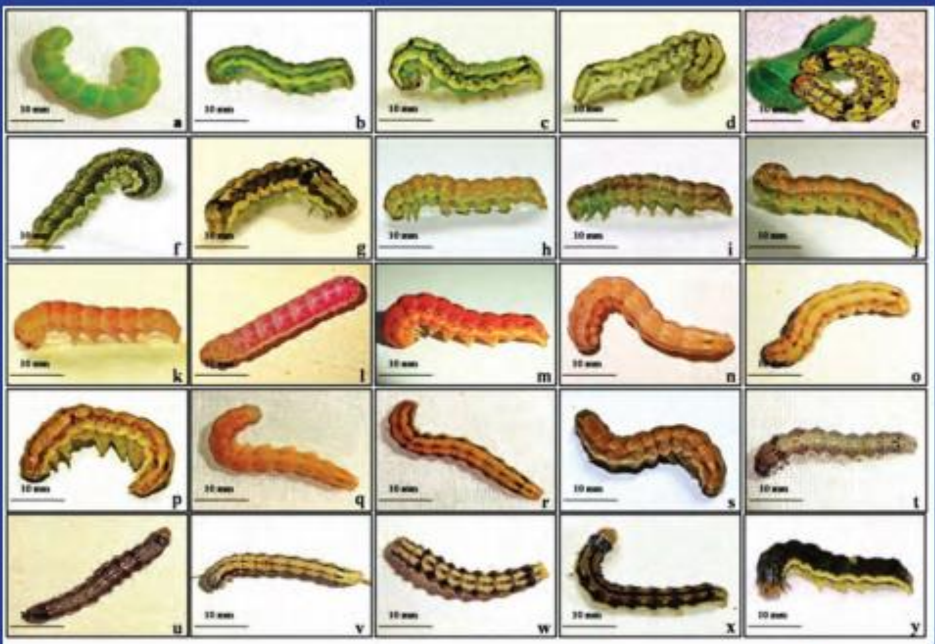
ISSN 0367-8288 (PRINT)
ISSN 0974-8172 (ONLINE)

INDIAN JOURNAL OF ENTOMOLOGY

VOLUME 82 PART 3 SEPTEMBER 2020



Larval body colour polymorphism in the gram pod borer *Helicoverpa armigera* (Hubner)
(for legends / details refer Snehal Chakravarthy et al., pp. 415-422, this issue)

Published by
The Entomological Society of India

Indian Journal of Entomology 82(3): 498-503 (2020) DoI No.: 10.5958/0974-8172.2020.00125.X

COMPARATIVE BIOLOGY OF INVASIVE RUGOSE SPIRALLING WHITEFLY *ALEURODICUS RUGIOPERCULATUS* MARTIN ON THREE HOST PLANTS

Sanjay Kumar Pradhan, A N Shylesha[1], K Selvaraj* and Sumalatha, B V[1]

Department of Agricultural Entomology, College of Agriculture,
University of Agricultural Sciences, Bengaluru, Karnataka 560065
[1]Division of Germplasm Conservation and Utilization,
ICAR-National Bureau of Agricultural Insects Resources,
Bengaluru, Karnataka 560024
*Email: selvaentomo@gmail.com (corresponding author)

ABSTRACT

Comparative biology of invasive rugose spiralling whitefly (RSW) *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae) was studied on three host plants viz., coconut (*Cocos nucifera* L), banana (*Musa* spp. L) and Indian shot (*Canna indica*) under caged as well as field conditions. The RSW life cycle was shorter on coconut as compared to that of banana and Indian shot plant. Thus, coconut is the preferred host for its growth and development with a fecundity of 49.50± 4.09 eggs and total duration of the nymphal instars being of 23.2± 1.38 days. Duration to lifestages on banana was less under field conditions as compared to that under caged conditions. These results on the comparative biology and growth will help to develop suitable IPM strategies for this invasive pest.

