Biological Control of Invasive Whiteflies in Coconut: Challenges and the Way Forward

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Coconut, *Cocos nucifera L.* (Arecaceae) is an important plantation crop grown mainly in the tropical and subtropical regions of the world, and millions of people depend on this crop directly or indirectly for their livelihood. India is one of the leaders in coconut farming and the third largest coconut producing country in the world. Coconut is a crop of small and marginal farmers since 98% of about five million coconut holdings in the country are less than two hectares. In the west coast of India, the palm is an essential component in the homestead system of farming.

Coconut is grown in a large area of more than 21.73 lakh hectares in more than 15 states and union territories in India with an annual production of 21,309 million nuts with productivity of 9346 nuts/ha. Among all the coconut producing states, Tamil Nadu, Kerala, Karnataka and Andhra Pradesh are the leading coconut producing states which account for more than 90% of the total coconut produced in the country. Coconut production and productivity was 3281.7 million nuts and 5238 nuts/ha during 1950-51 to 20736.12 million nuts and 9430 nuts/ha during 2020-21. India has been exporting coconut oil to Malaysia, Indonesia and Sri Lanka and dry coconut in large quantities to the U.S and European countries.

The coconut palm is attacked by several insect pests all around the year and more than 900 species of pest are associated with cultivated and wild coconut. Coconut Eriophid mite, *Aceria guerreronis Keifer* (Eriophyidae: Acari), rhinoceros beetle, *Oryctes rhinoceros L* (Coleoptera: Scarabaieidae), red palm weevil, *Rhynchophorus ferrugineus Olivier* (Coleoptera: Curculionidae), black headed caterpillar, *Opisina arenosella Walker* (Lepidoptera: Oecophoridae) and white-grub, *Leucopholis coneophora Burmeister* (Coleoptera: Scarabaieidae) are considered as the major pests of coconut. While the two whiteflies viz., areca nut whitefly, *Aleurocanthus arecae* David and Manjunatha (Hemiptera: Aleyrodidae) and spiraling whitefly, *Aleurodicus dispersus* recorded on coconut in India are considered as minor pests (Josephrajkumar et al., 2012).

Between 2016-2019, the following four exotic whiteflies viz., rugose spiraling whitefly, *Aleurodicus rugioperculatus Martin* during 2016; Bondar's nesting whitefly, *Paraleyrodes bondari Peracchi*, nesting whitefly, P. minei Iaccarino during 2018 and palm infesting whitefly, *Aleurotrachelus atratus Hempel* (Sundararaj et al., 2021) invaded to coconut ecosystem (Fig.1). It was reported that *Aleurodicus rugioperculatus* co-exist with *Aleurotrachalus atratus*, P. bondari, A. dispersus and P. minei on coconut. Infestations of A. atratus and *A. rugioperculatus* along with *Aleurocanthus arecae*, a native whitefly species were commonly observed on coconut. These invasive species are native to the Neotropical region mostly from Central America and the Caribbean. Invasion of these exotic species leads to abrupt outbreaks in several locations due to favourable weather condition and availability of host plants. The most insidious spread are those mediated by humans through infested seedlings.

Invasive species pose constant threat to agriculture and a strategic science based approach is needed to promote environmentally sustainable plant health management practices to reduce excessive reliance on chemical pesticides. Biological control through parasitoids, predators and entomopathogens constitutes a significant component in holistic management of insect pests.

Fig. 1. Invasive whiteflies infesting coconut

Moreover, Agricultural policies in India have emphasized adopting biological control as a component of Integrated Pest Management (IPM) to minimize the indiscriminate and injudicious use of chemical pesticides. Implementation of biological control at the national level not only scaled down the dependence on pesticide usage but also reduced pest-induced losses in the country. In addition to catering to domestic requirements, the research and development on biological control in India have extended global support by providing the natural enemies of Indian origin to be established in other countries for crop pest suppression, thereby becoming a global player in providing clean and green pest management strategies.

The recent advances in artificial intelliance (AI), the internet of things (IOT), Drones and Genome Editing technologies have opened new vistas leading to need based temporal and spatial specific plant protection interventions to ensure minimized usage of synthetic pesticides. Further such approaches fit into SDG and Global one-health goals. Biological control using parasitoids, predators and entomopathogens are the most feasible, efficient, eco-friendly method and alternative to the use of insecticides. Success of any biological control programme depends on their effective and timely application in a systematic way. This can be made possible by creating awareness to farmers, early detection of the pest, frequent monitoring, large scale approach and repeated release of parasitoids.

