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Biology and Host Suitability of *Paracoccus marginatus* (Williams and Granara de Willink, 1992) (Hemiptera: Pseudococcidae) on Five Different Hosts

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ABSTRACT

The present study evaluates the biological parameters of the papaya mealybug (PMB), *Paracoccus marginatus* (Williams and Granara de Willink, 1992), on five different host plants viz. papaya *(Carica papaya* L.*)*, hibiscus (*Hibiscus rosa-sinensis* L.), jatropha (*Jatropha curcas* L.), mulberry (*Morus alba* L.) and marigold *(Tagetes erecta* L.*),* to determine the host suitability. An in-vitro experiment was conducted by maintaining the colony at a temperature of 25±5˚C and relative humidity of 65% and a photoperiod of 12:12 (L:D). *P. marginatus* completed its life cycle on all tested hosts, but its biological parameters varied based on host preference. The highest female fecundity was recorded on jatropha (309.0±27.68 eggs), while the lowest was on marigold (104.3±11.31 eggs). The pre-imaginal phase was longest on papaya and shortest on marigold. The total lifespan of *P. marginatus* was highest on Papaya (38.0±0.05 days for females and 24.6±1.66 days for males) and shortest on marigold (26.3±0.88 days for females and 16.3±1.33 days for males). These findings indicate that papaya is the most suitable host for *P. marginatus* while marigold is the least preferred. The present study builds a foundation for designing the management strategies for the future.

Keywords: Papaya mealybug, *Paracoccus marginatus*, host suitability, biological parameters, life cycle.

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INTRODUCTION

The papaya mealybug (*Paracoccus marginatus*) was first detected in Florida in 1998 and has since spread across the Caribbean and Central America, causing severe damage to tropical fruits, especially papaya. It infests numerous host plants and is believed to be native to Mexico or Central America (Miller et al., 1999). The mealybug *P. marginatus* has emerged as a globally significant invasive pest, owing to its remarkable host-range and distribution. It has been documented attacking plants in around 193 genera across nearly 58 families, and has established populations in 70 countries including India, spanning tropical and subtropical regions worldwide. Such extensive polyphagy and geographic breadth underscore its capacity to threaten a wide array of crop, ornamental and wild host systems (Garcia et al., 2016). In India, it was first reported in the Coimbatore district of Tamil Nadu in 2008, where it infested papaya (Muniappan et al., 2008). It later caused severe damage to 3,000-acre plantation of mulberries and rapidly spread across tropical regions of India, including Kerala, Karnataka, Andhra Pradesh, Odisha, Maharashtra, Jammu and Kashmir, and West Bengal. The pest has since emerged as a major threat of horticultural, ornamental, and agricultural plants (Ramalakshmi, Das, & Padhy, 2021; Prakash, Veershetty, Shukla, Subrahmanyam, & Moorthy, 2024). Such extensive polyphagy and geographic breadth underscore its capacity to threaten a wide array of crop, ornamental and wild host systems (Garcia et al., 2016). Being a highly polyphagous pest, it is important to study the ability of the mealybug to thrive, survive and multiply. In a study, the biology of the *P. marginatus* was compared on sprouted potato (*Solanum tuberosum*) and long bottle gourd (*Lagenaria siceraria*) under semi-controlled conditions. Results confirmed that the mealybug completed its life cycle on both hosts, but performed comparatively better on sprouted potatoes, showing a longer lifespan, higher fecundity (168.8 versus 103.4 crawlers/female), and greater female longevity. Parthenogenesis occurred on both hosts, indicating that sprouted potato is a more suitable laboratory host for rearing *P. marginatus* (Iqra, Tahir, Channa, & Anwar, 2019). Several studies conducted across the world investigated the host preference and biology of *P. marginatus* on different host plants, which provided valuable information about female fecundity as well as average nymphal and adult life stages (Seni and Sahoo, 2015; Okeke, Omoloye, Umeh, & Goergen, 2019).