Key words: *Aleurodicus rugioperculatus*, coconut, banana, *Canna indica*, *egg*, fecundity, nymphal instars, duration, lifecycle, host preference

Globalization in agriculture has led to deliberate or accidental introduction of many quarantine pests, diseases and weeds (USDA, 2001). These introduced pests pose major threat to the native biodiversity and such insects species invading India include whiteflies viz., *Aleurothrixus trachoides* (Back) (Dubey and Sundararaj, 2015), *Aleurodicus rugioperculatus* Martin (Sundararaj and Selvaraj, 2017), *Paraleyrodes bondari* Peracchi, *Paraleyrodes minei* Iccarino (Josephrajkumar et al., 2019; Mohan et al., 2019), *Aleurotrachelus atratus* (Selvaraj et al., 2019) and *Aleurothrixus floccosus* (Maskell) (Sundararaj et al., 2020).Whiteflies get accidentally introduced owing to their small size, cryptic nature and immature stages being attached to the under surface of leaves. Due to these characteristics, these are one of the most commonly transported arthropod groups through trade of plant materials (Simala et al., 2015). In India, 463 whitefly species belonging to 68 genera are known to feed on many agricultural, horticultural and forestry crop plants (Selvaraj et al., 2019).

Among the invasive whiteflies, the RSW *A. rugioperculatus* is polyphagous, feeding on 35 host plants in India, including many economically important plants. Within two years it has spread to many intensive coconut growing states viz., Kerala, Karnataka, Tamil Nadu, Goa, Assam, West Bengal, Maharashtra, Gujarat and Andhra Pradesh. Due to its excreting excessive honey dew, its damage is more serious. It is now well established on coconut, banana and oil palm (Selvaraj et al., 2019). The female oviposits on the abaxial surface of leaves and cover them with white, fluffy wax, creating distinctive spiral patterns. Nymphs complete development on a broad range of native and non-native host plants (Mannion, 2010). There is meager information available on the biology of this whitefly, except for few studies in Florida and in India (Taravati and Mannion, 2014; Elango et al., 2019). Due to its invasiveness and rapid spread, there is a need to study its biology variations to facilitate IPM. As it is recently introduced into India, this comparative biology study was conducted on its three important host plants viz., coconut, banana and Indian shot plant.

MATERIALS AND METHODS

Rugose spiralling whitefly was maintained on banana plant in a greenhouse at 28± 2°C at the ICAR- National Bureau of Agricultural Insect Resources, Bengaluru (13⁰.05ˊ.48˝N,77⁰.34ˊ.30˝E) with a natural photoperiod (L:D) of approximately 12:12 hr following recommended package of practices. Adults were collected from this culture for the inoculation and evaluated the biology on the three host plants under caged conditions. Coconut

(*Cocos nucifera* L. var. Deejay), banana (*Musa* spp. L Var. local) and Indian shot (*Canna indica* L.var. Local) plants were raised in mud pot inside cages (150x70x70 cm) in the polyhouse. Plants were used when they reached 3-4 leaf stages (3-4 weeks old) and recommended packages of practices followed to raise healthy plants. Biology on banana was also studied under field conditions using transparent square (10x10x3 cm) shaped cages fabricated from plastic sheets.

Five plants of each host plant (replications) were planted in mud pots and placed inside the cage. Each host plant was maintained in separate cage and 20 pairs of adults were released. Observations on size of lifestages (in mm) and egg laying pattern, fecundity (numbers) and egg, nymphal, total nymphal, adult longevity and total developmental periods (days) were made at 24 hr intervals. Changes in the morphology of nymphal instars were observed. The leaves were observed under 40x stereozoom microscope to determine instars. Range and mean values for the developmental period of each instar, females and males, fecundity and longevity were calculated from these observations. The number of observations for each of the life history parameter varied depending upon the progress in development and survival of the crawlers and adults. Similarly, to study the biology under field conditions on banana, freshly emerged 20 pairs of adults were released in transparent plastic cages and adults were removed three days after release. 20 pin sized small holes were made on the transparent plastic cages for air circulation and maintain the temperature and humidity. Egg spirals on the leaves were marked and observations were made as described in biology under caged conditions. Ten samples of lifestages were observed under 40x stereozoom microscope and the measurement of length and width of eggs, nymphs (I to IV) were made. Besides these, length, width, length of pincer (in males) was also measured, along with observations on the change in morphology of instars. The ratio between the length and width (L: W) of each lifestage was calculated.

