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Seasonal Abundance of *Paracoccus marginatus* (Williams and Granara de Willink) (Hemiptera: Pseudococcidae) and Damage to Papaya Seedlings in Three Agroecological Zones in Southwestern Nigeria

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Abstract

The Papaya Mealybug, *Paracoccus marginatus* Williams and Granara de Willink, is an invasive species. The abundance of the papaya mealy bug and its damage to seedlings were investigated in the field at three agro-ecological zones: which includes Akure (Rainforest), Ogbomoso (Guinea savannah), Ibadan (Derived savannah) in the 2016 growing seasons. At each site, 10 healthy mother plants with fruit (>17cm GBH) were randomly selected from which five infested and non-infested leaves (fifth to the 13th leaf from the top) were randomly selected. Number of infesting larvae were counted manually. Infestation, typified by woolly presence of the larvae on the leaves was 80.08% on the leaves and 75.58.6% on the fruits. The most susceptible papaya was recorded for Ogbomoso in March. This was done to determine the combined effects of time of the year (period) and geographical location (Agroecology) on populations and infestations of adult and immature *P. marginatus* on fruits and leaves of Pawpaw, and it was not significantly different ($p>0.05$) from the other levels of infestation at the other locations in the same month of March. The highest population of *P. marginatus* on Pawpaw leaves (60.33) and fruits (59.83%) was recorded for Akure in March. Results showed that there was general reduction in mean number of healthy leaves of papaya seedlings as the age of the seedlings increased. It could be concluded that *P. marginatus* were able to establish colonies on papaya seedlings, it is only in rare cases on a few susceptible genotypes, that mealybugs colonize plants during vegetative stage.

Keywords: *Carica papaya*, papaya mealybug, *Paracoccus marginatus,* Agroecology.

INTRODUCTION

Papaya fruit is a significant source of Vitamin C and foliate. Papaya skin, pulp and seeds also contain a variety

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of phytochemicals, carotenoids and polyphenols. Over the years, several insect pests have been documented to infest *Carica papaya* (Caricaceae). All of which have never resulted in economic loss. The only exception to this is the Papaya Mealybug (*Paracoccus marginatus)*, an invasive species documented to resulting in substantive economic loss to Papaya, especially across Africa (David *et al*., 2011). Colonies of *P. marginatus* excrete honeydew which coats the surface of papaya fruits thereby fouling plant leaves. More so, heavy infestations of thin-skinned papaya variety can make them unmarketable and cause serious economic losses. Due to the increasing distribution of *P. marginatus* as it continues to invade new countries in Africa including Ghana and Tanzania, it is paramount that geographical influences on *P. marginatus* be studied as it poses serious threat to pawpaw farmers in tropical countries including Nigeria.

Paracoccus marginatus is a small sap-sucking insect in the family, Pseudococcidae. It parasitizes a number of different hosts, including economically important tropical fruit trees and ornamental plants. It is native to Mexico and/or Central America (Miller *et al*., 1999). It has the capacity to cause serious damage to Papaya, other tropical fruits and ornamentals such as *Annona* and *Hibiscus* spp. (Miller and Miller, 2001). The insect abundance and distribution are regulated by several biotic and abiotic factors and their interactions (Ricklefs, 2005). It is against this background that this research work investigated the seasonal abundance and infestation level of Papaya mealybug *P. marginatus*. With a view of assessing the level of damage caused by the papaya mealybug on *Carica papaya*.

MATERIALS AND METHODS

Study Area

This study was conducted in three agroecological zones of Nigeria namely Akure (Rainforest), Ogbomoso (Guinea savannah) and Ibadan (Derived savannah) which represent the major three ecological zones in Southwestern Nigeria (Figure 1). The study site in each of these agroecological zones were divided into three replicates, which made a total number of nine sites in all. In order to ensure adequate coverage of the area of the study, the selection of the sites was based on the areas with relative abundance of the papaya mealybugs.

Combined Effects of Time of the Year (January to December 2016) and Geographical Location (Agroecology) on Infestation of *P. marginatus* on leaves and fruits of Pawpaw

Ten papaya plants were selected at each site. five Infested leaves and five infested fruits were counted and recorded in each of the ten plants. Therefore, the counts were rated following the system developed by Galanihe *et al*. (2010) with slight modifications. The level of infestation was ranked as follows:

0 = No Infestation;
1 = <25% of Leaves/Fruits Looks Healthy, Tips/Side Shoots Curly;
2 = <25% of Leaves/Fruits Covered with Papaya Mealybug (PM);
3 = 25-50% of Leaves/Fruits Covered with Papaya Mealybug (PM);
4 = >50% of Leaves/Fruits Covered with Papaya Mealybug (PM);