Biological control of invasive whiteflies

Alarmed by the invasion of these invasive species unknown to them, farmers resorted to spraying of chemical pesticides to control. But the efforts were in vain as the chemicals turned out to be a temporary fix and moreover, other ill effects like environmental pollution, killing of natural enemies, pollinators and other non-target organisms and health risks to the people involved in spraying operations made the insecticide application a risky business apart from being uneconomical.

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Biological control based approach for the management of these invasive whiteflies is an effective and sustainable solution. Explorative surveys were carried out for the biological control of these invasive pests through naturally occurring insect predators and parasitoids which are economically feasible, ecologically compatible and environmentally benign.

Two parasitoids, *Encarsia guadeloupae Viggiani* and *E. dispersa Polaszek* (Hymenoptera: Aphelinidae) on *A. rugioperculatus* and *A. dispersus* and a parasitoid, *Encarsia cubensis* on *A. atratus* (Selvaraj et al., 2017; Selvaraj et al., 2023) were recorded (Fig.2); Predators such as *Apertochrysa* (=Pseudomallada) astur (Neuroptera: Chrysopidae), *Jauravia pallidula, Cheilomenes sexmaculata* (Coleoptera: Coccinellidae) and *Cybocephalus indicus* (Coleoptera: Nitidulidae) were also observed to be feeding on these invasive whitefly species in coconut (Fig.3).

Fig. 3. Predators: a) Apertochrysa astur, b) Cybocephalus indicus, c). Jauravia pallidula

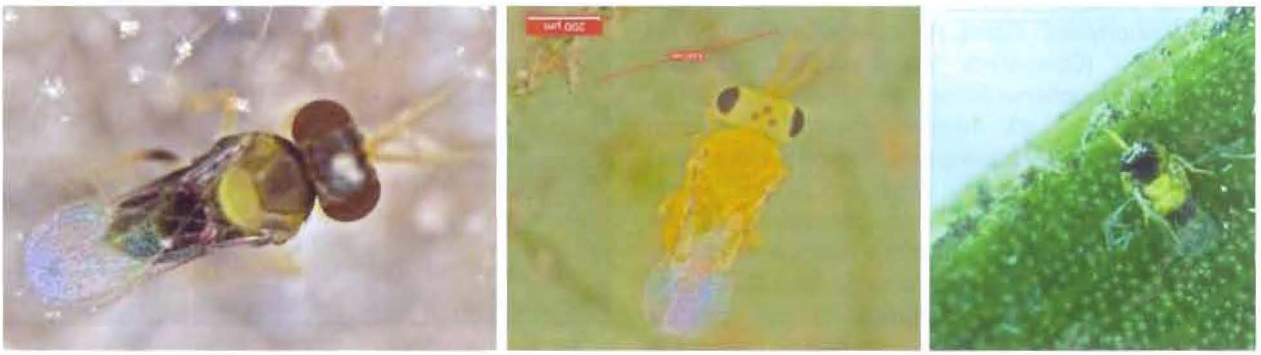

Fig.2 Parasitoids: a) Encarsia guadeloupae, b) Encarsia dispersa, C) Encarsia cubensis

In addition, a species of entomopathogenic fungus, *Isaria fumosorosea* (Hypocreales: Clavicipitaceae) was found to be effective against all the life stages of these invasive whitefly species. *Isaria fumosorosea* is highly pathogenic to the egg and early nymphal instar stage with mortality up to 91% in these stages and up to 80% mortality in the late nymphal instar stages (Fig.4).

Fig.4. Isaria fumosorosea infection on a) A. rugioperculatus, b) A. atratus, c). P. bondari, d) P. minei

Re-distribution/re-introduction of parasitoids: Non-native species can achieve invasive pest status when they are accidentally introduced to areas where they are separated from their potential natural enemies and if local (indigenous) beneficial species (predators and/or parasitoids) are unable to suppress pest population. Moreover, pests mostly disperse during egg stage from infested area to uninfested areas through seedlings results detachement of natural enemies from the host as this parasitoid parasitize on second instar nymphs.

Since natural enemies, particularly *E. guadeloupae* and *E. cubensis* were found to be suppressing the population of *A. rugioperculatus*, *A. dispersus* and *A. atratus*, effectively; farmers and other stakeholders were advised to re-distribute/re-introduce the parasitoids wherever they were absent or found in inadequate numbers by using field insectary techniques such as strategically placing the field collected parasitized nymphs in, on or next to infested vegetation for augmentation (Fig.5).