RESULTS AND DISCUSSION

The observations on the adult longevity, fecundity, total duration and nymphal durations on coconut, banana and Indian shot are given in (Table 1). The eggs of RSW were observed to be laid on the ventral surface of the coconut leaves. The observations on the adult longevity revealed that it lasted for 10.2± 0.80 days and 7.2± 0.58 days in female and male, respectively with fecundity as 49.50± 4.09 eggs. The total duration for the nymphal instars was 23.2± 1.38 days and 37.6± 2.55 days taken to complete life cycle on coconut, including adult longevity. The present results on coconut, are almost in agreement with earlier reports (Taravati and Mannion, 2014; Taravati et al., 2018; Elango et al., 2019). On banana, the fecundity was 58.00± 5.12; total duration of nymphal instars was 29.6± 1.67 days; and took 48.7± 2.98 days to complete its lifecycle, including adult. On *Canna indica*, fecundity was 56.60± 5.04 with 25.7± 1.66 days and a duration of 42.9± 2.95 days. The present results on biology of RSW on *C. indica* are in agreement with those of Taravati and Mannion (2014) and Taravati et al. (2018).

Under field conditions, the fecundity was 61.10± 5.30 and duration of nymphal instars was 27.4± 1.44 days; took 41.9± 2.36 days to complete the lifecycle including adult longevity on banana. Duration to complete lifestages on banana was less under field conditions compared to caged conditions. The developmental period of RSW on coconut is shorter as compared to that on banana and *C. indica*. Thus, coconut is observed to be the preferred host.

The adult female laid eggs in loose spiral pattern on the abaxial surface of leaves overlaid by wax but sometime on the adaxial surface of leaves, fruits, and stems also. Later, it spreads to entire leaves with overlapping generations (Fig.1a-d). The eggs are elliptical, yellowish and attached with a pedicel (Fig.1e). Pedicel is a hollow extension of chorion which was inserted into stomata of host plant during oviposition (Paulson and Beardsley, 1985). Moisture absorbed from the host plant through pedicel is essential for normal egg development. It also provides security to the eggs (Deshpande, 1936; Poinar, 1965). The present study observed that the egg changed from translucent to pale yellow and before hatching to brown. Egg was observed to be translucent yellowish green or light green to yellow (Gill, 1990). The eggs measured 0.53± 0.01 mm x 0.23± 0.003 mm and thus is larger than those of *A. dispersus*. Length: width (L:W) ratio was observed to be 2.28± 0.05 (Table 1).

The first instar is known as crawlers, which is the mobile stage having functional legs and crawled few millimeters before settling to feed. It was oval/ elliptical in shape and molted into several immature stages that are oval and initially flat, and then become more convex (Fig.1f). Some of these immature stages will secrete long white filaments of wax (Mannion, 2010). The

Table 1. Biology and morphometrics of *A. rugioperculatus*on three host plants (caged and field conditions)