The female *P. marginatus* undergoes three nymphal instars, while males progress through two nymphal instars followed by prepupal and pupal stages. Adult males possess a single pair of wings but are weak fliers, whereas females remain neotenic and larviform (Chellappan, Lawrence, & Ranjith, 2013).

Understanding the life cycle of an insect pest is essential for predicting its development, emergence, distribution, and abundance (Amarasekare, Chong, Epsky, & Mannion, 2008). Such knowledge is also crucial for implementing effective pest management strategies. This study investigates the biological parameters of male and female *P. marginatus* across five different host plants to assess their suitability for mealybug development.

MATERIAL AND METHODS

The study was conducted under laboratory conditions at the Department of Entomology, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (India). The temperature was maintained to be 25±5˚C, relative humidity was 65±2% and a photoperiod of 12:12 (L:D) (Amarasekare, 2008). The papaya mealybug (*Paracoccus marginatus*) specimens used in this study were identified using the taxonomic keys provided by Miller & Miller (2002) and later confirmed by Dr. Sunil Joshi, Principal Scientist, NBAIR, Bengaluru. The five host plants evaluated in this study were papaya (*Carica papaya* L.), jatropha (*Jatropha curcus* L.), mulberry (*Morus alba* L.), hibiscus (*Hibiscus rosa sinensis* L.) and marigold (*Tagetes erecta* L.).

Laboratory culture of *Paracoccus marginatus*

The laboratory culture of *Paracoccus marginatus* was maintained on sprouted potatoes following Gautam (2008). Cleaned and air-dried potato tubers were incised (2 cm in length and 7 mm in depth) and treated with 1% gibberellic acid (GA_3) for 30 minutes to promote sprouting. Treated tubers were placed in trays with sterilised moist sand, covered with black muslin cloth, and kept in the dark with daily watering. After one week, when sprouts reached 2.5–3.0 cm, freshly sprouted potatoes were inoculated with four to five *P. marginatus* ovisacs per tuber. To sustain the colony, fresh sprouted potatoes were inoculated with *P. marginatus* ovisacs weekly.

Life cycle of *Paracoccus marginatus* on five different host plants

a- Management of host plants

Leaves of all five host plants, along with petioles, were plucked and placed in petri plates lined with agarose gel to maintain freshness and nutrition for approximately one week. The insects were transferred to new leaves as needed (Da Silva, Nondillo, Galzer, Garcia, & Botton, 2017).

b- Pre-imaginal time duration of male and female *P. marginatus*

The experiment was replicated three times, with ten eggs per host plant (mean of 10 observations was taken per host for getting a precised data, making it more dependable for analysis and comparison between host plants), constituting a replicate. Eggs were inoculated onto each host plant using a camel hair brush (10 eggs per leaf). All eggs used in each replication were collected from a single female within 24 hours of oviposition. Egg hatch was monitored daily. The interval between each moult was recorded by examining exuviae under a 10X magnification hand lens, and the exuviae were removed after each moult. Morphological determination of all the instars was conducted using a stereo zoom microscope. The following developmental parameters were recorded:

- Duration of egg hatch
- Emergence of first instars
- Duration of second instar males and females
- Duration of third instar males (pre-pupa) and females

- Duration of pupa

From these data, the pre-imaginal time (egg to pupa in males and egg to third instars in females) was calculated (Zaviezo, Cadena, Flores, & Bergmann, 2010).

c- Reproductive period and generation time

To assess the reproductive period, ten adult female mealybugs were individually transferred to new petri plates containing leaves of each host plant lined with agarose gel. The pre-oviposition, oviposition and post-oviposition periods were recorded. From these data, the generation time of female mealybugs (egg to oviposition) was calculated **(**Zaviezo et al., 2010**)**.

d- Adult longevity and fecundity

Adult longevity was determined by observing male and female mealybugs until their death. Fecundity was assessed by counting the number of eggs in each ovisac on different host plants.