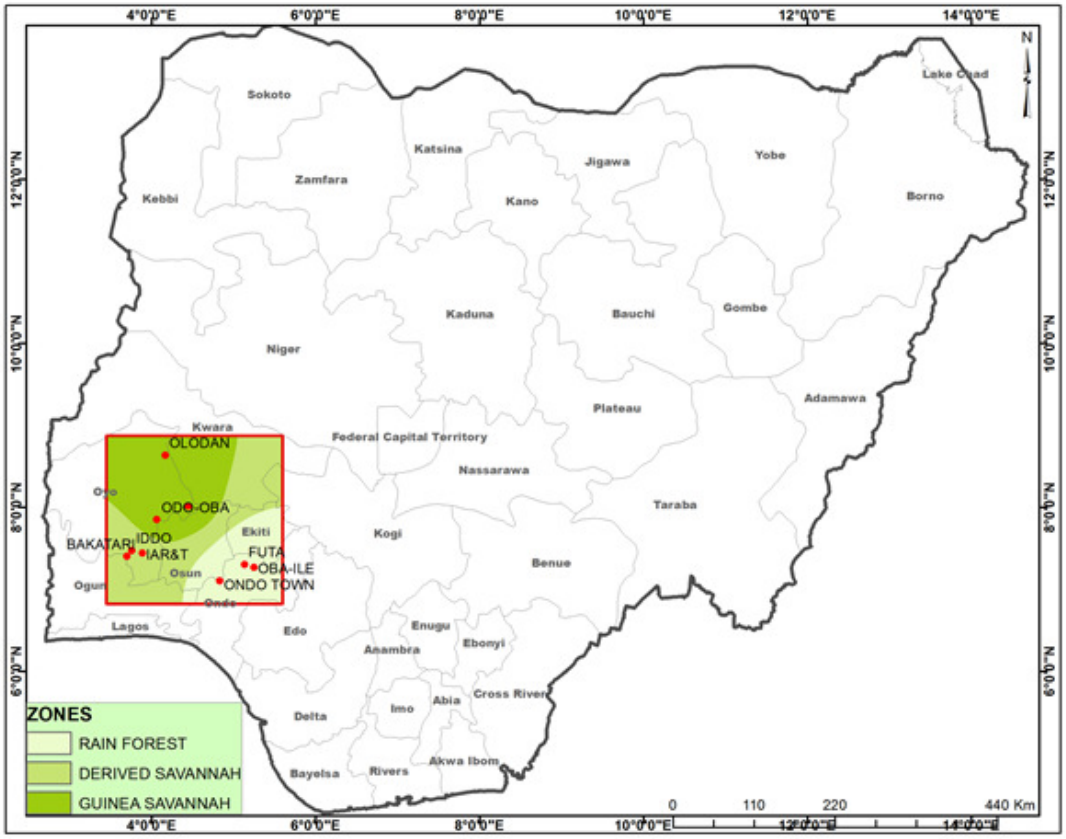

Figure 1: The study sites at the three agroecological zones in Southwestern Nigeria

Combined effects of time of the year (period) and geographical location (Agroecology) on population of *P. marginatus* on fruits and leaves of Pawpaw

Five papaya plants were selected at each site. Five infested leaves and five infested fruits were counted and recorded in each of the ten plants. Therefore, the counts were rated following the system developed by Galanihe *et al*. (2010) with slight modifications. This was done to determine the population of adult and immature *P. marginartus.*

Damage Assessment of Mealybug on Papaya Seedlings

Six leaves (two from bottom, two from middle and two from top) were selected as a sampling unit. The leaves were randomly selected and carefully detached to prevent damage to the specimen. The damage assessment of *P. marginatus* on *C. papaya* seedlings was investigated in the Experimental Laboratory of the National Horticultural Research Institute (NIHORT) Ibadan. Six insectary boxes were provided for each of the ecological zones. Hence each ecological zone had a total of six insectary boxes.

The mealybugs were raised on *C. papaya* seeds of "Solo variety" obtained from NIHORT, Ibadan. The seeds were planted in seedling buckets. Three seedling buckets were kept into each insectary box. After six weeks, twelve (six copulating pairs) nymph of papaya mealybug, *P. maginatus* were introduced to the pawpaw seedlings with the

aid of a camel hair brush. The seedlings were kept for another three weeks for the purpose of acclimatization and to allow establishment of *P. marginatus* on the plants. The number of leaves for this period was monitored at three days interval for the three weeks. This was recorded in a sample sheet (Appendix 2).

Statistical Analysis

The population and infestation of *P. marginatus* on both the fruits and the leaves were recorded. Infestation index was computed according to Puntener (1981) using the formula:

$$\text{Infestation index} = \sum \frac{(ab)}{NR} * 100$$

Where N = Total number of investigated plants
R = Highest category value
a= Number of plant parts in each category
b= Value of category

The data obtained were subjected to Analysis of Variance (ANOVA) at 95% confidence limit. The means of the obtained values were separated using Tukey's test after Analysis of Variance (ANOVA). All these were done using the Statistical Packages for Social Sciences (SPSS version 21.0).

