Food Host Preference and Life cycle characteristics of the Papaya mealybug, *Paracoccus marginatus* Will. and Granara de Willink in Ibadan, Southwest Nigeria

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Abstract

Papaya mealybug, *Paracoccus marginatus* is an invasive polyphagous hemipteran that causes enormous damage to different host plants in Nigeria. However, information on the pest's damage potential and host range is scanty; therefore, the host preference and life cycle of *P. marginatus* were investigated. Six economic plants: *Carica papaya* (Caricaceae), *Solanum lycopersicum* (Solanaceae), *Manihot esculenta* (Euphorbiaceae), *Abelmoschus esculentus* (Malvaceae), *Psidium guajava* (Myrtaceae) and *Tectona grandis* (Lamiaceae) were evaluated as food hosts to *P. marginatus* using free-choice and no-choice tests in screen cages (1.80x0.60x1.50m). The developmental biology was investigated following standard procedures at ambient conditions of $27\pm 2^{\circ}\text{C}$; $70\pm 5\%$ RH and 12:12 hour photoperiod. Significantly more *P. marginatus* migrated to and utilized *C. papaya* (27.5 ± 2.9) and *M. esculenta* (20.75 ± 1.3) as food host. This pest occurred on other plants in decreasing order; *S. lycopersicon* (17.0 ± 1.3) > *P. guajava* (12.5 ± 0.4) > *A. esculentus* (11.8 ± 1.2) and *T. grandis* (10.00 ± 1.4) appeared to be the least preferred. The duration of development from egg to adult ranged from 23.52 ± 0.1 to 25.76 ± 0.4 days in the females and 25.91 ± 0.6 to 30.62 ± 0.8 in the males, which passed through more nymphal instars (4) than in females (3). The life cycle of *P. marginatus* was completed in shorter time on *C. papaya* than on any other host plants. The differences between male and female adult weights ($2.98\pm 0.4\text{mg}$ and $3.90\pm 0.6\text{mg}$) were not significant. *Paracoccus marginatus* preferred pawpaw and cassava to the other crops. This information is useful for development of appropriate integrated management programme for the pest.

Keywords: *Carica papaya*, Host plant preference, Life-cycle, Developmental biology, *Paracoccus marginatus*.

INTRODUCTION

The papaya mealybug, *Paracoccus marginatus* Williams and Granara de

Willink, is a polyphagous hemipteran pest that infests several host plants, including economically important tropical fruits, vegetables and ornamentals (Tanwar *et al.*, 2010). It is believed to be native to Mexico

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and/or Central America but has never attained pest status, probably due to the presence of an endemic natural enemy complex in the native home (Miller *et al.*, 1999).

Mealybugs constitute a very important pest group with highly varied host range from over 25 plant families including economic and weedy plants in genera such as *Acacia*, *Acalypha*, *Ananas*, *Annona*, *Bidens*, *Capsicum*, *Hibiscus*, *Ipomoea*, *Mangifera*, *Manihot*, *Persea*, *Plumeria*, *Punica*, *Solanum* and *Vigna* (Ben-Dov, 2008). Characteristically, they suck the sap of the host plants and weaken it making the leaves crinkled, yellowish and wither. Sooty mould develops on the honeydew excreted by mealybugs which cover the leaves, fruits and stems; impeding photosynthesis and gaseous exchange. Heavy infestations often cause the papaya plant to die within a few months (Heu *et al.*, 2007). Due to the wide host range, the economic impact of infestation is considered to be high.

Paracoccus marginatus was first reported in Africa in Ghana in 2009 (Cham *et al.*, 2011), in South and South East Asian regions between 2008 and 2009. The insect was also reported in Java, Indonesia in May 2008 from where it spread to Bali and Sulawesi (Muniappan *et al.*, 2008; 2009). In July 2008, the papaya mealy bug was reported in the Colombo and Gampaha districts of Sri Lanka (Galanihe *et al.*, 2010). The pest was also reported in Manila, Philippines in 2008; Joyedpur, Bangladesh and Phnom Penh, Cambodia in 2010 as well as in Thailand in 2010 (Galanihe *et al.*, 2010). Thus, the status of this insect pest has risen to a significant level of importance.

Since the first report in Africa in 2009, the papaya mealybug has raised great concern especially in Ghana, where an estimated 85% of papaya farms were devastated causing about 65% yield losses.

