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RESEARCH ARTICLE

Taxonomy of Whiteflies' Natural Enemies in Tamil Nadu Cotton Ecosystem

Sadhana V[1*], Senguttuvan K[1] and Murugan M[1]

[1]Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore 641003.

Corresponding email: sadhanaveeramani@gmail.com

ABSTRACT

Native predators and parasitoids were identified against the invasive whiteflies in the cotton ecosystem. Over the past several decades, its control has been increasingly based on the use of its natural enemies. The natural enemies identified include *Cheilomenes sexmaculata, Chrysoperla carnea, Diadiplosis sp, Orius insidiosus*, two coleopteran beetles, *Cybocephalus nipponicus, Delphastus catalinae* and two species of Aphelinidae parasitoids, *Encarsia guadeloupae* and *Encarsia dispersa*. *E. dispersa* can be distinguished from *E. guadeloupae* by a combination of characters, including body colour, colour of the meso-scutellar suture, antennal segments, tarsal formula, etc. The identification of the predators and parasitoids was determined through taxonomical based on key characters. During the survey, several predators and parasitoids were recorded and maximum parasitism was recorded by *Encarsia guadeloupae* and *Encarsia dispersa* (Hymenoptera: Aphelinidae).

Keywords: *Cotton; Natural enemies; Predators; Parasitoids; Whitefly complex*

INTRODUCTION

Cotton is the world's most important cash crop and commonly known as "white gold". Cotton is grown in more than 70 different countries throughout the world. In India, there are 443 whiteflies split into 64 genera that live on a broad variety of agricultural, horticultural, and forestry crop plants (Sundararaj and Selvaraj, 2017). Among them, some species are economically significant pests. In India, the whitefly has

emerged as a major problem in terms of sucking pests because it is a carrier of the cotton leaf curl virus, which reduces seed cotton yields by up to 92.2 percent (Balakrishnan *et al*., 2009; Singh *et al.*, 2013). There are four species of whiteflies associated with the cotton ecosystem, *viz*., *B. tabaci, A. dispersus, A. rugioperculatus and P. bondari.* The common whitefly, *B. tabaci* Gennadius is an important pest in the agricultural and horticultural ecosystems, causing direct and indirect damage (Jones, 2003). In Greece, it was first identified as a tobacco pest in 1889. Spiralling whitefly, *A. dispersus* Russell is indigenous to the Caribbean islands and Central America which made its way to India, most likely via Sri Lanka. In India, it was the first damage record for cassava in 1993. The rugose spiralling whitefly, *A. rugioperculatus* Martin, is native to Belize and was introduced to coconut palms in Pollachi (Tamil Nadu) and Palakkad (Kerala). The invasive Bondar's Nesting Whitefly (BNW), *P. bondari* Peracchi (Hemiptera: Aleyrodidae), was first recorded in India in 2021 on cotton in Tamil Nadu (Sadhana *et al*., 2021). A total of 48 natural enemies attacking 17 species of aleyrodids were discovered. Previously, all of these whitefly species were identified in southern Anatolia (Ulusoy and Ülgentürk, 2003). The whitefly is reported to have 62 natural enemies in various nations, including eight parasitoids, 53 predators and one fungal pathogen (Mani and Krishnamoorthy, 2002). Predators and parasitoids can help control whitefly infestations. Aphelinids of the genera *Encarsia* sp and *Eretmocerus* sp (Hymenoptera: Aphelinidae) are the most prevalent parasitoids of *B. tabaci* (Polaszek *et al*., 2004). Numerous species from these two genera have been proposed as biocontrol agents for *B. tabaci* (Gennadius) in crops (Goolsby *et al.*, 1998). Various indigenous predators have been observed feeding on *A. rugioperculatus* and *A. dispersus*. *Pseudomallada* sp. (Neuroptera: Chrysopidae), *Cybocephalus* sp. (Coleoptera: Cybocephalidae), *Diadiplosis* sp. (Diptera: Cecidomyiidae), and *Jauravia pallidula* Motschulsky were the most abundant and active predators (Coleoptera: Coccinellidae). Numerous coccinellid predators were also spotted on whitefly-infested bananas and coconuts, including *Cryptolaemus montrouzieri* Mulsant, *Chilocorus nigrita* (F.), *Sasajiscymnus dwipakalpa* (Ghorpade), *Scymnus saciformis* Motschulsky, and Sc*ymnus nubilus* (Ramani *et al*., 2002). According to Elango and Jeyarajan Nelson (2020) one Aphelinid parasitoid, *E. guadeloupae*, as well as three predators, *Mallada desjardinsi*, *Chrysoperla zastrowi sillemi*, and *C. montrouzieri*, were found in large numbers, voraciously feeding on RSW and suppressing the population. The invasive whiteflies, *P. bondari* and *A. rugioperculatus* were first recorded in the cotton crop and the associated parasitoids and predators were recorded. (Sadhana *et al*., 2021). This was identified based on morphological characters in this research paper.