Stage	Caged conditions (days)						Field conditions (days)	
	Cocos nucifera		*Musa* spp.		*Canna indica*		*Musa* spp.	
	Duration	Range	Duration	Range	Duration	Range	Duration	Range
Biology								
Egg	4.2 ± 0.37	3.0 - 5.0	6.6 ± 0.68	5.0 - 8.0	6.2 ± 0.58	5.0 - 8.0	5.5 ± 0.60	4.0 - 7.0
First instar nymphs	5.4 ± 0.24	5.0 - 6.0	6.9 ± 0.40	5.0 - 8.0	6.0 ± 0.45	5.0 - 7.0	5.6 ± 0.24	5.0 - 6.0
Second instar nymphs	5.0 ± 0.45	4.0 - 6.0	7.1 ± 0.40	5.0 - 9.0	6.0 ± 0.32	5.0 - 7.0	6.8 ± 0.37	6.0 - 8.0
Third instar nymphs	6.0 ± 0.32	5.0 - 7.0	7.1 ± 0.67	5.0 - 9.0	6.8 ± 0.49	5.0 - 8.0	7.0 ± 0.32	6.0 - 8.0
Fourth instar nymphs	6.8 ± 0.37	4.0 - 9.0	8.5 ± 0.20	6.0 -10.0	6.9 ± 0.40	5.0 - 9.0	8.0 ± 0.51	6.0 - 10.0
Total nymphal duration	23.2±1.38	18.0-28.0	29.6 ± 1.67	21.0 - 36.0	25.7 ± 1.66	20.0 - 31.0	27.4 ± 1.44	23.0 - 32.0
Adult female	10.2±0.80	8.0 - 12.0	12.5 ± 0.63	9.0 - 14.0	11.0 ± 0.71	9.0 - 13.0	9.0 ± 0.32	8.0 - 10.0
Adult male	7.2 ±0.58	6.0 - 9.0	9.0 ± 0.53	6.0 - 11.0	8.2 ± 0.49	7.0 - 10.0	6.8 ± 0.37	6.0 - 8.0
Total life cycle	37.6 ±2.55	29.0-45.0	48.7 ± 2.98	35.0 - 58.0	42.9 ± 2.95	34.0 - 52.0	41.9 ± 2.36	35.0 - 49.0
Fecundity	49.5±4.09	33.0-72.0	58.0±5.12	41.0-82.0	56.6±5.04	36.0-79.0	61.1±5.30	52.0-78.0

Morphometrics	Length (in mm)	Width (in mm)	L: W ratio
Eggs	0.53 ± 0.01	0.23±0.003	2.28 ± 0.05
First instar nymphs	0.63 ± 0.01	0.34±0.003	1.86 ± 0.02
Second instar nymphs	0.85 ± 0.01	0.52 ± 0.01	1.63 ± 0.04
Third instar nymphs	1.12 ± 0.02	0.81 ± 0.02	1.39 ± 0.02
Fourth instar nymphs	1.91 ± 0.05	1.32 ± 0.06	1.46 ± 0.04
Adult female	3.30 ± 0.07	1.11 ± 0.05	3.01 ± 0.12
Adult male	3.16 ± 0.08	0.79 ± 0.04	4.05 ± 0.12

nymphs are light to golden yellow, and will produce a dense, cottony wax as well as long, thin waxy filaments (Stocks and Hodges, 2012) which get denser over time. Gill (1990) reported that this kind of colouration is due to the transparent nature of the crawlers. These arrange themselves on the leaf surface parallel to vein or veinlet and during warmer days, crawlers walk quickly over the leaf surface in search of an available minor vein (Walker and Aitken, 1985). In *A. dispersus*, there were no wax secretions on the body of crawlers as these lacked compound wax pores but have two puffs of wax at the anal end (Aiswariaya et al., 2007). In the present study, it was observed that first instar was white at the time of hatching and turned yellowish green. Crawlers measured 0.63± 0.01x 0.34± 0.003 mm. L:W ratio was 1.86± 0.02. They moulted to second instar in about five to eight days. The crawler with restricted movement and feeding completed its nymphal period quickly (Geetha, 2000). Prolonged developmental periods of crawlers on banana are attributed to waxy coating on the leaves. So, it took more time to establish as compared to coconut which had more fibrous lamina.

Second instar nymphs were fringed with marginal wax along the transverse grooves on their dorsum and the compound pores produce glassy wax filaments (Fig.1g). These were transparent to pale yellowish green and were bigger compared to first instar. The second instar measured 0.85± 0.01 mm x 0.52± 0.01 mm (Table 1), which is larger as compared to *A. dispersus* and as described by Mariam (1999) and Geetha (2000). L: W ratio was 1.63± 0.04. Growth and development of sooty mould disrupts the photosynthesis process (Stocks and Hodges, 2012).