RESULTS

Combined effects of time of the year (period) and geographical location (Agroecology) on infestation of *P. marginatus* on leaves of Pawpaw

The infestation level of *Paracoccus marginatus* on leaves of Pawpaw for different locations at different periods is presented on Table 1. The highest level of infestation (80.08%) which was recorded for Ogbomoso in March was not significantly different ($p>0.05$) from the other levels of infestation recorded for the other locations in the same month of March. The lowest level of *P. marginatus* infestation; (5.83%) was recorded at Ibadan in August. This value was not significantly different ($p>0.05$) from those recorded in July at Akure (14.75%), Ibadan (14.75%), and those recorded in August at Akure (6.00%), Ogbomoso (6.42%), and September for Ogbomoso (15.50%), Akure (13.50%) and Ibadan (14.25%).

Table 1: Monthly variation of mealy bug, *Paracoccus marginatus* infestation on pawpaw leaves in three agroecologies in South-west Nigeria

Location	Period of the year											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Ogbomoso	2.92±0.6^{f-h}	61.83±3.1^{i}	80.08±3.0^{j}	8.50±1.3^{e-h}	29.17±3.7^{dh}	3.42±1.4^{bg}	17.25±1.5^{b}	6.42±.5^{a}	15.50±1.5^{ab}	8.42±1.1^{bc}	22.40±1.2^{bf}	0.67±0.8^{b-d}
Akure	2.50±0.3^{e-h}	61.08±0.5^{i}	79.75±3.6^{j}	3.42±1.3^{gh}	22.17±5.4^{b-e}	17±1.8^{b}	14.75±0.6^{ab}	6.00±0.6^{a}	3. 50±0.6^{ab}	7.33±1.1^{b}	19.33±0.9^{bd}	2.50±0.8^{b-f}
Ibadan	35.08±1.7^{h}	58.08±2.3^{i}	78.58±2.7^{j}	1.67±0.4^{e-h}	29.08±3.7^{dh}	13.17±1.2^{bg}	14.75±0.6^{ab}	5.83±0.8^{a}	4.25±0.5^{ab}	7.92±0.8^{b}	19.50±1.0^{bd}	2.s92±0.5^{b-g}

Means followed by same alphabet are not significantly different at $p<0.05$ using Tukey's post hoc test.

Combined effects of time of the year (period) and geographical location (Agroecology) on infestation of *P. marginatus* on fruits of Pawpaw

Table 2 shows the infestation level of *Paracoccus marginatus* on fruits of Pawpaw for different locations at different periods. The highest level of infestation (75.58%) which was recorded for Ogbomoso in March was not significantly different ($p>0.05$) from infestation levels recorded at all other locations in March and Ogbomoso at February (64.00%). The lowest level of *P. marginatus* infestation; (4.75%) was recorded at Akure and Ibadan in August. This value was not significantly different ($p>0.05$) from those recorded in the sampled populations for the month of July, August, September, October and Ibadan for the month of November (17.08%) and Akure for June (17.08%) and July (13.83%).

Combined effects of time of the year (period) and geographical location (Agroecology) on population of *P. marginatus* on leaves of Pawpaw

Table 3 shows the population of *Paracoccus marginatus* on leaves of Pawpaw for different locations at different periods. The highest population of *P. marginatus* on Pawpaw leaves; 60.33 which was recorded for Akure in March was not significantly different ($p>0.05$) from populations recorded at Ogbomoso (57.67%) and Ibadan (55.83%) in the same month and Ogbomoso for February (50.83%). The lowest leaf population of *P. marginatus*; 7.17% was recorded at Ibadan in August. This value was not significantly different ($p>0.05$) from those recorded in August at Ogbomoso (7.83%), Akure (7.50%), and those recorded in July at Ogbomoso (12.17%).

Table 2: Monthly variation of mealy bug, *Paracoccus marginatus* infestation on pawpaw fruits in three agroecologies in South-west Nigeria

Location	Period of the year											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Ogbomoso	33.58±1.1^{f}	64.00±5.8^{gi}	75.58±0.6^{i}	8.67±1.8^{bd}	21.00±2.1^{cf}	19.92±3.0^{d}	5.67±1.5^{a-c}	6.25±1.3^{ab}	5.33±0.6^{ac}	6.67±1.7^{ad}	20.00±0.7^{cf}	19.92±1.6^{ce}
Akure	33.00±1.4^{f}	59.00±0.6^{gh}	71.58±0.6^{hi}	20.83±0.6^{cf}	17.08±4.3^{ad}	.83±1.6^{a-c}	7.82±2.8^{a-c}	4.75±0.0^{a}	3.78±0.7^{ac}	6.83±0.3^{ad}	9.17±1.1^{bd}	30.08±1.0^{df}
Ibadan	30.08±1.7^{ef}	52.58±4.6^{g}	74.17±4.7^{i}	21.08±0.7^{cf}	21.00±2.1^{cf}	9.92±2.8^{c-e}	8.92±2.8^{a-c}	5.65±0.0^{a}	3.00±0.2^{a-}	7.08±0.7^{ad}	7.08±1.5^{ad}	20.83±0.9^{cf}

Means followed by same alphabet are not significantly different at p<0.05 using Tukey's post hoc test.