These redistribution was advocated through a plastic container (35 cm height x 25 cm width) where top and side provide with wire mesh (50-60 micron) which allow to escape parasitoid adults from the container but not whitefly adults (Fig.5). This way, we can avoid the distribution of pests and enhance the *E. guadeloupae* and *E. cubensis* population in the field. Parasitoid, *E. guadeloupae* was introduced accidently to India along with *A. dispersus* in 1990s.

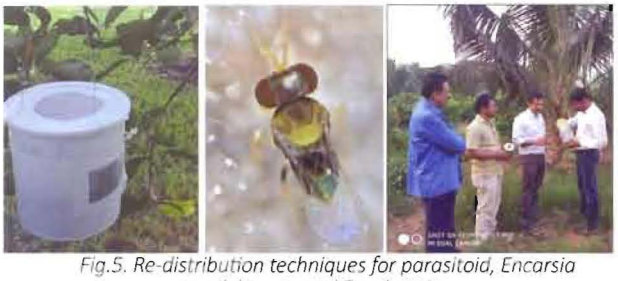

Fig.5. Re-distribution techniques for parasitoid, Encarsia guadeloupae and E. cubensis

Conservation strategies for parasitoids

Conservation biological control is the implementation of farm practices that maintain and enhance the reproduction, survival, and efficacy of natural enemies of pests. Approaches to conservation of these natural enemies involve avoidance of practices harmful to them, as well as adoption of practices that benefit them. Like other animals, insect natural enemies require food, water, and shelter, and protection from adverse conditions. One strategy to improve biological control by resident natural enemies is enhancing habitat diversity through the provision of semi-natural vegetation in or around agricultural field.

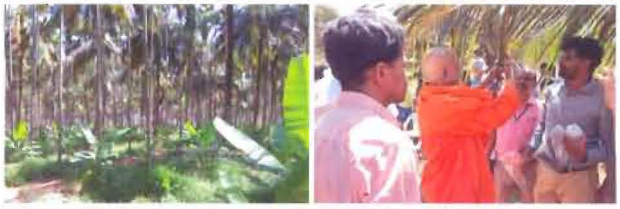

Fig.6. Coconut intercropping with banana (a) and Parasitod releasing technique (b)

During the initial stage of invasion of these pests, few farmers resorted to spraying of chemical pesticides to control but their efforts were in vain as the chemicals turned out to be a temporary fix. The pest resurgence was observed in pesticides sprayed garden. Subsequently, growers advocated not to spray any pesticides for the management of these exotic whiteflies and pesticides holiday declared. In areas where chemicals were not applied, parasitoids population were observed to have multiplied rapidly and natural parasitism increased phenomenally thus preventing severe outbreaks. Therefore, frequent monitoring of the pest occurrence was done so as to conserve the natural enemies.

Banana and *Canna indica* were found to be harbouring maximum parasitoids population at field as well as in net-house condition (Fig. 8). The growers were advised to grow these plants as banker plants in coconut garden as intercrop or border crops for

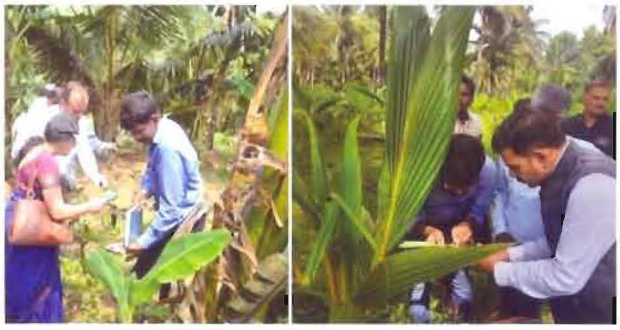

Fig.7. Monitoring of whiteflies and their natural enemies

Fig.8. Canna indica as banker plant for conservation of E. guadeloupae

conservation and augmentation. The main function of these banker plants are the supporting of natural enemies reproduction and therefore the maintenance of their populations. Natural enemies can reproduce such that their numbers increase on alternative hosts or prey on banker plants, and the pests are not found on crops.

ICAR-NBAIR is striving hard to sensitize and popularize the augmentation (re-distribution, inoculative & innudative release) and conservation strategies (pesticide holiday & habitat manipulation, awareness program) for these potential biocontrol agents in collaboration with line departments, Krishi Vigyan Kendras and farmers producing organizations. To popularize these biocontrol technologies among the stakeholders, ICAR-NBAIR is imparting training on mass production protocol for these biocontrol agents against these invasive whiteflies and various augmentative and conservation strategies for these biocontrol agents.