Third instar nymphs have numerous evenly spread short, glass like rods of wax along the sides of the body (Waterhouse and Norris, 1989). Waxy cottony secretions emerge from each of the compound pores on the dorsal surface of the body. Cottony secretions were abundant than in second instar and were larger (Fig. 1h). Third instar nymph measured 1.12± 0.02 x0.81± 0.02 mm, which is larger as compared to *A. dispersus* earlier described by Waterhouse and Norris (1989) and Geetha (2000). L: W ratio was 1.39± 0.02. Fourth instar nymphs were covered with copious amount of opaque white waxy material dorsally as tufts and the dorsal waxes produced from compound pores were long, cylindrical and often longer than the length of the puparium (Fig. 1 i, j). Ribbon like wax filaments were also present and these were as long as or longer than the body and flat on the ventral surface. The compound eyes of developing adults appeared as red spots through the puparium as observed earlier by Gill (1990). These have a swollen ventral surface and are colourless or yellowish, oval or elliptical. Fourth instar nymph (pupae) measured

1.91± 0.05 x1.32± 0.06 mm and L: W ratio was 1.46± 0.04 (Table 1).

Plant stage, nutrients, photoperiod and temperature play a key role on biology of *A. dispersus*. Dhaliwal and Arora (1996) reported that high level of nutrients increases the attractancy and development of whitefly; and temperature affects the biology and behaviour. In the present study, the biology of RSW was studied at 20.05- 23.9°C and 67- 71.5% RH, which might be the reason for varied development period across the different lifestages. RSW adults emerged with "T" shaped exit slit on the dorsal surface of the puparia (Fig.1 k) and it differs from parasitoid exit hole (Fig.1 l). After emergence, the wings of newly emerged adults were clear, later covered with a thick coat of white waxy powder (Gill, 1990). The eyes were dark reddish brown and each of the forewings had two characteristic dark spots and female was bigger than male (Fig.1 m, n). Female's lack pincers at the end of abdomen but have waxy puffs (Fig.1 o, p). Female measured 3.30± 0.07 x1.11± 0.05 mm and L: W ratio was 3.01± 0.12 (Table 1).

Fig. 1. *A. rugioperculatus* a. infestation on banana; spiralling pattern of oviposition; c. on banana bunch; d. irregular pattern of oviposition; e. eggs; f. first instar nymph; g. second instar nymph; h. third instar nymph; i-j. fourth instar nymph (puparia); k. adult emerged puparia with 'T' shaped opening; l. parasitoid emerged puparia, with circular opening; m. adult male; n. adult female; o. pincers at abdominal tip of adult male; p. fluffy mass at abdominal tip of adult female.

Males had long, simple pincer at the end of the abdomen (Gill, 1990) which were exposed from the distal end of the abdomen in between the wings. Male measured 3.16± 0.08x 0.79± 0.04 mm, excluding pincer length and L: W ratio was 4.05± 0.12. Adult females had more longevity in all the observed host plants.

Eggs were laid singly in a spiraling fashion at right angles to the leaf veins, which were covered with white waxy materials (Fig.1 b). Female whiteflies feed and oviposit on the same leaf and due to the concurrent feeding and oviposition, circular egg patterns were observed on relatively smooth leaves and as the female turns around the point where her stylets are embedded into the leaf. Both regular and irregular fashion of egg laying was observed at ovipositional sites. During the initial period of infestation on coconut and banana, regular circular and elliptical fashion of egg laying was observed. During the later period, irregular pattern of egg laying was found more on almost all leaves of the crops (Lenteren and Noldus, 1990; Taravati and Mannion, 2014). Ovipositional behaviour of whitefly is influenced by leaf hairiness (Mound, 1965). In the present study, during the initial stage of infestation on smaller leaf size, circular or elliptical regular pattern of egg laying was observed. On larger sized leaf, the adults move irregularly while feeding which coincide with egg laying and it might be the reason for irregular egg laying patterns on broader leaves of *Musa* sp., *Canna indica*. The absence of trichomes on *Musa* sp. might not disturb the adults while laying eggs. Continuous egg laying on the same leaf is the reason for more of irregular pattern.

This study infers that compatible host plants should be avoided as intercrops, as in coconut the developmental period is less as compared to other host plants and the susceptible stages needs to be aimed for effective management.

ACKNOWLEDGEMENTS

The authors thank the Director, ICAR-NBAIR, Bengaluru for providing facilities and the Indian Council of Agricultural Research, New Delhi for the Junior Research Fellowship of the senior author.

REFERENCES

Aiswariaya K K, Manjunatha M, Naik M. 2007. Biology and host range of spiralling whitefly. Karnataka Journal of Agricultural Sciences 20(1): 149-152.

