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Population fluctuations of the papaya mealybug, *Paracoccus marginatus* (Hemiptera: Pseudococcidae) in urban and peri-urban areas of Lomé (Togo)

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Abstract
The papaya mealybug, *Paracoccus marginatus* Williams and Willink's Granara (Hemiptera: Pseudococcidae) is an exotic, invasive and polyphagous insect that causes considerable damage to several plant species of economic importance in sub-Saharan Africa. Its preferred host plants are cotton, cassava, jatropha and especially papaya. To contribute to the efficient and sustainable management of populations of this pest in Togo, the fluctuation in its populations was monitored in 2016 in the urban and peri-urban areas of Lomé. The monitoring, based on direct observations of papaya plants, showed that the infestation rate of papaya trees by *P. marginatus* and the population density of this species varied with the sites surveyed and were relatively higher in the dry season with values ranging from 56.66 ± 29.69% to 86.66 ± 29.81% and from 0.04 ± 0.05 to 1.72 ± 2.13 ind./cm², respectively. These data allow to determine the parasite procession associated with this pest on the one hand and to study the interactions between these natural enemies and the mealybug on the other hand.

Keywords: Fluctuation, infestation rate, mealybug density, papaya, *Paracoccus marginatus*

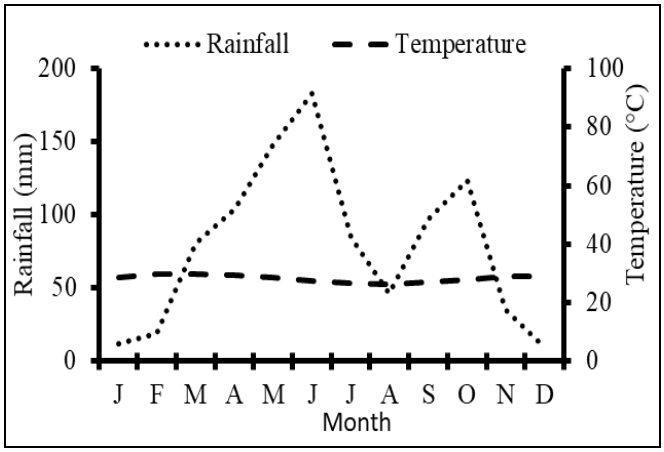
Introduction
Native to Mexico, *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Pseudococcidae) is an insect which invaded the West African coast through Ghana in 2009 [1]. It is a prolific, multivoltine pest that can have up to 11 generations per year [2]. It is highly polyphagous, developing on more than 190 host plant species belonging to 56 families [3]. The papaya, a plant of great economic importance, is its main host. *P. marginatus* is a biting, sucking insect with a soft body. The body of the females is white because of a covering of a white waxy secretion [4]. The larvae are light yellow, with pinkish pupae and males [5-7]. The development of its populations is strongly linked to climatic conditions such as temperature and humidity [2, 6]. It causes significant damage to fruit and ornamental arboriculture and to market garden produce [8]. This damage is due to the production of honeydew on which the fumagin develops, covering the plant organs, preventing photosynthesis and making them undesirable. The absence of photosynthesis causes chlorosis and leads to the fall of flowers and fruits and death of the plant [7]. In Ghana, for example, infestation of papaya fields with this pest has resulted in an 85% yield loss and a loss of employment of more than 1700 workers [1]. In order to reduce the infestation rate of *P. marginatus* below the harmful economic threshold, growers often resort to conventional control methods using synthetic insecticides. In general, twice the normal dosage is applied when treating mealybugs because of the waxy layer covering their entire body [9]. Also, as mealybugs are often hidden in damaged leaves and buds, chemical control is only partially effective and requires multiple applications. The uncontrolled applications of these chemicals results in pest resistance and non-target effects on natural enemies, making this control method less desirable for managing populations of the papaya mealybug [5]. Under these conditions, alternative methods using biological organisms have been considered for long-term control of the pest. In this perspective, predators [5] and especially parasitoids, such as *Acerophagus papayae* (Hymenoptera: Encyrtidae) have been identified and used against *P. marginatus* [10]. Despite these measures, the pest remains a major constraint on the production and marketing of quality papayas.