Statistical analysis

The effects of the host plant on development time, longevity, reproduction and fecundity of *P. marginatus* were analyzed using one-way analyses of variance (ANOVA) under CRD (Completely Randomized Design), Duncan's Multiple Range Test (DMRT) was carried out to find the substantial differences and comparision among treatments. Statistical analyses were conducted using SPSS software version 16.0.

RESULTS

The life cycle of *P. marginatus* varied across the five host plants, showing significant differences in the duration of various developmental stages (Tables 1- 4 and figures 1- 7).

Egg incubation period

The incubation period was longest on mulberry (6.6±0.33 days) and shortest on marigold (3.6±0.33 days) while, the duration on papaya and hibiscus was intermediate (Table 1).

First instar duration

The longest duration was observed on papaya (5.6±0.33 days), while the shortest was on hibiscus (3.3±0.33 days). The duration on jatropha, mulberry, and marigold was found to be statistically similar (Table 1).

Second instar duration

The maximum duration was recorded on papaya (5.3±0.33 days), significantly different from marigold (2.6±0.33 days) while, the mulberry and hibiscus showed no significant difference (Table 1).

Third instar duration

The longest duration was recorded on papaya (5.3±0.33 days), while hibiscus and mulberry had statistically similar durations. The shortest was on marigold (3.3±0.33 days) (Table 1).

Male developmental stages

Second instar (male)

Papaya recorded the highest duration (4.3±0.33 days), followed by mulberry (4.0±0.57 days), with the lowest on marigold (2.6±0.33 days) (Table 1).

Prepupal stage

The longest duration was on hibiscus (3.6±0.33 days), while papaya and mulberry had the shortest and were statistically similar (2.3±0.33 days) (Table 1).

Pupal stage

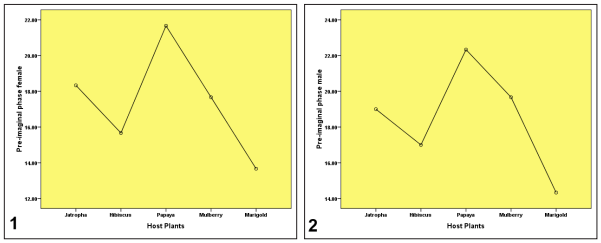
The longest duration was on papaya (4.6±0.33 days), followed by jatropha (4.3±0.33 days), with the shortest on marigold (Table 1).

Table 1. Duration of incubation period and nymphal stages of male and female *P. marginatus* on different host plants.

Host plants	Developmental stages of male and female nymphs (Mean duration in days ± S.E)						
	Eggs	1st instar nymph	Female*	Female	Male*	Male	Male
			2nd instar nymph	3rd instar nymph	2nd instar nymph	Prepupa	Pupa
Jatropha (*Jatropha curcas*)	5.0^{cd}±0.57	3.6^{b}±0.33	4.3^{ab}±0.33	5.3^{a}±0.33	3.3^{a}±0.66	2.6^{a}±0.66	4.3^{a}±0.33
Hibiscus *(Hibiscus rosa-sinensis)*	5.3^{bc}±0.33	3.3^{b}±0.33	3.3^{bc}±0.33	3.6^{bc}±0.33	3.3^{a}±0.66	3.6^{a}±0.33	2.3^{b}±0.33
Papaya *(Carica papaya)*	6.3^{ad}±0.33	5.6^{a}±0.33	5.3^{a}±0.33	4.6^{ab}±0.33	4.3^{a}±0.33	2.3^{a}±0.33	4.6^{a}±0.33
Mulberry *(Morus alba)*	6.6^{a}±0.33	3.6^{b}±0.33	3.6^{bc}±0.33	3.6^{bc}±0.33	4.0^{a}±0.57	2.3^{a}±0.33	3.0^{b}±0.57
Marigold *(Tagetes erecta)*	3.6^{b}±0.33	3.6^{b}±0.66	2.6^{c}±0.33	3.3^{c}±0.33	2.6^{a}±0.33	2.6^{a}±0.33	1.6^{b}±0.33

Pre-imaginal development

The total developmental period was longest on papaya (22.3±1.33 days for males, 21.6±0.88 days for females) and shortest on marigold (14.3±1.33 days for males, 13.6±0.88 days for females) as presented in the table 2 and figures 1- 2.