Table 3: Monthly variation of mealy bug, *Paracoccus marginatus* population on pawpaw leaves in three agroecologies in South-west Nigeria

	Period of the year											
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Ogbomoso	27.33±0.6^{hk}	50.83±2.6^{n}	57.67±2.8^{n}	27.62±3.3^{ik}	30.83±3.1^{jm}	20.40±2.6^{di}	12.17±0.3^{ad}	7.83±0.3^{ac}	17.66±1.3^{dg}	21.93±2.1^{ej}	26.50±1.0^{fk}	21.83±0.9^{ej}
Akure	28.17±1.6^{il}	38.67±1.6^{m}	60.33±0.6^{n}	33.42±1.3^{jm}	17.35±3.1^{cf}	16.83±2.4^{be}	16.82±1.4^{be}	7.50±0.0^{ab}	17.33±0.4^{cf}	19.83±1.3^{di}	18.83±1.4^{di}	22.00±1.1^{ej}
Ibadan	27.17±0.6^{gk}	37.50±0.5^{lm}	55.83±1.86^{n}	32.50±0.2^{km}	31.17±3.1^{jm}	24.00±1.2^{ek}	15.83±1.4^{be}	7.17±0.3^{a}	18.00±0.5^{dh}	23.33±0.9^{ek}	21.00±1.2^{di}	22.83±0.3^{ej}

Means followed by same alphabet are not significantly different at p<0.05 using Tukey's post hoc test.

Combined effects of time of the year (period) and geographical location (Agroecology) on population of *P. marginatus* on fruits of pawpaw

The population of *Paracoccus marginatus* on fruits of Pawpaw for different locations at different periods is shown on Table 4. The highest population of *P. marginatus* on Pawpaw fruits (59.83%), which was recorded for Akure in March was not significantly different ($p>0.05$) from those observed in other locations for the same month and Ogbomoso at February (53.67%). The lowest fruit population of *P. marginatus* (7.33%), was recorded at Ibadan in August. This value was not significantly different ($p>0.05$) from those recorded in other locations in the same month and for the months of July and September in Ogbomoso, Akure and Ibadan.

Damage Assessment of Papaya Seedlings inoculated with *Paracoccus marginatus.*

Table 5 shows the mean number of healthy leaves after infestation with *P. marginatus* obtained from different ecological zones. This experiment was carried at the Insectary experimental laboratory of the National Horticultural Research Institute Ibadan. There was general reduction in mean number of healthy leaves of papaya seedlings as the age of the seedlings increased. However, the control showed an increase in the number of leaves with age. For instance, mean of healthy leaves (7.33) was recorded on day 45 while day 63 showed a higher number (8.33) but both were not significantly different ($p<0.05$) from each other.

Akure Rain Forest

Plates 1 show the extent of morphological damage after infestation with *P. marginatus* obtained from rain forest ecological zone. Highest number of healthy leaves recorded at Federal University of Technology Akure (7.50 leaves) was significantly different ($p<0.05$) from (7.17 leaves) obtained from Ondo town but not significantly different ($p>0.05$) from Oba-ile or the control.

Day 63 recorded the lowest number of healthy leaves for FUTA (2.00), Ondo town (1.33) and Oba-ile (1.67). These values of healthy leaves were significantly different ($p<0.05$) from the control.

Ogbomoso Guinea Savannah

Although Odo-Oba had the highest mean number 7.80 of healthy leaves on day 45. The mean value of healthy leaves was not significantly different from the mean values recorded at Olodan (6.83) and control at 95% confidence limit. Both were significantly different from 6.50 recorded at Abogunde. The least number of healthy leaves was recorded at day 63. Mean values of healthy leaves obtained at Abogunde, Odo-oba and Olodan were not significantly difference ($p>0.05$) from one another but significantly different ($p<0.05$) from the control. Plates 2 show the pictorial extent of morphological damage at varying period after infestation.