In Togo, *P. marginatus* was first identified at Hillacondji (border between Togo and Benin) and in Lomé in early 2010 by Goergen *et al*. [11]. Apart from the work done by the Plant Protection Division (DPV: Direction de la Protection des Végétaux) on the status of the pest (its spatial distribution in the territory) [12, 13], no data are available on the influence of biotic conditions such as parasite pressure and abiotic conditions such as climatic conditions on its fluctuation density. However, the establishment and application of a cheaper, effective, sustainable and environmentally sound management method for *P. marginatus*, requires control of the bio-ecology of the pest and its associated natural enemies under natural conditions. The objective of this study is to build up a database on the bio-ecological and ethological parameters of *P. marginatus*, for the long-term monitoring of its populations in different agrosystems. The aim was to (i) determine the variation in the infestation rate of papaya plants, leaves and fruits by *P. marginatus* according to the seasons; (ii) determine the fluctuation in its density and identify the host plant species with which it is associated in urban and peri-urban areas.

Materials and Methods

Study area and site selection

The work was done in the Lomé commune located in the south-west of ecological zone V. This zone is made of a mosaic of disparate forest islands, highly anthropized savannas, coastal thickets, halophilic or swampy meadows, mangroves, fallow land and crops [14]. It enjoys a tropical climate of the Guinean type characterized by two rainy seasons (April-July and September-October) and two dry seasons (November-March and August). It has an average annual rainfall of 941.5 mm; a high average temperature of 28.3°C (Figure 1); a high average relative humidity of 73% and an average sunshine duration of 6.62 h/day.



(**Source:** National Meteorology Directorate, Lomé-airport station)

Fig 1: Shadow-thermal curve of Ecological Zone V based on averages (2000-2016).

The surveys were carried out in urban (University of Lomé (UL) and Todman respectively sites 1 and 2) and peri-urban (Logopé, Zopomahé and Apédokoé respectively sites 3, 4 and 5) areas of the city of Lomé. Apédokoé, Logopé and Zopomahé are located at 14, 12 and 16 km respectively to the north-west of Lomé. A total of 5 sites were selected based on well-defined floristic surveys and they are relatively rich in mealybug host plants (Table 1).

The different sites are free from phytosanitary treatments and are accessible throughout the study period. Papaya was grown with cassava in Todman throughout the year and maize during the rainy season at the UL, Todman, Zopomahé and Apédokoé sites. However, at Logopé, there was no year-round cultivation.

Table 1: Floristic surveys of the survey sites

Study sites	Main characteristic plant species
UL	*Jatropha curcas, Cleome viscosa, Zea mays, Azadirachta indica*
Todman	*Cleome viscosa, Zea mays, Euphorbia hirta, Trianthema portulacastrum, Ipomea triloba, Manihot esculenta*
Logopé	*Cocos nucifera, Elaeis guineensis, Mangifera indica, Ocimum gratissimum, Borassus aethiopum, Vernonia amygdalina, Moringa oléifera, Caesalpinia pulcherrima*
Zopomahé	*Zea mays, Ipomea triloba,*
Apédokoé	*Zea mays, Hibiscus esculenta, Manihot esculenta, Moringa oléifera*

Fluctuation in the rate of infestation of papaya plants, leaves and fruits by *P. marginatus* in Lomé and its suburbs

At each of the five (5) study sites, six (6) randomly selected regular papaya plants (a variety for which the 6 plants could be found at all sites) were marked so that they could be identified each time we passed through the site. The plants were numbered from 1 to 30, with 6 per site. Thus, plants with numbers 1-6, 7-12, 13-18, 19-24 and 25-30 were located at UL, Todman, Logopé, Zopomahé and Apédokoé, respectively. Careful and systematic observations (using a hand-held magnifying glass and a ladder to climb the papaya trees) of the different parts (leaves, fruits) of the 30 selected plants were made every two weeks from January to December 2016. On each trip and at each site, the number of plants hosting adult and pre-imaginal stages of *P. marginatus* (infested plants) was first recorded and ten (10) leaves and ten (10) fruits randomly selected from each of the six (6) plants selected for the study were examined. Similarly, the number of leaves or fruits bearing any stage of development of the mealybug was recorded. Finally, knowing the number of infested plants, leaves and fruits on the different materials observed, it was possible to determine the different rates of infestation.

