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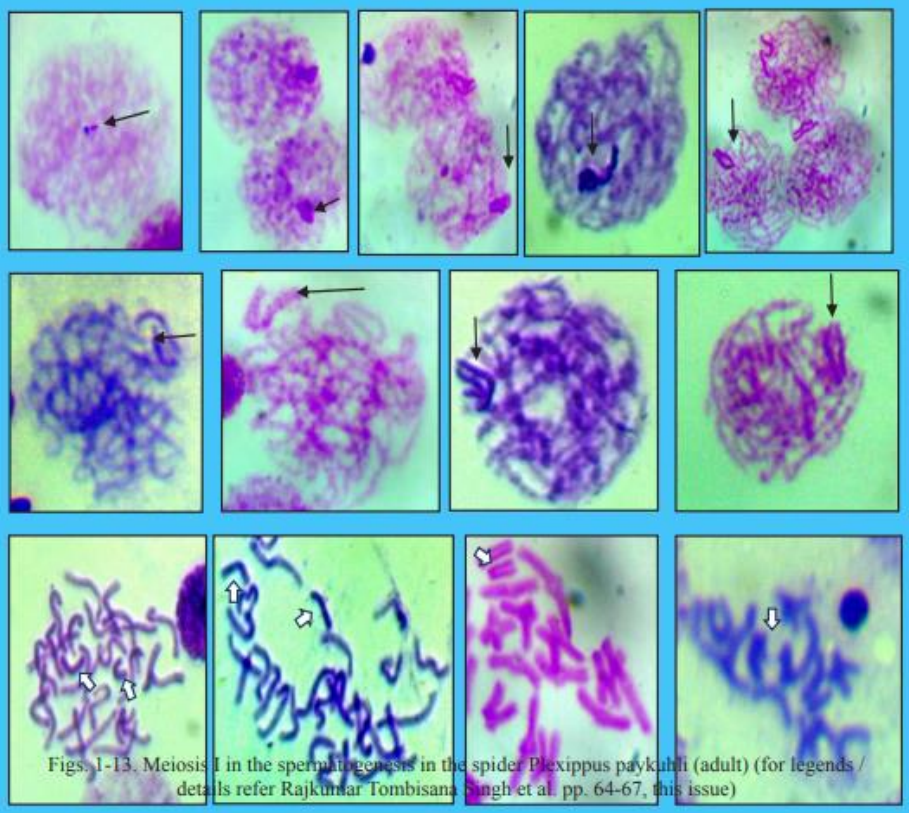

Figs. 1-13. Meiosis I in the spermatogenesis in the spider Plexippus paykulli (adult) (for legends / details refer Rajkumar Tombisana Singh et al. pp. 64-67, this issue)

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FIRST RECORD OF THE INVASIVE WOOLLY WHITEFLY *ALEUROTHRIXUS FLOCCOSUS* (MASKELL) FROM INDIA

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ABSTRACT

Occurrence of the highly polyphagous woolly whitefly, *Aleurothrixus floccosus* (Maskell) (Hemiptera: Aleyrodidae) on guava (*Psidium guajava* L.) was recorded as invasive in India. The whitefly is believed to be neotropical origin but is now found throughout the warmer parts of the world. The identification of *A. floccosus* was done through taxonomic characters of puparium and reconfirmed by DNA barcoding of adult whitefly using partial (658 bp) mitochondrial cytochrome oxidase 1 (CO1) gene. This is the first report of the breeding of *A. floccosus* on guava in India. Identification details, diagnosis, symptoms of damage and impact of its infestation on guava and citrus are discussed.

Key words: *Aleurothrixus floccosus*, first record, invasive, guava,citrus, taxonomy, diagnsotics, symptoms of damage, life stages, mtCo1, natural enemies

Whiteflies (Hemiptera: Aleyrodidae) are distributed throughout the major zoogeographical regions of the world, with their greatest diversity in tropical and south temperate regions. The trade of exotic plants is responsible for many accidental introductions of insects from their native area (Simala et al., 2015). Most alien species of whiteflies were accidentally introduced along with their host plant through plant trade, small in size, cryptic nature and immature stages being attached to the host-plant and due to these characteristics, they are one of the most commonly transported arthropod groups. They are also among the most successful groups in terms of invading new geographical areas. Moreover, changes in climate and global warming could influence new introductions and distribution of exotic whitefly species and increase the chances of their survival in new environment (Simala et al., 2015).

Aleurothrixus floccosus (Maskell) was first described from Jamaica in 1896 (Martin and Mound, 2007) and was noticed in Florida in 1909. This whitefly is native to the Neotropical region but is now found throughout the warmer parts of the world, wherever citrus is grown (Malumphy et al., 2015). It was reported from Europe and Mediterranean countries, Palaearctic, Ethiopian, Austro-Oriental, Neotropical and Nearctic Regions, Montenegro, Croatia (Martin et al., 2000; Radonjic and Hrncic, 2003; Simala and Milek, 2008). It is broadly polyphagous, feeding on more than 20 plant families and exhibits a strong preference for citrus species (Malumphy et al., 2015). In India it is found breeding on guava, *Psidium guajava* L. (Myrtaceae) for the first time at Kerala. Martin et al. (2000) indicated its presence in India, but it may not be authentic as there was no information on its host plant in India.