The potential economic and ecological impacts of an outbreak in Nigeria could therefore be devastating considering the nation's production capacity. Nigeria produces 94% of the papaya from West Africa (FAO, 2010; Georgen *et al.*, 2011). The food species that polyphagous insects feed on varies and this has been reported to influence the life history parameters such as developmental time and survival of the insect (Amarasekare, *et al.* 2008; Awmack and Leather 2002).

There are however reports that the pest has been reported on papaya since 2012 in Ibadan, South-western Nigeria (Umeh, *pers comm.*). Currently, there is very little information on the potential of the papaya mealybug to infest other economic plants as well as on its life history and interactions with other host plant species in Nigeria. Yet, this is important for the formulation of a meaningful pest management programme. The objective of this study was to evaluate the potential of selected crops as suitable food host of *P. marginatus* in Nigeria.

MATERIALS AND METHODS

The study was conducted at the Crop Research Garden and Entomology Research Laboratory of the Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria at ambient conditions ($27\pm 2^{\circ}\text{C}$, $70\pm 5\%$ RH and 12:12 hour photoperiod).

Insect Culture

Pawpaw fruits infested with *P. marginatus* were collected from the Biological Control Unit of National Horticultural Research Institute (NIHORT), Idi-Ishin, Jericho, Ibadan. The culture was maintained at the Entomology Research Laboratory of the Department of Crop Protection and Environmental Biology University of Ibadan

where a larger culture was raised on 8-12 weeks old pawpaw seedlings. The insects were carefully placed on the seedlings and allowed to mate and reproduce.

Source of Planting Materials

The potential host crops seedlings evaluated in the study are listed in Table 1. *Carica papaya* and *Psidium guajava* seedlings were obtained from NIHORT while *Solanum lycopersicum* and *Abelmoschus esculentus* seeds were purchased at Premier seeds,

Ibadan. *Manihot esculenta* stem cuttings were purchased from Eagle seeds, Ibadan while the *Tectona grandis* seedlings were obtained from the Department of Forest Resources Management, University of Ibadan. One seed was sown per pot of polythene bag containing 2kg soil collected from the Crop Research Garden of the Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan.

Table 1: List of crops evaluated as host plants

Scientific name	Common name	Family	Type
<i>Carica papaya</i> L*	Pawpaw	Caricaceae	Fruit
<i>Solanum lycopersicum</i> L#	Tomato	Solanaceae	Fruit
<i>Manihot esculenta</i> Crantz #	Cassava	Euphorbiaceae	Root and Tuber
<i>Psidium guajava</i> L*	Guava	Myrtaceae	Fruits
<i>Abelmoschus esculentus</i> L.#	Okra	Malvaceae	Fruit vegetable
<i>Tectona grandis</i> L*	Teak	Lamiaceae	Tree crop

Used at 8 weeks old, # Used at 3 weeks old.

Evaluation of six tropical plant species as food host of *P. marginatus* in Ibadan, Nigeria

The six crops listed in Table 1 were evaluated for preference as food host by *P. marginatus* in the screen house. Six (6) screen cages (1.80x0.60x1.50m) each with the six plants arranged in completely randomized design in three replicates were set up at the Crop Research Garden of the Department of Crop Protection and Environmental Biology (CPEB), University of Ibadan, giving a total of 18 plants per cage. The experiment was divided into two phases; free-choice and no-choice tests.

Free-choice Test

The six host plant species used were fitted to the edges of a 50cm diameter cardboard and 100 third instar mealybugs were placed in the middle. This gave them equal opportunity to

choose their preferred host. The number of mealybugs that migrated to specific host plants at 6, 24, 48 and 72 hours after the setup was recorded.

No-choice Test

For this test, 10 third instar crawlers were carefully placed directly on the leaves of the seedlings of different host plants using a camel hair brush. Their percentage survival at 96 hours after placement, were observed and recorded.

Developmental biology study of *P. marginatus* on the six host crops

The developmental biology was investigated at ambient conditions ($27\pm 2^{\circ}\text{C}$; $70\pm 5\%$ RH and 12:12 hour photoperiod). Ovisacs of *P. marginatus* were carefully placed on the plants using a fine camel hair brush and their life cycle was studied by observing their

development on a daily basis using a hand magnifying lens. Data were collected on duration of development of the various stages of its lifecycle and weight of adult on the different hosts.

Data collection and Analysis

Data collected were subjected to one way Analysis of Variance (ANOVA) using the statistical software DSAASTAT, 2014 version and significant means were separated using Duncan's Multiple Range Test at α .05 probability level.