The plant infestation rate (T_{ip}) was calculated with the following formula [15]:

$T_{ip} = (N_{ip}/N_{tp}) \times 100$

(N_{ip}) = number of infested plants;

(N_{tp}) = total number of plants observed.

The infestation rates of leaves (T_{iL}) and fruits (T_{iR}) were also calculated using the same formula by replacing the number of plants (P) by the number of leaves (L) or fruits (R). The calculation of the different infestation rates on each run allowed monitoring their variation over time.

Fluctuation in *P. marginatus* density

The density of *P. marginatus* was assessed on each of the 30 papaya plants at different survey sites by sampling the main lobe of a randomly selected infested leaf at the base of the

foliage of each plant. If the main lobe was not infested, one of the secondary lobes was sampled. Samples collected from all plants were placed in previously labelled plastic, parallelepiped, translucent boxes (19 x 13 x 6.5 cm). The boxes containing the samples are stored in a large container and brought back to the Applied Entomology Laboratory at the University for identification and enumeration of the different stages of development (all larval stages combined and adults of both sexes) of the insect. All individuals of each stage are counted on each sampled leaf part, using a binocular magnifying glass. Each sampled leaf part is staggered on graph paper and the corresponding leaf areas were determined. The density of *P. marginatus* (Dc) was then evaluated using the following formula [16]: Dc = Nc/S.

(Nc) = Number of mealybugs counted

(S) = Leaf area

Sampling coupled with determination of mealybugs density done every two weeks made it possible to monitor the fluctuation in the pest populations over time.

Statistical analyses

The results obtained were analysed using the software SPSS version 16.0. Comparison of the means was done by an analysis of variance (ANOVA). The means were then discriminated with the Student-Newman-Keul (SNK) test at the 5% threshold.

Results and Discussion

Fluctuation in the rate of infestation of papaya trees by *P. marginatus* in Lomé and its suburbs

In the dry season (November to March and August), the average rate of infestation of papaya plants in the urban and peri-urban areas of Lomé (Sites combined) varies between 56.66 ± 29.69 and 86.66 ± 29.81% with a peak in March; while in the rainy season (April to July and September to October), it is between 52.35 ± 39.50 and 78.33 ± 26.80% with a peak in October (Table 2). At all the sites surveyed, the average degree of trunk infestation remained constant and a maximum (100%) throughout the study period in Todman (Table 2). However, during the dry season at UL, Logopé, Zopomahé and Apédokoé, infestation varied respectively from 24.99 ± 11.78 to 100%, 33.33 ± 0 to 83.83 ± 0%, 58.33 ± 11.78 to 100%, 66.66 ± 0 to 100% with peaks in March (UL), August (Logopé) and February (Zopomahé, Apédokoé). Compared to the dry season, the degree of infestation at the same sites during the rainy season, ranged from 16.66 ± 0 to 91.66 ± 11.78% (UL), 8.33 ± 11.78 to 75.24 ± 11, 78% (Logopé), 41.66 ± 11.78 and 91.91 ± 11.78% (Zopomahé), 74.99 ± 11.78 and 100% (Apédokoé) with respective peaks in April (UL), October (Logopé, Zopomahé) and July (Apédokoé) (Table 2). In general, papaya trees are relatively less infested in Logopé throughout the monitoring period except in August when infestation is relatively high (83.83 ± 0%). Overall, infestation of papaya plants in urban areas is relatively higher than in the peri-urban area.