MATERIAL AND METHODS

In the cotton ecosystem, conduct a survey to determine the distribution of the whitefly complex and the presence of its natural enemies. The survey was carried out on the 45th day of the crop stage in cotton from 2020 to 2021 in major cotton-growing districts of Tamil Nadu viz., Coimbatore, Erode, Tiruppur, Perambalur and Thiruchirapalli (112 locations from 5 districts). During the survey in different cotton-growing ecosystems of Tamil Nadu, adults of whiteflies and associated predators were determined by having been observed feeding on the whiteflies. Parasitoids were reared from parasitized nymphs along with immature to adult predators kept for some time on leaf material stored in cages. Generally, the whitefly puparium is transparent yellow in colour. However, parasitized whitefly pupae are identified by their blackish brown colour. Puparia and adults of whitefly were collected separately and observed for the emergence of parasitoids. Percent parasitization was calculated using total parasitization. Adult predators were collected by aspirator and net when observed feeding on whiteflies. Predatory larvae were taken to the laboratory for rearing to adulthood on their prey. When the larvae became adults, they were killed and examined under a Stereozoom Microscope (M205 C) with a Leica DMC 2900 camera and a Phase Contrast Microscope (LEICA DM750) with a Leica DFC295 camera. Finally, predators and parasitoids were collected in vials with 70% alcohol and identified at the biosystematics laboratory, Department of Agricultural Entomology, Tamil Nadu Agricultural University for identification based on a dichotomous key.

RESULTS AND DISCUSSION

Natural enemies associated with whitefly species

In this study, eight natural enemies were found associated with whitefly species among an aleyrodid species. Totally, eight predators and parasitoids were identified in cotton ecosystems, viz., *C. sexmaculata* (Coccinellidae: Colepoptera*), C. carnea* (Chrysopidae: Neuroptera), *Diadiplosis* sp, (Cecidomyiidae: Diptera), *O. insidiosus* (Anthocoridae: Hemiptera), *C.nipponicus* (Cybocephalidae : Coleoptera) *and D. catalinae* (Coccinellidae: Colepoptera) and *E. guadeloupae* and *E. dispersa (Aphelinidae: Hymenoptera)*. Generally, the whitefly puparium is transparent yellow in colour. But parasitized whitefly pupae are identified by their blackish brown colour with a circular exit hole on the last abdominal segments of the whitefly complex, *viz*., *B. tabaci, A. dispersus*, *A. rugioperculatus* and *P. bondari* (Fig 1 a-d). The most commonly found parasitoids are *E. guadeloupae* and *E. dispersa* (Hymenoptera: Aphelinidae). Key characteristics of female E. guadeloupae are as follows: except for the mesoscutum and scutellum side lobes, the body is dark brown; the midlobe is mostly dark brown. The hind coxa and femur are dark brown in colour and the rest of the

legs are light yellow to white. The forewing and the hind wings are hyaline in nature (Selvaraj *et al*., 2016). The coccinellid predator named as C. sexmaculata was commonly found in all cultivated crops except some crops was observed. It has been recorded feeding on *B.tabaci* on the cotton ecosystem (Kapadia and Puri, 1992). Rao *et al*. (1989) in Andhra Pradesh reported that *B. tabaci* was predated by *C. sexmaculata* and *Chrysoperla carnea* were observed in pulses. *Cybocephalus* sp and *Diadiplosis* sp. were the most abundant and active predators (Ramani *et al*., 2002).