RESULTS

Free-choice test for host preference of *P. marginatus* on six plant species

More *P. marginatus* individuals were found on *C. papaya* than on other plants during the entire period of the free choice test (Table 2). There were significant differences in the population of *P. marginatus* at each period of observation (6 hrs, 24 hrs, 48 hrs and 72 hrs), with *C. papaya* having a significantly ($p < 0.05$) higher population (6.25, 11.5, 23 and 27.5) across all time intervals respectively. This was followed closely by *M. esculenta* which recorded a population of

4, 11.25, 18 and 20.75 respectively at each period of observation. *Solanum lycopersicum* followed up with a population of 2.75, 7.75, 15 and 17, > *P. guajava* with a population of 2.0, 5.25, 10.5 and 12.5 > *A. esculentus* with a population of 1.25, 4, 8.5 and 11.75 respectively. *Tectona grandis* had the lowest population of *P. marginatus* with 0.75, 3, 7.25 and 10.0 all through the periods of observations. While the population of *P. marginatus* on the *C. papaya* remained significantly higher than the rest at 72 hours (27.5), there was no significant difference in the populations on *M. esculenta* and *S. lycopersicum* (20.7 and 17 respectively).

No-choice test for host preference of *P. marginatus* on six host species

Percentage survival of *P. marginatus* under no-choice test for host preference is presented in Fig 1. Survival was highest in *C. papaya* (86.5%) and *M. esculenta* (77.1%). This was followed by *S. lycopersicum* (62.1%), *A. esculentus* (46.2%) and *P. guajava* (38.5%). *Tectona grandis* (29.2) had the lowest percentage surviving *P. marginatus* after 96 hrs.

Table 2: Population of *P. marginatus* on different host species under free-choice test for host preference at CPEB, University of Ibadan (Mean $\pm$ S.E)

Crops	6 hours	24 hours	48 hours	72 hours
<i>Carica papaya</i>	6.25 $\pm$ 1.5a	11.50 $\pm$ 2.2a	23.00 $\pm$ 3.5a	27.50 $\pm$ 2.9a
<i>Solanum lycopersicum</i>	2.75 $\pm$ 0.7ab	7.75 $\pm$ 0.6ab	15.00 $\pm$ 1.7b	17.00 $\pm$ 1.3b
<i>Manihot esculenta</i>	4.00 $\pm$ 0.7ab	11.25 $\pm$ 1.0a	18.00 $\pm$ 1.2b	20.75 $\pm$ 1.3b
<i>Psidium guajava</i>	2.00 $\pm$ 0.4b	5.25 $\pm$ 0.6bc	10.50 $\pm$ 0.3c	12.50 $\pm$ 0.4c
<i>Abelmoschus esculentus</i>	1.25 $\pm$ 0.2b	4.00 $\pm$ 0.7bc	8.50 $\pm$ 0.2c	11.75 $\pm$ 1.2c
<i>Tectona grandis</i>	0.75 $\pm$ 0.2b	3.00 $\pm$ 0.7c	7.25 $\pm$ 0.4c	10.00 $\pm$ 1.4c

Mean values $\pm$ standard error within a column followed by the same letter(s) are not significantly different at $p > 0.05$ using Duncan's Multiple Range Test (DMRT).

Figure 1: Percentage survival of *P. marginatus* on different host species under no-choice test for host preference at CPEB, University of Ibadan

Bars on which the same letters are shown are not significantly different at $\alpha.05$ using Duncan's Multiple Range Test (DMRT).

Lifecycle of *P. marginatus* on Six Different Host Species

The mean number of days taken for *P. marginatus* to develop on six host species at the University of Ibadan is presented in Table 3. For all crops, development of eggs generally occurred within 6 days with the shortest (6.12 ± 0.1) and longest (6.82 ± 0.3) egg development duration occurring in pawpaw and tomato seedlings respectively. No significant differences ($p > 0.05$) were observed amongst the time taken for *P. marginatus* egg to develop into first instar on all crop types. Development of first instar larvae of *P. marginatus* was shortest (5.90 ± 0.3) in pawpaw and longest (6.81 ± 0.5) in teak. There was a significant difference ($p < 0.05$) between 1st instar developmental period on pawpaw and teak. Other crops did not show any significant difference in first instar developmental time ($p > 0.05$) from pawpaw or teak. Development of 2nd instar larvae was generally shorter for females than