Figures 1- 2. Graphical representation of pre-imaginal phase of *Paracoccus marginatus*.

Reproductive parameters

- Pre-oviposition period: The longest duration was on jatropha (3.6±0.33 days) and the shortest on hibiscus (2.3±0.33 days).

- Oviposition period: The highest oviposition period was on jatropha (7.3±0.33 days) and the lowest on hibiscus (4.3±0.88 days).

- Post-oviposition period: The longest was on jatropha (4.6±0.33 days), and the shortest on marigold (2.6±0.66 days) (Table 2, Fig. 3)

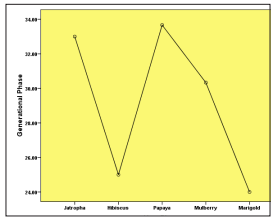


Figure 3. Graphical representation of the generational phase of *Paracoccus marginatus*.

Adult longevity

Female *P. marginatus* lived longer than males across all host plants (Table 2). The longest female longevity was recorded on jatropha (17.3±0.33 days), followed by papaya (16.3±0.33 days), while the shortest was on marigold (12.6±0.33 days).

Table 2. Pre-imaginal phase, generational period and adult longevity of *P. marginatus* on different host plants.

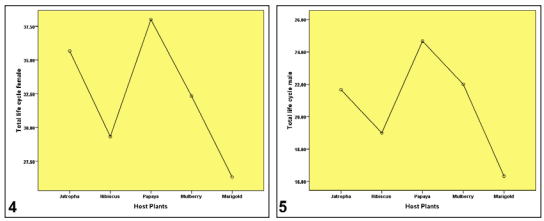
Host Plants	Pre-imaginal phase (days)		Average reproductive parameters of *P. marginatus* (days)				Adult Longevity (days)	
	Female	Male	Pre-oviposition	Oviposition	Post oviposition	Generational phase	Female	Male
Jatropha (*J. curcas)*	18.3^{b}±0.33	19.0^{ab}±1.73	3.6^{a}±0.33	7.3^{a}±0.33	4.6^{a}±0.33	33.0^{a}±1.52	17.3^{a}±0.33	2.6^{a}±0.33
Hibiscus *(H. rosa-sinensis)*	15.6^{c}±0.33	17.0^{bc}±1.15	2.3^{a}±0.33	4.3^{b}±0.88	3.3^{ab}±0.33	25.0^{b}±0	13.6^{bc}±0.33	2.0^{a}±0
Papaya *(C. papaya)*	21.6^{a}±0.88	22.3^{a}±1.33	3.3^{a}±0.66	6.3^{a}±0.33	3.6^{ab}±0.33	33.6^{a}±1.85	16.3^{a}±0.33	2.3^{a}±0.33
Mulberry *(M. alba)*	17.6^{b}±0.33	19.6^{ab}±0.88	3.0^{a}±0.57	6.6^{a}±0.33	4.3^{a}±0.33	30.3^{a}±1.2	14.6^{b}±0.33	2.3^{a}±0.33
Marigold *(T. erecta)*	13.6^{c}±0.88	14.3^{c}±1.33	2.6^{a}±0.33	6.0^{a}±0	2.6^{b}±0.66	24^{b}±2.3	12.6^{c}±0.33	2.0^{a}±00

Total life cycle duration

The total life cycle duration (Table 3) was longest on papaya (38.00±0.05 days), followed by jatropha (35.66±5.17 days), and shortest on marigold (26.33±0.88 days). Males had shorter developmental times, with the longest on papaya (24.6±1.66 days) and the shortest on marigold (16.3±1.33 days) (Figs. 4- 6).

Table 3. Complete life cycle duration of male and female *P. marginatus* on different host plants.