Recently there is a surge in the invasion of exotic whiteflies to India particularly through south India. The record of *A. floccosus* in Kerala confirms the fact that it is a species which has been slowly extending its range for many years, and has been the cause of economic problems in several parts of the world (Martin, 1999). The occurrence of this whitefly on guava, *P. guajava* was confirmed for the first time in India.

MATERIALS AND METHODS

Whitefly specimens were collected from infested guava plants by Ranjith, M from several places in Kozhikode (11.58°N; 75.78° E) and Malappuram (11.11° N; 76.17° E) districts in Kerala. Whitefly adult individuals were used for DNA based identification and adult emerged puparium processed for permanent mounting as per Dubey and David (2012) and identification is confirmed based on the puparial

taxonomic characteristics specific to the species. The confirmed mounted slides were deposited in the collection of ICAR- NBAIR, Bengaluru. Heavily infested leaves were kept in separate containers to observe and study the emergence of parasitoids. Population and intensity of damage of whitefly on five randomly selected guava tree at three strata (basal, medium, lower leaves) was assessed.

Samples of whitefly from which individuals had been identified by senior author were used in barcode development. Genomic DNA was extracted from individual whiteflies using the GIAGEN DNeasy® kit, Germany following the manufacturer's protocols. The DNA barcode region was amplified from whitefly species using 10 µl of universal DNA primers LCO1490 (5'-GGTCAACAAATCATAAAGATATTGG-3') and HCO 2198 (5'-TAAACTTCAGGGTGACC AAAAAATCA-3') for the amplification of mitochondrial cytochrome c oxidase subunit I (Folmer et al., 1994). The extracts were subjected to PCR amplification of a 658bp region near the 5' terminus of the COI gene following standard protocols. The amplified products were sequenced by M/s Chromous Biotech Pvt Ltd, Bengaluru and the same were uploaded to GenBank after annotation.

RESULTS AND DISCUSSION

Taxonomy

The slide mounts were obtained from the puparia from which adults had emerged and the identity was confirmed as *Aleurothrixus floccosus* (Maskell) (Hemiptera: Aleyrodidae). Pale white to brown puparia covered with flocculent wax; puparial margin not deflexed, overall concentric, regularly toothed, each tooth with a basal gland, without any modifications at thoracic and tracheal pore regions; submargin wide separated from dorsal disc by submarginal/ subdorsal fold, which arranged in distinct sections and complete; cephalic and first abdominal setae absent, submedian metathoracic setae present, eight abdominal and caudal setae long extending beyond puparial margin; inner submargin with a row of five pairs of minute setae in cephalothorax and anterior abdomen; submedian ridge prominent; vasiform orifice elevated, transversely elliptical, operculum similarly shaped, almost filling the orifice and obscuring the lingula (Martin, 1987) (Fig. 1).

This species is quite distinct from *A. trichoides*, the other already invaded known species of *Aleurothrixus* in India by the submargin without band of microtubercles; submarginal/ subdorsal fold almost concentric with

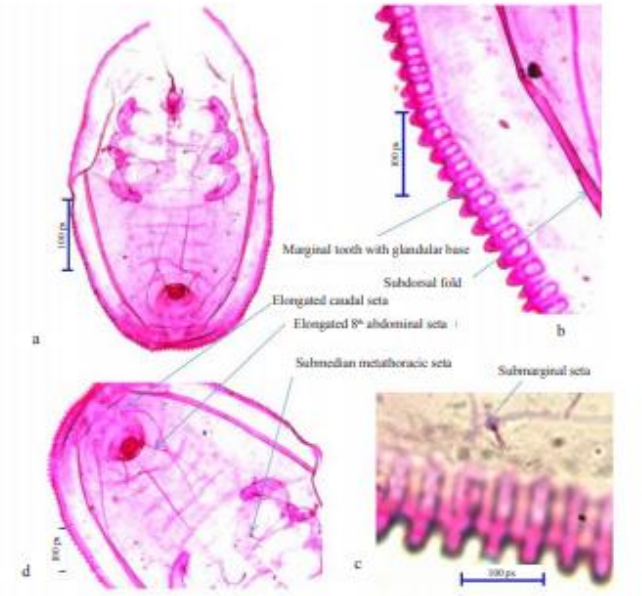

Fig. 1. *Aleurothriocus floccosus*: a. Dorsal view of mounted puparium, b. Margin, c. Posterior region showing elongated caudal and 8th abdominal setae, d. Submargin with submarginal seta

margin, arranged in distinct sections and complete between vasiform orifice and puparial margin; comparatively longer 8th abdominal and caudal setae, 8th abdominal setae reaching beyond puparial margin; inner submargin with a row of five pairs of tiny setae in cephalothorax and anterior abdomen and lingula tip not bilobed. The determined slides are deposited in the collection of ICAR-NBAIR (Acc. No NBAII/HEM-ALEU/8-12/2019).