males in all crop types. A significant difference ($p < 0.05$) was observed in the time taken for 2nd instar larvae males to develop on pawpaw (6.38 ± 0.5) compared to Okra (7.01 ± 0.4) or Teak (7.32 ± 0.3). All these 3 crops did not differ significantly ($p < 0.05$) in developmental time of male 2nd instar larvae when compared with tomato, cassava and guava. The developmental time of 2nd instar female larvae did not however differ significantly amongst all crops. Unlike the 2nd instar larvae, the development of 3rd instar female larvae was generally longer than that of males in all crop types. The lowest developmental periods for male and female 3rd instar larvae were observed in cassava (3.51 ± 0.4 ; 5.7 ± 0.4 respectively) and pawpaw (3.72 ± 0.4 ; 5.82 ± 0.5 respectively) while the highest values (4.91 ± 0.1 ; 6.32 ± 0.6 respectively) were observed in teak. The developmental time of 3rd instar male *P. marginatus* on cassava and pawpaw were significantly lower ($p > 0.05$) than those of

guava, okra and teak but not from tomato. On the contrary, developmental time of 3rd instar female *P. marginatus* on cassava and pawpaw were not significantly different ($p>0.05$) from guava and okra. A similar trend was observed in the developmental time of male 4th instar larvae on all crop types.

Total developmental period of male and female *P. marginatus* from egg to adult was shortest in pawpaw (25.91 ± 0.6 and 23.52 ± 0.1 respectively) and longest in teak (30.62 ± 0.80 and 25.76 ± 0.4). The total developmental period of male *P. marginatus* on pawpaw was significantly lower than those of tomato, guava okra and teak but not cassava. Similarly, the total developmental

period for female *P. marginatus* on pawpaw was significantly lower than okra and teak, but did not differ significantly from cassava, tomato and guava.

Table 4 shows the mean weight of adult *P. marginatus* reared on different host species. The highest weight of 3.90 mg was recorded on *M. esculanta*. Adults reared on *C. papaya* had a mean weight of 3.58mg. The lowest mean weight of adult *P. marginatus* was recorded on *T. grandis* (2.98 mg). Mean adult weights of 3.45mg, 3.20 mg and 3.08mg were recorded on *A. esculentus*, *P. guajava* and *S. lycopersicum* respectively. However, there was no significant difference in the mean weight of adult *P. marginatus* reared on all six crop types.

Table 3: Duration of development (Days) of *P. marginatus* reared on six host species at CPEB, University of Ibadan

Host	Total								
	Egg	First	Second		Third		Fourth		Total
			Male	Female	Male	Female	Male	Female	
Pawpaw	6.12 $\pm$ 0.1a	5.90 $\pm$ 0.3a	6.38 $\pm$ 0.5a	5.68 $\pm$ 0.2a	3.72 $\pm$ 0.4a	5.82 $\pm$ 0.5ab	3.82 $\pm$ 0.3a	25.91 $\pm$ 0.6a	23.52 $\pm$ 0.1a
Tomato	6.82 $\pm$ 0.3a	6.01 $\pm$ 0.4ab	6.56 $\pm$ 0.2ab	5.81 $\pm$ 0.1a	4.00 $\pm$ 0.2ab	6.15 $\pm$ 0.2b	4.56 $\pm$ 0.3b	27.95 $\pm$ 0.5b	24.79 $\pm$ 0.1abc
Cassava	6.24 $\pm$ 0.4a	6.15 $\pm$ 0.5ab	6.56 $\pm$ 0.2ab	5.80 $\pm$ 0.5a	3.51 $\pm$ 0.4a	5.70 $\pm$ 0.4a	3.70 $\pm$ 0.1a	26.16 $\pm$ 0.3a	23.89 $\pm$ 0.1ab
Guava	6.53 $\pm$ 0.3a	6.30 $\pm$ 0.3ab	6.52 $\pm$ 0.3ab	5.93 $\pm$ 0.3a	4.13 $\pm$ 0.4b	5.90 $\pm$ 0.4ab	4.81 $\pm$ 0.5bc	28.29 $\pm$ 0.1b	24.66 $\pm$ 0.1abc
Okra	6.37 $\pm$ 0.2a	6.50 $\pm$ 0.3ab	7.01 $\pm$ 0.4b	6.12 $\pm$ 0.3a	4.35 $\pm$ 0.5b	6.00 $\pm$ 0.7ab	4.50 $\pm$ 0.4b	28.73 $\pm$ 0.4b	24.99 $\pm$ 0.3bc
Teak	6.54 $\pm$ 0.4a	6.81 $\pm$ 0.5b	7.32 $\pm$ 0.3b	6.09 $\pm$ 0.2a	4.91 $\pm$ 0.1c	6.32 $\pm$ 0.6b	5.04 $\pm$ 0.4c	30.62 $\pm$ 0.8c	25.76 $\pm$ 0.4c

Means values $\pm$ Standard error within a column followed by the same letter(s) are not significantly different ($p > 0.05$) using Duncan's Multiple Range Test (DMRT).