Complete life cycle on different host plants (days)		
Host plant	Female	Male
JATROPHA (*Jatropha curcas)*	35.6^{b}±0.33	21.6^{ab}±1.45
HIBISCUS *(Hibiscus rosa-sinensis)*	29.3^{d}±0.66	19.0^{bc}±1.15
PAPAYA *(Carica papaya)*	38.0^{a}±1.15	24.6^{a}±1.66
MULBERRY *(Morus alba)*	32.3^{c}±0.33	22.0^{ab}±1.15
MARIGOLD *(Tagetes erecta)*	26.3^{e}±0.66	16.3^{c}±1.33



Figures 4- 5. Representation of the total life cycle of female and male *Paracoccus marginatus* on different host plants.

Fecundity

The average fecundity of *P. marginatus* varied significantly across host plants (Table 4, Fig. 7), following this trend: papaya (330.3±36.28 eggs) > jatropha (309.0±27.68 eggs) > mulberry (296.0±16.64 eggs) > hibiscus (135.3±6.74 eggs) > marigold (104.3±11.31 eggs) (Fig. 7).

Table 4. Fecundity of female *P. marginatus* on different host plants.

Host Plants	Fecundity (No. of eggs)*
Jatropha (*Jatropha curcas* L.)	309.0^{a}±27.68
Hibiscus (*Hibiscus rosa-sinensis* L.)	135.3^{b}±6.74
Papaya (*Carica papaya* L.)	330.3^{a}±36.28
Mulberry (*Morus alba* L.)	296.0^{a}±16.64
Marigold (*Tagetes erecta* L.)	104.3^{b}±11.31

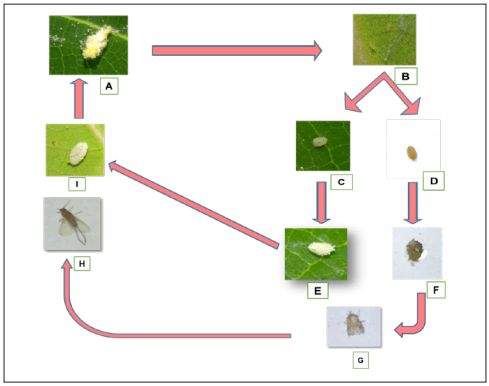


Figure 6. A) Egg mass of *Paracoccus marginatus*, B) First instar nymphal stage, C) Second instar female, D) Second instar male E) Third instar female, F) Pre-pupal male, G) Pupal stage Male, H) Male adult stage, I) Female adult stage.

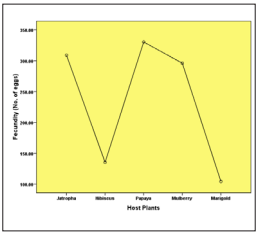


Figure 7. Fecundity of female *Paracoccus marginatus* on different host plants.

DISCUSSION

Understanding the biology of an insect is crucial for assessing its development, distribution, and population dynamics. The biology of *P. marginatus* varies depending on the host plant, as different plants provide different levels of nutritional suitability. In this study, *P. marginatus* successfully developed, survived, and reproduced on all five host plants, but with significant differences in developmental time and reproductive parameters.

Developmental period

The egg incubation period varied between six to four days, where it was found to be highest on mulberry and at par on papaya, these findings align with the findings of Chellappan et al. (2013) who reported incubation period of 5.8±0.7 days on mulberry, and 8.5±0.8 d on papaya. Similarly, Suganthy, Janaki, & Sakthivel (2012) studied the biology of *P. marginatus* on sunflower and claimed the egg period to be 6.33±0.5 days. In present study, the duration of the first and second nymphal instars, was longest on papaya (5.6±0.33 and 5.3±0.33 days) in conformity with Rasheed et al. (2015) who recorded the duration of first instar as 5.80 + 0.19 days on papaya. The third female nymphal instar duration ranged in around five to four days and the male prepupa lasted between three to two days. Almost similar findings were given by Chellappan et al. (2013) who reported the durations for females (6.11±0.6 to 4.7±0.6 days) and slightly different durations for males. The male pupal period was longest on papaya followed by jatropha and lowest on marigold. The pre-imaginal period was generally longer in males than in females due to additional nymphal stages in males. The longest pre-imaginal period was recorded on papaya, followed by jatropha, while the shortest was on marigold. These results are in accordance with Kumar et al. (2014), who reported a pre-imaginal period of 17.32±1.6 days on jatropha. Salman, Javed, Khan, & Khan (2024) also claimed that the developmental duration of cotton mealybug varied across host plants as the first instar ranged from 4.17 to 5.38 days on bottle gourd and apple gourd, the second instar from 4.35 to 5.05 days bottle gourd and apple gourd, the third instar from 10.12 to 12.67 days on okra and bottle gourd and the adult stage from 8.00 to 9.42 days on apple gourd and potato.