Taxonomic identification of predators and parasitoids

Key to the species of the family Aphelinidae parasitoids (Order: Hymenoptera)

1. Dark brown head and gaster, pedicel, Flagellar segment (F1) and F2 usually subequal in length; gaster segments TII – TIV each at least 1+1 setae, usually more.....***Encarsia guadeloupae*** **Viggiani (Fig 2 a-d)**
2. Pale yellow head and gaster; F1 shorter than pedicel and F2, gaster segments TII – TIV each with 1+1 setae .....***Encarsia dispersa*** **Polaszek (Fig 2 a-d)**

Key to the species of family Coccinellidae predator (Order: Coleoptera)

1. Six-spotted zigzag marking on elytra, 3mm in body length, yellow to canary yellow body colour, convexed body, larvae have a mandibulo-suctorial mouth parts and urogomphi present in larvae's last abdominal segment .....***Cheilomenes sexmaculata*** **(Fig 3 a-c)**

Key to the predator species in the family Chrysopidae (Order: Neuroptera)

1. Larval head capsule markings were dominated by a pair of longitudinal, dorso-lateral brown stripes with baso-lateral expansions extending toward the eyes, larvae of full body are lengthwise lines or rows of spots that are light brown, flattened with distinct legs, tubelike mouthparts that curve inwards and pair of pincer-like mandibles .....***Chrysoperla carnea*** **(Fig 4 a-c)**

Key to the predator family Cecidomyiidae (Order: Diptera)

1. Body cylindrical, integument smooth, with the exception of a thin terminal segment,head with elongated antenna, short styliform mandible,spatula absent, six dorsal papillae with long setae present on all thoracic and abdominal segments.....***Diadiplosis*** **sp (Fig 5 a-b)**

Key to the predatory species of family Cybocephalidae (Order: Coleoptera)

1. Adults have a 4-4-4 tarsal formula, body is shiny brown to black with convex and rounded edges, larvae have a head without dorsal sutures, larvae are covered with minute hairs, in the 9th abdominal tergite and there are no urogomphi.....*Cybocephalus nipponicus* (Fig 6 a-b)

2. Adults are very tiny, their bodies are brown to blackish colour and the heads female has a black in colour, while males have an orange head. Larvae are elongated, cream in colour, covered with short fine hairs and have a conspicuous leg.....*Delphastus catalinae* (Fig 6 c-d)

Key to the species of family Anthocoridae predator (Order: Hemiptera)

1. Forewings are hemelytra, they areblack with white patches on the wings, the *wing* membrane is white and the base of the *wings is* brown and mouth parts are pierced.....*Orius insidiosus* (Fig 7 a)

Figure 1 (a-d) Parasitized whitefly pupae on cotton leaves (a) *Bemisia tabaci* parasitized by *Encarsia* sp (b) Parasitized *Paraleyrodes bondari* pupa (c) *Encarsia* sp emerged from *Aleurodicus dispersus* pupa (d) Parasitized *Aleurodicus rugioperculatus* pupae

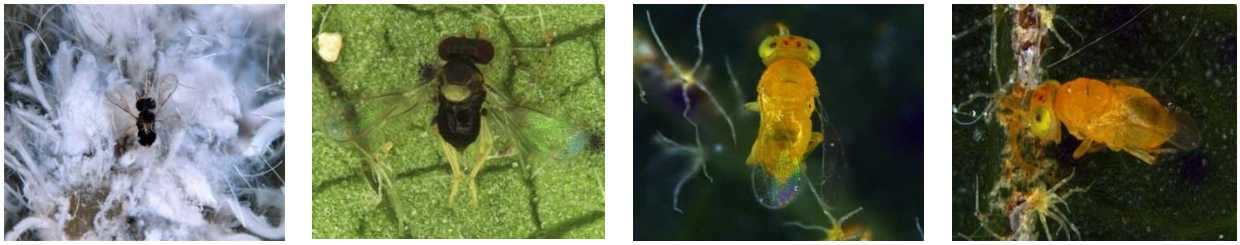

Figure 2 (a-d) Adult stages of *E. guadeloupae* and *E. dispersa*

Figure 3 (a-c) Life cycle of *Cheilomenes sexmaculata* (a) Egg (b) Grub (c) Adult

Figure 4 (a-c) Life cycle of *Chrysoperla carnea* (a) Egg (b) Grub (c) Adult

Figure 5 (a-b) Life cycle of *Diadiplosis* sp. (a) Larva (b) Larva feeding on eggs (c) Pupa