Ibadan Derived Savanna

The highest mean number of healthy leaves (7.33) was obtained at the Institute of Agricultural Research and Training (IAR&T), and was not significantly different ($P>0.05$) from the control (7.33). The lowest mean number of healthy leaves (1.00) on day 63 was recorded on those obtained at the (IAR&T) but this value was not significantly different ($p>0.05$) from the Iddo and Bakatari. However, they were significantly different ($p<0.05$) from the control (8.33). Plates 3 show the morphological damage observed at different period.

Table 4: Monthly variation of mealy bug, *Paracoccus marginatus* population on pawpaw fruits in three agroecologies in South-west Nigeria

	Period of the year											
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Ogbomoso	28.67±0.4^{fi}	53.67±0.6^{k}	59.50±0.8^{k}	25.67±2.3^{dh}	27.50±2.2^{eh}	21.00±2.8^{bg}	13.16±1.2^{ab}	7.83±1.7^{a}	17.67±0.4^{bd}	21.67±2.4^{bg}	25.33±0.7^{ch}	21.17±1.1^{bf}
Akure	28.67±2.9^{f}	38.50±0.5^{j}	59.83±1.3^{k}	29.50±1.3^{gj}	21.33±4.4^{bg}	19.33±2.4^{bf}	16.00±1.7^{ac}	7.32±0.3^{a}	16.67±0.4^{ad}	18.67±0.4^{be}	19.33±1.2^{bf}	22.67±1.1^{bg}
Ibadan	24.33±2.6^{ch}	37.33±0.6^{ij}	57.50±0.5^{k}	31.67±0.4^{hj}	30.00±3.1^{gj}	21.33±0.6^{bg}	15.83±1.5^{ac}	7.33±0.1^{a}	17.84±0.6^{bd}	21.83±0.7^{bh}	19.50±0.7^{bf}	21.67±1.3^{bg}

Means followed by same alphabet are not significantly different at p<0.05 using Tukey's post hoc test.

Table 5: Mean number of healthy leaves after inoculation with *Paracoccus marginatus* obtained from different location in three different ecological zones.

		Mean number of healthy leaves/ days after inoculation						
Zone	Location	45	48	51	54	57	60	63
Rain Forest	FUTA	7.50±0.43^{e}	6.33±0.49^{de}	5.50±0.43^{cd}	4.00±0.37^{bc}	3.17±0.48^{ab}	2.80±0.43^{ab}	2.00±0.45^{a}
	Ondo Town	7.17±0.60^{d}	5.67±0.42^{cd}	4.83±0.48^{bc}	4.33±0.33^{bc}	3.17±0.40^{ab}	2.17±0.40^{a}	1.33±0.49^{a}
	Oba-Ile	7.33±0.67^{e}	6.33±0.67^{de}	5.50±0.62^{cde}	4.50±0.56^{bcd}	3.50±0.56^{ab}	2.50±0.56^{ab}	1.67±0.42^{a}
Guinea Savanna	Abogunde	6.50±0.43^{d}	5.33±0.42^{de}	4.67±0.33^{cd}	4.00±0.37^{bcd}	3.50±0.43^{bc}	2.67±0.33^{ab}	1.67±0.42^{a}
	Odo-Oba	7.80±0.48^{e}	6.50±0.42^{de}	6.00±0.58^{cde}	4.67±0.49^{bcd}	3.67±0.49^{abc}	2.83±0.60^{ab}	2.00±0.58^{a}
	Olodan	6.83±0.60^{e}	5.50±0.56^{cd}	4.67±0.56^{bcd}	4.33±0.49^{bc}	3.33±0.49^{abc}	2.67±0.49^{ab}	1.83±0.48^{a}
Derived Savannah	IAR & T	7.33±0.49^{e}	6.33±0.49^{de}	5.00±0.52^{cd}	3.83±0.40^{bc}	2.66±0.42^{ab}	1.67±0.33^{a}	1.00±0.37^{a}
	Iddo	7.33±0.61^{d}	6.00±0.52^{cd}	5.00±0.37^{bc}	4.67±0.49^{bc}	3.33±0.49^{ab}	2.33±0.43^{a}	1.50±0.34^{a}
	Bakatari	7.17±0.60^{e}	5.67±0.42^{de}	4.67±0.42^{cd}	4.00±0.45^{bcd}	3.33±0.42^{bc}	1.83±0.31^{ab}	1.00±0.14^{a}
	CONTROL	7.33±0.43^{e}	7.50±0.60^{e}	7.50±0.56^{e}	7.67±0.61^{e}	7.67±0.61^{e}	7.83±0.48^{e}	8.33±0.56^{e}

Means followed by the same alphabets in the same column are not significantly different at p>0.05 using Tukey's post hoc test.