Effect of *Isaria fumosorosea* on invasive whiteflies

ICAR-NBAIR has identified a promising fungal entomopathogenic strain of *Isaria fumosorosea* (ICAR-NBAIR pfu-5) for the management of *A. rugioperculatus, A. atratus, P. minei* and *P. bondari* in coconut. This fungus was found to be very effective with longer shelf life, persistence, host specific to the target insects and self-multiplicative capacity under natural favourable conditions. Once applied, they can grow on the insect surface exponentially and cause rapid killing of target insects.

Based on laboratory bioassays and multi-locational field evaluation, *I. fumosorosea* found to be effective in killing all the life stages of these pests in Andhra Pradesh, Karnataka, Kerala and Tamil Nadu. The eggs and early nymphal instar mortality was up to 91% and the late nymphal instars and pupal mortality was up to 80%. Mass production technology for this fungus has been standardized using solid state fermentation (broken rice grains) and liquid state fermentation technology (Sabouraud dextrose yeast extract broth & Potato dextrose broth media).

Talc, rice grain and oil formulations have been developed with longer shelf life. Due to its high field efficacy there is a huge demand for this fungus from the coconut farming community. Farmers in Andhra Pradesh are regularly trained on farm level production of this fungus using rice grains as a substrate for

Fig.9. Isaria fumosorosea infection on A. rugioperculatus A. eggs, B. Third & fourth instar nymphs

their use in the coconut gardens. Further, studies on standardization of liquid fermentation technology for mass production of *Isaria fumosorosea* is under progress.

Socio-economic impacts of biological control of invasive whiteflies

The impact of biological control was clearly evident in the pest affected coconut gardens after six months after innundative release of parasitoids, *Encarsia guadeloupae* and *E. cubensis* and foliar application of *Isaria fumosorosea.* The release parasitoids

Fig.10. Different formulations of Isaria fumosorosea (PFU-5)

successfully established and regulated the invasive whiteflies population. The pests population has come down (less than 10 live colony/leaflet) substantially in the entire severely infested coconut garden. Further the self-perpetuating parasitoids prevented the spread to neighboring garden also. The joint efforts of the various organizations weaned and prevented the farmers from resorting to use of hazardous insecticides like monocrotophos, Imidacloprid and Buprofezin in the coconut garden. Keeping in view of chemical intervention cost i.e minimum two sprays of chemical insecticide were compared with two release of parasitoids and two sprays of *Isaria fumosorosea,* we analysed the cost benefit ratio. Economic analysis on the impact of biological control revealed about Rs 9500/ha crop protection cost and 900 ml of pesticides/ ha are being saved. Further, this per hector benefit may be correlated with total areas affected by the invasive whiteflies in India gives the overall saving due to biological control intervention.

Challenges and way forward

These whiteflies are highly invasive, mobile and capable of spreading very fast from one location to another location. Available evidence suggests that new infestations have often resulted from transportations of infested plants. Chemical control is not practicable because of the abundance of host plants and wide spread distribution. It is fortunate to note that biological control agents can readily reduce the spiraling whitefly, rugose spiraling whitefly and palm infesting whitefly populations to sub-economic numbers. It would seem to be highly desirable to augment and conserve the host specific natural enemies *Encarsia guadeloupae* and *E. cubensis* to any locality seeking biological control. Moreover it is imperative to mention that correct and timely identification of this complex is very essential for carrying out further studies on their bioecology, population dynamics on different environments and development of management strategies especially biocontrol programs. There is urgent need to document a potential natural enemy complex or introduce from their native countries to develop efficient biocontrol management strategies for nesting whiteflies. Further, a nation-wide surveillance programme is required to mapping of the potential areas of its distribution, and host range to prevent further spread by restricting the exchange of planting materials.

Awareness, early detection of invasive species and immediate implementation of biological control methods could minimize the economic losses caused by the invasive whiteflies. Presently control strategies rely heavily on the augmentation and conservation of parasitoid, *Encarsia guadeloupae* and E. cubensis, foliar application of, *I. fumosoroea* and periodic release of predator, *Apertochrysa astur.* These biocontrol agents are more effective in suppressing these invasive whiteflies infesting coconut when implemented in integrative approach. *I. fumosorosea* may be successfully integrated with the augmentation and conservation of *E. guadeloupae* to achieve long term pest suppression of this notorious pest in coconut. *Isaria fumosorosea* is also effective against other invasive whitefly species like nesting and palm infesting whiteflies. Further, spraying in coconut plantation is major constratins, therefore, studies on aerial spraying using drone and dispersing *I. fumosorosea* using whiteflies adults through horizontal transmission.

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