Table 2: Fluctuation in the average rate of infestation of papaya plants by *P. marginatus* in the urban and peri-urban areas of Lomé during 2016

Period (month)	UL	Todman	Logopé	Zopomahé	Apédokoé	All sites combined
J	66,66 ± 0	100 ± 0	33,33 ± 0	66,66 ± 47,14	91,66 ± 11,78	71,66 ± 26,08
F	83,33 ± 23,57	100 ± 0	41,66 ± 35,35	100 ± 0	100 ± 0	84,99 ± 25,27
M	100 ± 0	100 ± 0	33,33 ± 0	100 ± 0	100 ± 0	86,66 ± 29,81
A	91,66 ± 11,78	100 ± 0	8,33 ± 11,78	75 ± 35,35	74,99 ± 0	69,99 ± 36,13
M	49,99 ± 47,14	100 ± 0	0	41,66 ± 11,78	83,33 ± 0	55 ± 38,90
J	16,66 ± 0	100 ± 0	11,11 ± 9,61	50 ± 0	83,83 ± 0	52,35 ± 39,50
J	41,66 ± 11,78	100 ± 0	33,33 ± 0	75 ± 35,35	100 ± 0	69,99 ± 31,51
A	41,66 ± 11,80	100 ± 0	83,83 ± 0	75,24 ± 11,78	100 ± 0	79,99 ± 24,01
S	66,66 ± 47,16	100 ± 0	16,66 ± 0	75 ± 35,35	100 ± 0	71,66 ± 34,15
O	33,33 ± 23,57	100 ± 0	75,24 ± 11,78	91,91 ± 11,78	91,91 ± 11,78	78,33 ± 26,80
N	38,88 ± 25,45	100 ± 0	33,33 ± 44,09	61,10 ± 41,94	94,44 ± 9,62	66,11 ± 30,78
D	24,99 ± 11,78	100 ± 0	33,33 ± 0	58,33 ± 11,78	66,66 ± 0	56,66 ± 29,69

J: January, F: February, M: March, A: April, M: Mai, J: June, J: July, A: August, S: September, O: October, N: November, D: December. ($F = 4.422$, $df = 44$, $P<0.001$)

For leaves, the average infestation rate throughout the study area also varies seasonally and is relatively higher in the dry season. During the dry season, the rate varies between 20.79 ± 29.25 and 47.16 ± 26.77% with a peak in March; whereas in the rainy season, it is between 8.66 ± 7.93 and 29.83 ± 23.38% with a peak in September (Table 3). At the different surveyed sites, the level of infestation of papaya leaves in the dry season varies respectively at UL, Todman, Logopé, Zopomahé and Apédokoé from 3.16 ± 2.59 to 66.66 ± 23.56%, 50.0 ± 4, 71 to 75.83 ± 8.24%, 0.83 ± 1.17 to 20.83 ± 5.89%, 6.66 ± 7.07 to 53.33 ± 7.07% and from 14.99 ± 4.71 to 57.5 ± 17.67% with respective peaks in March (UL, Zopomahé), February (Todman), August (Logopé, Apédokoé) (Table 3). However, during the rainy period, the level of infestation at the same sites ranged from 2.5 ± 1.18 to 42.49 ± 8.25% (UL), 19.99 ± 6.01 to 47.5 ± 3.53% (Todman), 0 to 14.16 ± 5.89 (Logopé), 5.83 ± 5.89 and 34.99 ± 4.71% (Zopomahé), 12.77 ± 3.46 and 64.16 ± 1.18% (Apédokoé) with peaks in April (UL, Todman), October (Logopé) and September (Zopomahé, Apédokoé) (Table 3). Leaves are relatively less infested at Logopé throughout the monitoring period.

Table 3: Fluctuation in the average rate of infestation of papaya leaves by *P. marginatus* in the urban and peri-urban areas of Lomé during the year 2016.