Plate 1: Effect of infestation by *P. marginatus* on seedlings of *C. papaya* in the Screenhouse

Plate 2: Effect of infestation by *P. marginatus* on seedlings of *C. papaya* in the Screenhouse

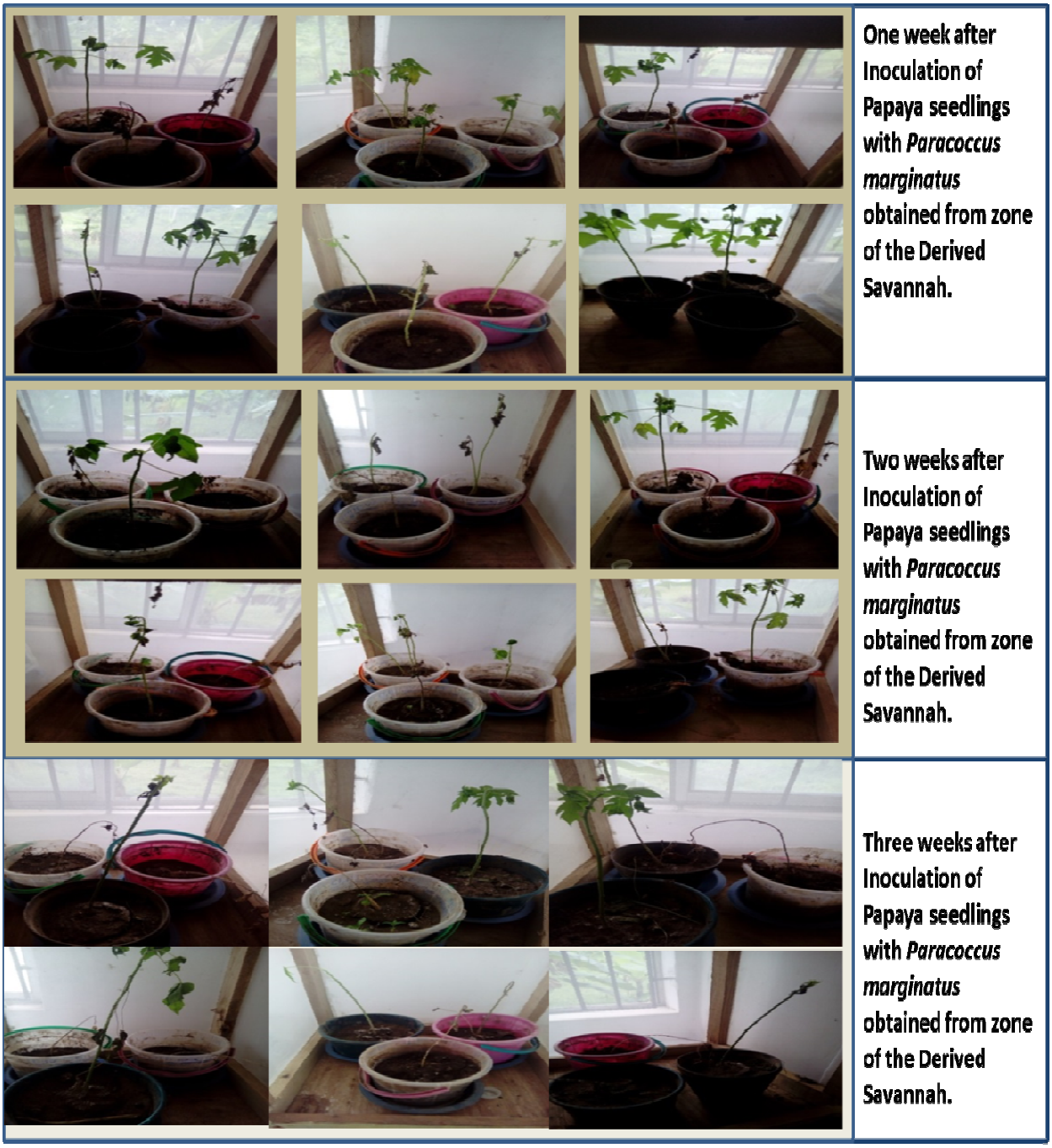

Plate 3: Effect of infestation by *P. marginatus* on seedlings of *C. papaya* in the Screenhouse

DISCUSSION

Effect of different ecologies on the infestation level of *Paracoccus marginatus* on leaves and fruits of Pawpaw

The differences observed in the infestations between the agroecological zones could be influenced by climatic factors, plant cultivation method and the presence of natural predators, parasitoids and pathogens (William *et al.,* 2014). This played significant role in the increase in the population of the papaya mealybug on leaves and fruits of pawpaw in Ogbomoso.

Conversely, the high population growth of *P. marginatus* on the leaves and fruits of pawpaw in Ogbomoso led to a corresponding increase in the percentage level of attack. This suggests that if the population was low, the percentage attack will itself be reduced, and vice versa. This observation is consistent with the findings of William *et al*. (2014) that reported a corresponding increase in infestation in the highest population of *P. matginatus* observed at Dimembe Village compared to Paslaten Village in North Minahasa regency of North Sulawesi Province of Indonesia.