Table 4: Mean weight of adult *P. marginatus* reared on different hosts species at CPEB, University of Ibadan

Crops	Weight (mg)
<i>Solanum lycopersicum</i> L	3.08 $\pm$ 0.5a
<i>Carica papaya</i> L	3.58 $\pm$ 0.2a
<i>Abelmoschus esculentus</i> L	3.45 $\pm$ 0.2a
<i>Tectona grandis</i> L	2.98 $\pm$ 0.4a
<i>Manihot esculenta</i> Crantz	3.90 $\pm$ 0.6a
<i>Psidium guajava</i> L	3.20 $\pm$ 0.4a

Mean values $\pm$ Standard error followed by the same letters are not significantly different ($p>0.05$) using Duncan's Multiple Range Test (DMRT).

DISCUSSION

Paracoccus marginatus preferred *C. papaya* followed by *M. esculanta* compared to the other hosts as revealed by the free-choice and no-choice tests for host preference. This was followed by *S. lycopersicum*, *A. esculentus*, and *P. guajava*. This agrees with the findings of Galanihe *et al.* (2010) and Muniappan *et al.* (2008) that *C. papaya* and *M. esculanta* are favoured food hosts of *P. marginatus*. Cham *et al.* (2011) also supported this and reported that the host preference of *P. marginatus* seemed to be influenced by the presence of latex.

Tectona grandis was the least suitable host plant among the six evaluated. Similarly, Marohasy (1997) was able to identify *Gossypium hirsutum* L., *Ageratum houstonianum* Miller, and *Clerodendrum cunninghamii* Benth as less suitable host plants for the development of *Phenacoccus parvus* compared to *Lantana camara*. This indicates that some hosts are not preferred.

Egg to adult emergence occurred in about 25-30 days for the males, and 23-25 days for the female on all plant species evaluated. Eggs were observed to be laid in an egg sac which is bigger than the body length and the incubation period took about 6-7 days. Similar biology observations were reported by Kumar *et al.* (2014); Miller and Miller (2002); Walker *et al.* (2011); Muniappan *et al.* (2009) and Singh and Beera (2010) who reported that the egg-laying of *P. marginatus* was usually in a small white ovisac and egg hatching occurred in about 5-10 days. Females had three nymphal instars, while males had an additional pupa stage. Male had longer developmental periods than the females due to the additional pupa stage. This is in line with the findings of Walker *et al.* (2011), who reported three nymphal instars besides

pupa and a winged adult stage in male *P. marginatus*.

Paracoccus marginatus seemed to be able to develop and survive on all the plant species, although the variation in number of days shows that of the six different host species, *C. papaya* and *M. esculentus* favoured its development the most. In polyphagous insects, life history can vary with the plant species it feeds on. Different plant species provide different nutritional quality and chemical constituents, which can affect the development, reproduction and survival of an insect. The differences observed in the life history of *P. marginatus* in the different plant species may be due to nutritive factors, allelochemical compounds, and physical differences in leaf structures (Amarasekare *et al.*, 2008). As have been reported by other researchers, different host plant species have affected the life history parameters of other mealybug species. The developmental time of female *Planococcus kraunhiae* (Kuwana) was shorter when reared on germinated *Vicia faba* L. seeds than on leaves of a *Citrus* sp. L. and on *Cucurbita maxima* Duchesne, and it survived better when reared on germinated *V. faba* seeds than on citrus leaves (Narai and Murai, 2002). Longer pre-reproductive period and a higher progeny production were observed for *Rastrococcus invadens* Williams reared on different varieties of *Mangifera indica* L. (Bovida and Neuenschwander, 1995). The pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green), was able to develop equally well on *Cucurbita pepo* L. as on *C. maxima* (Serrano and Lapointe, 2002).

CONCLUSION

It is important to know the developmental biology of an insect so as to understand its distribution and adopt an effective method of management. Apart from *C. papaya*, which

is the most preferred food host, several other economically important crops on which it has ability to complete life cycle conveniently; such as *S. lycopersicum* L, *M. esculenta* Crantz, *P. guajava* L, *A. esculentus* L and *T. grandis* L are at serious risk. This underscores the need to search for a sustainable pest management procedure for the pest. The information obtained from this study is vital to the development of appropriate Integrated Pest Management (IPM) programme for the pest.

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