The nucleotide sequence obtained with 637 bp size from M/s Chromous Biotech Pvt Ltd, Bengaluru were edited and then subjected for BLAST with NCBI nucleotide sequence data library. The sequence was submitted to GenBank (acc. no MN027508) and further BLAST analysis revealed that our sequence was matched 98% nucleotide identity with available sequence (KF059956) of *A. floccosus* at NCBI submitted by Ovalle et al (2013) from Colombia and whiteflies collected in *Citrus sinensis* and thus, confirm the identity of the species.

Symptoms and damage

Nymphs and adults suck phloem sap from host plants and indirectly damage by copious execration of honey dew which attract and support for development of the sooty mould on infested plants and blackening of entire leaves (Fig. 2a). Under severe infestation, the sooty mold might reduce the photosynthetic ability of infested plants significantly, leading to leaf fall, senescence and eventual death. This also reduces photosynthesis, resulting in decreased fruit size and also contaminates the fruits as well. Severe infestation (60-100% plants) of *A. floccosus* on *P. guajava* with the nymphal population of 59-363 and adult population 8-27 /leaf was observed alone or in association with spiralling whitefly *Aleurodicus dispersus* Russell colonies (Fig. 2b). Heaviest infestation was noticed to extent of 54.2 nymphs/ sq.cm and mostly colonizes on younger leaves than mature leaves (Fig. 2c).

Life stages

The sausage shaped, pale white eggs were deposited in a circular pattern and attached to the leaf with stalks which changes to brownish before hatching (Fig.3a). The first nymphal instar is light green in colour and subsequent stages turn brownish in colour with slight to heavy wool like wax filaments cover. The adult is approximately 1.5 mm in length, with a yellow-white body and wings that are covered with a white waxy powder (Fig.3 b-d) and they prefer to feed and oviposit on the undersides of young leaves that sprout when the host trees are actively growing.

Fig. 2. *A. floccosus*: a. Symptoms of damage; b. eggs, first and second instar nymphs; c. adults

Natural enemies

No natural parasitism either of the indigenous parasitoid or its potential parasitoid such as *Cales noacki* (Hymenoptera: Aphelinidae) was observed, though to the extent of 82% and 88% parasitism in Greece and

Fig. 3. *A. floccosus*: a. eggs; b. first and second instar nymphs; c. third instar nymphs; d. puparium

Turkey, respectively were reported (Katsoyannos et al., 1998; Telli and Yiğit, 2012). Few predators such as *Acletoxenus* sp. (Diptera: Drosophilidae and *Scymnus (Pullus)* nr. *utilis* Hoang (Coleoptera: Coccinellidae) were found associated with *A. floccosus* colony under field conditions. Yu et al. (2011) recorded predaceous drosophilid *Acletoxenus indicus* Malloch preying on larvae of *A. dispersus* and *Aleurocanthus* sp. in South China.

Impact on guava and citrus

A. floccosus may become invasive pest and cause economic loss for horticulture farmers not only on *P. guajava* but also on *Citrus* spp. as it is a serious pest on Citrus in many countries. In India, guava and citrus are two economically important fruit crops with rich source of vitamin C and widely cultivated. In guava, about 80 species of insects have been recorded to affecting yield and quality of fruits which include

three invasive whiteflies *viz., A. dispersus, P. bondari* and *A. rugioperculatus* especially in South India. Invasion and infestation of *A. floccosus* would further increase pest load on guava, inter-specific competition among whitefly species and yield loss. Similarly, other important likely host is citrus which commercially grown important crop in India.

The study conclude that more than 250 species of insects were found to feed on citrus including a dozen whiteflies *viz., A. dispersus* Russell, *A. rugioperculatus* Martin, *Acaudaleyrodes rachipora* (Singh), *Aleurocanthus citriperdus* Quaintance & Baker, *A. husaini* Corbett, *A. shillongensis* Jesudasan & David, *A. spiniferus* (Quaintance), *A. woglumi* Ashby, *Aleuroclava citri* Jesudasan & David, *Alwurolobus marlatti* (Quaintance), *Dialeurodes citri* (Ashmead) and *Dialeurolonga elongata* (Dozier). The polyphagous nature of the non-native *A. floccosus* warrants stringent quarantine protocols to prevent its further spread to other guava and citrus growing areas in India immediately. Furthermore, continuous monitoring through regular survey programme on its infestation, distribution, host plants and exploitation of natural enemies is need of the hour to formulate effective management measures against the pest.

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