Furthermore, the geographic distribution and infestation of insects such as *P. marginatus* is determined by agro-ecosystem environment (Babasaheb *et al.,* 2012). It is largely governed by interactions between abiotic (such as temperature, humidity, rainfall, soil factors, pollutants) and biotic (such as crop-plants, weeds, insect-pests, pathogens, nematodes) components. Hence, in the context of high severity of infestation recorded at Ogbomoso compared to other agroecological zones, it is probable that the composition of the agro-ecosystem resulted in altitude wise shift in the infestation recorded.

Monthly Variation in Population and Infestation of *Paracoccus marginatus* on leaves and fruits of *Carica papaya*

The result evinced that the highest population of *P. marginatus* on Pawpaw leaves and fruits was recorded in March while the lowest population of *P. marginatus* on Pawpaw leaves was recorded in the month of August. This is in line with the condition of rainfall. Changes in population abundance indicate a close relationship between the amount of rainfall and the growth of mealybug populations, where the highest population coincides with the dry period of the season Mamahit *et al.* (2009). This condition indicates a relationship between the population growth rate with the surrounding environment as explained by Painter (1951) and Chapman (1971). Williams *et al*. (2014) reported that mealybug take approximately 2 to 3 months to grow properly when climatic conditions support, such as low rainfall. In contrast, when the climatic conditions are not suitable, for example; in months with more amount of rainfall like August, the mealybug populations decline. More so, the high population in the dry season such as March is a common phenomenon that has long been known on tropical insects (Rauf, 1999).

In a study by William *et al.* (2014), observations on the abundance of population of *P. marginatus* done from the papaya mealy bug manifested overtly considerable differences in their infestation rate at different periods of the year. The highest infestation of *P. marginatus* on Pawpaw leaves and fruits was recorded in March, while the lowest infestation on Pawpaw leaves was obtained in the month of August. Siswanto *et al*. (2008) suggested that when the population of *P. marginatus* was high, the insects tend to aggregate, thus create more damage. Meanwhile when the population is low, the insect tended to distribute randomly or regularly, a distribution common in insects. It is probable that this might have played a role in the result obtained. In addition, the high values obtained in the month of March might be due to the presence of larger broad leaves compared to the smaller narrow leaves on the plant in August as the occupying area have

been reported to increase the degree of infestation in *P. marginatus* (Mani Chellappan *et al*., 2013).

Combined effects of time of the year (period) and geographical location of (Agroecology) on infestation and Population of *P. marginatus* on Pawpaw leaves and Fruits.

The effect of time and its interactive effect on geographical location assayed revealed that papaya mealybug infestation on leaves of *C. papaya* was highest in March at Ogbomoso and lowest in August at Ibadan. Similarly, papaya mealybug infestation on fruits of *C. papaya* was highest in March at Ogbomoso and lowest in August at Ibadan and Akure.

The result of the interactive effect of time of the year and geographical location recorded evinced that the population of *P. marginatus* on leaves and fruits of *C. papaya* was highest in March at Akure and the lowest in August at Ibadan.

Generally, ecological factors, whether biotic or abiotic do not just act independently of one another. Two or more factors may interact to complicate interpretation of data obtained through ecological studies (Omoloye, 2008). It is probable that the combined interaction between period and geographical location is the reason for the observed result the papaya mealy bug infestation and population. More so, it is probable that the type of vegetation found in the ecological zone might have played a role in the abundance and population of insect. Masters *et al.* (1988) stated the role of foliage in causing improved insect performance. It is likely that the type of vegetation cover in the rain forest, which is less to those in the guinea savannah, might have paved way for the observed difference in the mean percentage population and infestation of *P. marginatus*.

Leaves Damage Assessment of Papaya Seedlings inoculated with *Paracoccus marginatus*.

Generally, there was a reduction in the mean number of healthy leaves of papaya seedlings as the age of the seedlings increased. Overtime, the leaves of healthy Papaya seedlings infested with *P. marginatus* were damaged as each seedling wilted and died. This is in tandem with what Ahmed *et al.* (2011) reported that young papaya plants die due to heavy infestation and colony formation of *P. marginatus*. This study established that the number of healthy leaves of papaya seedlings was wiped out within three weeks after inoculation of pests. In common with other hemipterans, female mealybugs have piercing and sucking mouthparts and are generally active throughout their life (Ben-Dov, 1994). It is probable that their ebullient activity and their mouthpart might have played a role in inflicting such damage accretion. Furthermore, *P. marginatus* often attain high numbers, killing the host plant by depleting the sap and occasionally by injecting toxins, transmitting viruses, or by excreting honeydew, which is a suitable medium for the growth of sooty mold (Ben-Dov, 1994). The mold often covers the plant to such an extent that normal photosynthesis is severely reduced (Williams and Granara de Willink, 1992). Specifically, the derived savannah (Ibadan) suffered the greatest extent of damage by *P. marginatus* when compared to the leaf damage result obtained from the rain forest (Akure) and Guinea Savannah (Ogbomoso).

