidae) and its natural enemies in Thailand. Sugarcane Pest Management in the New Millennium, *In* **Proceedings of the IV ISSCT Sugarcane Entomology Workshop,** 7–10 February 2000. Khon Kaen, Thailand.

Suasa-ard, W. 2010. Natural enemies of important insect pests of field crops and utilization as biological control agents in Thailand. *In* **Proceedings of International Seminar on Enhancement of Functional Biodiversity Relevant to Sustainable Food Production in ASPAC**, 9–11 November 2010. Tsukuba, Japan.

Suasa-ard, W. and J. Permniyomkit. 2000. Mass-rearing of *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae), pp. 18–25. *In* **Proceedings of the IV ISSCT Sugarcane Entomology Workshop**, 7–10 February 2000. Khon Kaen, Thailand.

Suasa-ard, W. and K. Charernsom. 1992. Natural enemy complex of sugarcane moth borers in Thailand. *In* **Proceedings of XXI ISSCT Congress**, 5–14 March 1992. Bangkok, Thailand.

Suasa-ard, W. and K. Charernsom. 1999. Success of *Cotesia flavipes* (Cameron) for biological control of sugarcane moth borers in Thailand, pp. 559–568. *In* **Proceedings of XXIII ISSCT Congress**, 22–26 February 1999. New Delhi, India.

Suasa-ard, W. and P.G. Allsopp. 2000. Sugarcane pest management strategies in the New Millennium. *In* **Proceedings of the IV ISSCT Sugarcane Entomology Workshop**, 7–10 February 2000. Khon Kaen, Thailand.

Suasa-ard, W., K. Charernsom and O. Kernasa. 2006. Ten years of utilizing *Cotesia flavipes* (Cameron) for augmentative biological control of Sugarcane moth borers in Thailand. *In* **Proceedings of the VI ISSCT Entomology Workshop**, 14–20 May 2006. Cairns, QLD, Australia.

Suasa-ard, W., O. Kern-asa and S. Uraichuen. 2009. Diversity of sugarcane stem borers and their natural enemies in Thailand. *In* **Proceedings of the 7th ISSCT Entomology Workshop**, 20–25 April 2009. San Miguel de Tucumán, Argentina.

Suasa-ard, W., P. Sommartya, P. Buchatian, A. Puntongcum and R. Chiangsin. 2008. Effect of *Metarhizium anisopliae* on infection of sugarcane stems borer, *Dorysthenes buqueti* Guerin (Coleoptera: Cerambycidae) in laboratory. *In* **Proceedings of the 46th Kasetsart University Annual Conference, Kasetsart University (Subject: Plants),** 29 January–1 February 2008. Bangkok, Thailand.

Suasa-ard, W., T. Maneerat, P. Wonnarat and O. Kernasa. 2010. Technological development of *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae) for commercial production. *In* **Annual Reports of National Biological Control Research Center 2010**, 1–3 September 2010.Petchaburi, Thailand.

Tanwar, R.K. and A. Varma. 2002. Field trials with *Cotesia flavipes* Cameron against sugarcane borers in sub tropical India. **Sugar Tech.** 4: 153–156.

Van Hamburg, H. and M.P. Hassell. 1984. Density dependence and the augmentative release of egg parasitoids against graminaceous stalk borers. **Ecol. Entomol.** 9: 101–108.