Period (month)	UL	Todman	Logopé	Zopomahé	Apédokoé	All sites combined
J	19,16 ± 1,18	67,5 ± 29,46	3,33 ± 0	6,66 ± 7,07	20 ± 14,14	22,73 ± 25,77
F	47,49 ± 22,39	75,83 ± 8,24	2,5 ± 3,53	29,99 ± 11,78	44,99 ± 11,78	40,16 ± 26,79
M	66,66 ± 23,56	64,16 ± 15,31	0,83 ± 1,73	53,33 ± 7,07	50,83 ± 3,53	47,16 ± 26,77
A	42,49 ± 8,25	47,5 ± 3,53	0,83 ± 1,73	25,83 ± 20,03	25 ± 0	28,33 ± 18,31
M	7,5 ± 8,25	37,5 ± 3,53	0	5,83 ± 5,89	29,99 ± 2,35	16,16 ± 16,50
J	1,66 ± 0	19,99 ±6,01	1,11 ± 0,95	7,77 ± 1,92	12,77 ± 3,46	8,66 ± 7,93
J	2,5 ± 1,18	39,16 ± 5,89	6,66 ± 2,35	14,16 ± 3,53	29,16 ± 5,89	18,33 ± 15,45
A	4,16 ± 1,18	50 ± 4,71	20,83 ± 5,89	31,66 ± 4,71	57,5 ± 17,67	32,83 ± 21,62
S	6,66 ± 2,35	34,16 ± 8,25	9,16 ± 3,53	34,99 ± 4,71	64,16 ± 1,18	29,83 ± 23,38
O	5,83 ± 8,24	29,16 ± 5,89	14,16 ± 5,89	29,16 ± 3,53	48,33 ± 23,57	25,33 ± 16,30
N	5,99 ± 4,37	68,88 ± 6,01	6,11 ± 9,17	11,66 ± 7,63	52,22 ± 8,54	28,97 ± 29,51
D	3,16 ± 2,59	72,5 ± 27,10	5 ± 2,35	8,33 ± 0	14,99 ± 4,71	20,79 ± 29,25

J: January, F: February, M: March, A: April, M: Mai, J: June, J: July, A: August, S: September, O: October, N: November, D: December. ($F = 5.348$, $df = 45$, $P<0,001$)

Similarly, the average fruit infestation rate throughout the study area varied seasonally and was relatively higher in the dry season. For all sites combined, in the dry season, this rate varied between 7.76 ± 9.39 and 41.83 ± 29.85% with a peak in February; whereas in the rainy season, it ranged between 3.92 ± 5.21 and 20.52 ± 18.74% with a peak in September (Table 4). At the different surveyed sites, the level of fruit infestation in the dry season at UL, Todman, Logopé, Zopomahé and Apédokoé, varied respectively from 2.18 ± 0.73 to 68.88 ± 12.56%, 22.41 ± 5, 04 to 66.36 ± 10.67%, 0% to 24.5 ± 0.70%, 5.13 ± 7.35 to 73.72 ± 16.35%, 4.87 ± 6.89 to 32.51 ± 13.15% with respective peaks in March (UL, Logopé, Zopomahé), February (Todman), August (Apédokoé) (Table 4). On the other hand, during the rainy period, the level of infestation at the same sites ranged from 0% to 11.53 ± 16.31% (UL), 6.89 ± 9.75% and 29.72 ± 4.30% (Todman), 0% and 0.9 ± 1.27% (Logopé), 3.02 ± 3.24% and 32.14 ± 14.71% (Zopomahé), 1.61 ± 2.27% and 45.53 ± 3.78% (Apédokoé) with peaks in April (UL), September (Todman, Apédokoé), October (Logopé, Zopomahé) (Table 4). Like the leaves, fruits are relatively less infested at Logopé throughout the monitoring period.

Table 4: Fluctuation in the average infestation rate of papaya fruits by *P. marginatus* in the urban and peri-urban areas of Lomé during the year 2016

Period (month)	UL	Todman	Logopé	Zopomahé	Apédokoé	All sites combined
J	21,31 ± 10,64	61,68 ± 5,06	1,25 ± 1,76	19,57 ± 20,6	22,81 ± 4,77	25,32 ± 22,12
F	47,9 ± 11,17	66,36 ± 10,67	1,66 ± 2,35	71,79 ± 3,62	21,45 ± 12,09	41,83 ±29,85
M	68,88 ± 12,56	22,52 ± 12,34	24,5 ± 0,7	73,72 ± 16,35	16,12 ± 13,68	41,15 ±27,75
A	11,53 ± 16,31	28,94 ± 11,16	0	13,57 ± 9,09	1,61 ± 2,27	11,13 ±11,59
M	1,55 ± 2,14	6,89 ± 9,75	0	13,83 ± 10,72	4,60 ± 1,8	5,37 ±5,43
J	0	12,71 ± 6,69	0	3,027 ± 3,24	3,88 ± 2,4	3,92 ±5,21
J	3,41 ± 0,11	29,05 ± 13,9	0	10,89 ± 8,66	13,93 ±13,56	11,46 ±11,31
A	1,66 ± 2,35	49,96 ± 2,48	0	25,89 ± 16,41	32,51 ± 13,15	22,0 ±21,24
S	4,16 ± 3,53	29,71 ± 4,3	0	23,20 ± 3,95	45,53 ± 3,78	20,52 ±18,74
O	5,83 ± 3,53	16,53 ± 1,43	0,90 ± 1,27	32,14 ± 14,71	36,78 ± 13,45	18,43 ±15,76
N	4,44 ± 7,69	22,41 ± 5,04	0	5,13 ± 7,35	8,66 ± 5,03	8,13 ±8,55
D	2,18 ± 0,73	23,67 ± 4,46	0	8,08 ± 3,71	4,87 ± 6,89	7,76 ±9,39