Reproductive period

Regarding reproductive parameters, the longest pre-oviposition, oviposition and post-oviposition phases were observed on jatropha, followed by papaya. Total generational phase was longest on papaya, indicating that the duration of development is influenced by host plant suitability. Ramzan et al. (2023) reported a similar trend in *Coccinella undecimpunctata* (L. 1758), predator of *Myzus persicae* (Sulzer, 1776), where the duration of the oviposition period was extended due to increased food consumption and better nutrient availability, leading to early ovariole maturation and prolonged reproductive activity. The feeding preference of *P. marginatus* on jatropha had a significant impact on the adult longevity. Female and male longevity was highest on jatropha, followed by papaya, while the shortest lifespan was recorded on marigold. These findings align with Seni & Sahu (2015), who reported a male lifespan of two to three days and a female longevity of up to 18 days. Similarly, Nyamador et al. (2022) documented female *P. marginatus* longevity ranging from 13 to 27 days, with an average of 18.44±3.31 days.

Total life-cycle

The total life cycle duration was longest on papaya (38.0±0.05 days), in agreement with Iqra et al. (2020), who reported a female life cycle of 38.8±4.43 days and a male life cycle of 25.0±2.34 days. Suganthy et al. (2012) also found similar results, with female and male life cycles of 39.33±2.53 days and 24.00±1.73 days, respectively.

Female fecundity

Fecundity was highest on papaya, further confirming papaya's suitability as a host. These findings are consistent with Nisha & Kennedy (2014), who reported nearly 80% of the hatching of *Paracoccus marginatus* on papaya. Shehata, Mostafa, & Salama (2020) confirmed that the females of *Phenacoccus solenopsis* laid (386.69 ± 30.8 eggs/female) on okra, followed by eggplant (345.46 ± 35.3), purslane (331.7 ± 36.2), and cotton (309.62 ± 27.3).

In summary, while *P. marginatus* can develop on all five host plants, papaya emerged as the most favourable host, supporting longer developmental durations, higher fecundity, and greater adult longevity. In contrast, marigold was the least suitable host, with the shortest life cycle and lowest fecundity. These findings provide valuable insights for pest management strategies and further studies on host plant resistance against *P. marginatus*.

CONCLUSION

The papaya mealybug *Paracoccus marginatus* is a highly polyphagous and economically significant pest that infests a wide range of agricultural, horticultural, medicinal and ornamental crops. In our study, among the five host plants studied, *P. marginatus* exhibited the highest developmental and reproductive potential on papaya, jatropha, and mulberry, establishing these as the most suitable hosts.

The findings of this study give further research highlights about how different host plants provide varying levels of nutritional quality and chemical constituents and can affect the suitability of this pest. The biology of the mealybug on selected host plants indirectly indicates the presence of nutritional as well as defence compounds of the plants, which affects the survival of the pest. Understanding these chemical factors through life cycle studies would enable the development of sustainable, biochemically based pest management methods such as semiochemical control and reduced pesticide use in future. While this study provides valuable insights into host plant suitability, the specific chemical constituents responsible for enhancing the survival and reproduction of *P. marginatus* remain unclear; therefore, further research is needed to identify these biochemical factors, which could contribute to the development of targeted pest management strategies.

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