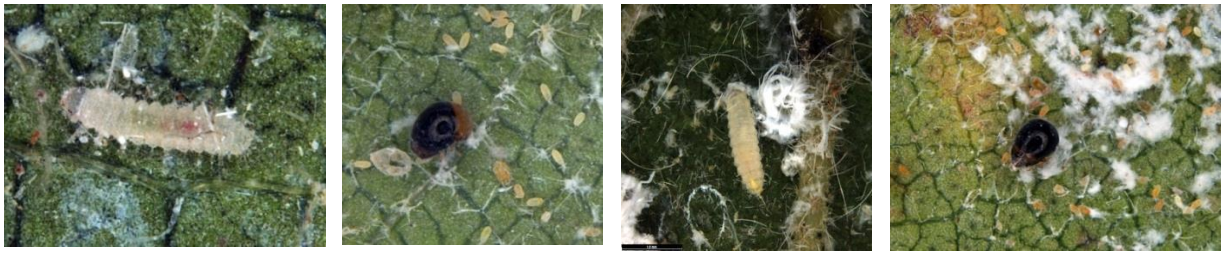

Figure 6 (a-b) Life cycle of *Cybocephalus nipponicus* and (c-d) Life cycle of *Delphastus pusilus*

Figure 7 (a) *Orius insidiosus* feeding on whitefly pupa

CONCLUSION

Encarsia guadeloupae was found to be parasitoida against *A. rugioperculatus* . This was supported by Ramani *et al*. (2002) as a well-known parasitoid of *A. dispersus*. Higher parasitism of *E. guadeloupae* at the rates of 60-92% was recorded on coconut RSW in Bangalore and Thrissur during 1999-2000 and in Minicoy during 2000 (Ramani, 2000). 20-60% parasitism of *A. rugioperculatus* by *E. guadeloupae* on coconut in Tamil Nadu and Kerala (Srinivasan *et al*., 2016) and Parasitisation range of *E. guadeloupae* is 40 to 70% in banana crop ecosystem (Selvaraj *et al*., 2016). Parasitism levels were found to be highly density-dependent and also varied with host plants. In addition, *C. sexmaculata* preferred the nymphs of *B. tabaci* and *A. dispersus*, which were regularly noticed in our study. Atuncha *et al*. (2013) confirm the same research findings. In our study, we observed that *C. carnea* consumed nymphal and adult stages of the whiteflies, as was confirmed by Klien *et al*. (1996). *E. dispersa* has been recorded as a parasitioid against this spiralling whitefly, *A. dispersus* (Poorani and Thanigairaj, 2017; Selvaraj *et al*., 2016). *Cybocephalus* sp. (Coleoptera: Cybocephalidae) and *Diadiplosis* sp. (Diptera: Cecidomyiidae) were found to be the most abundant and active predators on whitefly nymphs in this study. Ramani *et al*. (2002) also observed a similar report, which supports our findings. The whitefly complex, comprising *B. tabaci, A. dispersus, A. rugioperculatus* and *P. bondari* is likely to pose a threat to cotton cultivation in India in the near future due to its widespread and severe incidence in the cotton ecosystem. *Cybocephalus nipponicus* and *Delphastus catalinae* were the predominant predators of *P. bondari. E. guadeloupae* and *E. dispersa* are expected to spread to even more places, resulting in a major decline in the *A. dispersus* and *A. rugioperculatus* populations in India. In order to prevent the further spread of *A. dispersus* and *A. rugioperculatus*. These four natural enemies, *Cheilomenes sexmaculata, Chrysoperla carnea, Diadiplosis sp* and *Orius insidiosus* can be included in the IPM programme for regulating the population of *B. tabaci.*

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Ethics statement

There was no Human Participants and/or Animals included in this research.

Consent for publication

All the authors agreed to publish the content.

Competing interests

The authors, Sadhana V, Senguttuvan K and Murugan M of the research article entitled "Taxonomical Identification of Predators and Parasitoids Associated with Invasive Whitefly Complex on Cotton Ecosystem of Tamil Nadu" declared that they have no conflict of interest in the publication of this content

Author contributions

Experiments - Sadhana V, Writing- reviewing &editing - Senguttuvan K, Guidance - Murugan M

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