CONCLUSION

Paracoccus marginatus is a highly destructive pest of pawpaw capable of wiping out seedlings in about three weeks. It has been observed that the mealybugs were unable to establish colonies on the cotton crop during early vegetative and peak vegetative stages. It is only in rare cases,

which is generally possible on a few susceptible genotypes, that mealybugs colonize plants during vegetative stage (Nagrare *et al*., 2011). Several parasitoids (predominantly *Aenasius bambawalei*.) and coccinellid beetle predators are now found to keep mealybug populations under control, thereby preventing spread and damage (Nagrare *et al*., 2011). Insecticides such as profenophos, chlorpyriphos, monocrotophos and other insecticides which are being commonly used for mealybug control, destroy the parasitoids and predators and can result in mealybug outbreaks (Nagrare *et al*., 2011). Therefore, insecticide applications should be avoided until peak boll formation stage, to allow further establishment of the parasitoid and predator complex in the ecosystem. Eco-friendly insecticides such as neem oil-based botanicals and buprofezin can be used, if necessary, at the initial stages so as to keep mealybugs under check while causing minimum disturbance to the ecosystem. However, during peak boll formation stage, mealybugs can establish colonies but are initially restricted to a few plants along the border rows, adjacent to the source of infestation and thus can be effectively managed through early detection and initiation of interventions to control early stages of infestation. If timely scouting and appropriate control measures are not initiated papaya plant is likely to be severely damaged with mealybugs.

It is hereby recommended that the investigation should be carried out on the first range of the pawpaw mealybugs in order to ascertain its reservoir of wild hosts. *P. marginatus*is a polyphagous invasive pest and its effect on closely related species of *Carica papaya* should be investigated. More work should be done in other regions of Nigeria and West Africa to determine the prevalence of *P. marginatus* and how difference in climatic conditions affects its development.

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APPENDICES

APPENDIX I: Sheet for scoring and ranking mode of infestation/ population of *P. marginatus*

Morning: Temp……; Hum……; Rainfall…… . Evening: Temp……; Hum……; Rainfall…….

Date:		Location	
GPS:		KM	Sampling No
Presence of PM in Years: (0-3) (0-5)	Environment: Town Village Bush		

(A) PM Infestation On 10 Leaves Randomly Selected		1	2	3	4	5	6	7	8	9	10
	Plant 1										
	Plant 2										
	Plant 3										
	Plant 4										
	Plant 5										
	Plant 6										
	Plant 7										
	Plant 8										
	Plant 9										
	Plant 10										

(B) PM Infestation On 10 Fruits Randomly Selected		1	2	3	4	5	6	7	8	9	10
	Plant 1										
	Plant 2										
	Plant 3										
	Plant 4										
	Plant 5										
	Plant 6										
	Plant 7										
	Plant 8										
	Plant 9										
	Plant 10										

(C) PM Population Consisting of Adults and Inmature on Leaves/Fruits in 5 Categories: 0=0; 1-9=1; 10-99=2; 100-1000=3; >1000=4		5 Leaves					5 Fruits				
	Plant 1										
	Plant 2										
	Plant 3										
	Plant 4										
	Plant 5										
	Plant 6										
	Plant 7										
	Plant 8										
	Plant 9										
	Plant 10										

Infestation/Damage Score for Table A and B: 0= No Infestation; 1= < 25% of Leaves/Fruits Looks Healthy, Tips/Side Shoots Curly; 2= <25% of Leaves/Fruits Covered with Papaya Mealybug (PM); 3= 25-50% of Leaves/Fruits Covered with Papaya Mealybug (PM); 4= >50% of Leaves/Fruits Covered with Papaya Mealybug (PM);	+= Parasitoid species 1……..; ++= Parasitoid species 2……..; +++= Parasitoid species 3……..; *Cocc; Ants=A, Spiders= S.
% of Infested Plants species in the locality, Control 20 Plants Randomly…….; Indicate the species on the Back Page of this Form	

APPENDIX II: Sheet for damage assessment ranking

Number of Healthy Leaves

Site	Exp. Unit	42 Days	45 Days	48 Days	51 Days	54 Days	57 Days	60 Days	63 Days
		Leaves/ seedling	Leaves/ seedling	Leaves/ seedling	Leaves/ seedling	Leaves/ seedling	Leaves / seedling	Leaves/ seedling	Leaves / seedling
1	1								
	2								
2	1								
	2								
3	1								
	2								