Deshpande VG. 1936. Miscellaneous observations on the biology of Aleyrodidae (*Aleyrodes brassicae*). Journal of Bombay Natural History Society 39: 190-193.

Dhaliwal G S, Arora R. 1996. Principles of insect pest management. National Agricultural Technology Information Centre, Ludhiana.

Dongyin H, Kui L, Fangping Z, Wuren H, Jingbao Z, Qian J, Yueguan F. 2009. Biological characteristics of the spiralling whitefly, *Aleurodicus dispersus* Russell (Homoptera: Aleyrodidae). Acta Entomologica Sinica 52(3): 281-289.

Douressamy S N, Chandramohan N, Sivaprakasam A, Subramanian, Sundrababu P C. 1997. Management of spiralling whitefly. Indian Silk 36: 15-16.

Dubey A K, Sundararaj R. 2015. A new combination and first record of genus *Aleurothrixus* Quaintance & Baker (Hemiptera: Aleyrodidae) from India. Biosystematica 9: 23-28.

Elango K, Nelson S J, Sridharan S, Paranidharan V, Balakrishnan S. 2019. Biology, distribution and host range of new invasive pest of India coconut rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin in Tamil Nadu and the status of its natural enemies. International Journal of Agricultural Sciences 11: 8423-8426.

Geetha B. 2000. Biology and management of spiralling whitefly *Aleurodicus dispersus* Russell (Homoptera: Aleurodidae), Ph.D Thesis, Tamil Nadu Agricultural University, Coimbatore.

Gill R J. 1990. The morphology of whiteflies. Whiteflies: their bionomics, pest status and management. Gerling, D (ed.). Intercept Ltd., London. pp. 13-46.

Lenteren J C V, Noldus L P J J. 1990. Whitefly plant relationships, behavioural and ecological aspects. D Gerling (ed.), Whiteflies: their bionomics, pest status and management. Intercept, Newcastle upon Tyne, England. pp. 47-90.

Mannion C. 2010. Rugose spiraling whitefly, a new whitefly in South Florida, Tropical Research and Education Center, University of Florida.

Martin J H. 2004. The whiteflies of Belize (Hemiptera: Aleyrodidae) Part 1- introduction and account of the subfamily Aleurodicinae Quaintance and Baker. Zootaxa 681: 1-119.

Mohan C, Josephrajkumar A, Babu M, Krishna A, Prathibha P S, Krishnakumar V, Hegde V. 2019. Non-native Neotropical nesting whitefly, *Paraleyrodes minei* Iaccarino on coconut palms in India and its coexistence with Bondar's nesting whitefly, *Paraleyrodes bondari* Peracchi. Current Science 117 (3): 515-519.

Mound L A. 1965. Effect of leaf hair on cotton whitefly populations in the Sudan Gezira. Empire Cotton Growing Review 42: 33-40.

Palaniswami M S, Pillai K S, Nair R R, Mohandas C. 1995. A new cassava pest in India. Cassava Newsletter 19: 6-7.

Paulson G S, Beardsley J W. 1985. Whitefly (Homoptera: Aleyrodidae) egg pedicel insertion into host plant tomato. Annals of the Entomological Society of America 78: 506-508.

Poinar G. 1965. Observations on the biology and ovipositional habits of *Aleurocybotus occiduus* (Homoptera: Aleyrodidae) attacking grasses and sedges. Annals of the Entomological Society of America 58: 618-620.

Schoeller E N, Redak R A. 2018. Temperature-Dependent development and survival of giant whitefly, *Aleurodicus dugesii* (Hemiptera: Aleyrodidae) under constant temperatures. Environmental Entomology 47: 1586-1595.

Selvaraj K, Sundararaj R, Sumalatha B V. 2019. Invasion of the palm infesting whitefly, *Aleurotrachelus atratus* Hempel (Hemiptera: Aleyrodidae) in the Oriental region. Phytoparasitica 47: 327-332.

Selvaraj K, Sundararaj R, Venkatesan T, Ballal C R, Jalali S K, Gupta A, Mrudula H K. 2016. Potential natural enemies of the invasive rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin in India. Journal of Biological Control 30: 236-239.