J: January, F: February, M: March, A: April, M: Mai, J: June, J: July, A: August, S: September, O: October, N: November, D: December. ($F = 5.109$; $df = 45$; $P<0.001$)

Finally, the rate of infestation of pawpaws by *P. marginatus* in Lomé and its surroundings is higher in the dry season than in the rainy season. Similarly, this rate is higher in urban than in peri-urban areas in all seasons. As a result, papaya plants are relatively less infested in Logopé (peri-urban zone) compared to other survey sites. At all sites, the level of infestation of leaves is relatively higher than that of fruits in both dry and rainy seasons.

Fluctuation in *P. marginatus* densities at the different sites surveyed

The average density of *P. marginatus* on papaya leaves in Lomé and its periphery varies with the seasons and is higher in the dry season. For all sites combined, the density is between 0.04 ± 0.05 and 1.72 ± 2.13 ind./cm² in the dry season, while in the rainy season it varies from 0.001 ± 0.001 to 0.16 ± 0.33 ind./cm² with peaks in January and February during the dry season and September during the rainy season (Table 5).

Table 5: Fluctuation in the average density of *P. marginatus* in the urban and peri-urban areas of Lomé during the year 2016.

Période	UL	Todman	Logopé	Zopomahé	Apédokoé	Sites confondus
J	0,253 ± 0,2	3,23 ± 0,06	0,00164 ± 0	0,037 ± 0,05	0,16 ± 0,16	0,739 ± 1,39
F	1,91 ± 0,38	5,27 ± 2,5	0,005 ± 0,007	0,201 ± 0,17	1,209 ± 0,82	1,72 ± 2,13
M	0,87 ± 0,04	0,23 ± 0,3	0	0,53 ± 0,58	1,104 ± 0,3	0,54 ± 0,45
A	0,11 ± 0,07	0,12 ± 0,03	0	0,023 ± 0,03	0,24 ± 0,03	0,10 ± 0,09
M	0,03 ± 0,04	0,032 ± 0,02	0	0,0016 ± 0,002	0,043 ± 0,04	0,02 ± 0,01

J	0	0,004 ± 0,004	0	0	0,0019 ± 0,0001	0,001 ± 0,001
J	0	0,032 ± 0,03	0	0,0038 ± 0	0,05 ± 0,03	0,017 ± 0,02
A	0,001 ± 0,002	0,1 ± 0,03	0	0,0128 ± 0,001	0,79 ± 0,28	0,18 ± 0,34
S	0	0,009 ± 0,009	0	0,047 ± 0,007	0,77 ± 0,23	0,165 ± 0,33
O	0	0,002 ± 0,002	0	0,005 ± 0,008	0,23 ± 0,08	0,047 ± 0,10
N	0,002 ± 0,003	0,128 ± 0,18	0	0	0,07 ± 0,01	0,04 ± 0,05
D	0,008 ± 0	1,52 ± 0,45	0	0	0,013 ± 0,01	0,309 ± 0,68

J: January, F: February, M: March, A: April, M: Mai, J: June, J: July, A: August, S: September, O: October, N: November, D: December. ($F = 5.483$, $df = 44$, $P<0,001$)

Of all the surveyed sites, *P. marginatus* density was higher during the dry season at Todman with values ranging from 0.10 ± 0.03 to 5.27 ± 2.50 ind./cm² (Table 5). However, the density at UL, Logopé, Zopomahé and Apédokoé, varies respectively from 0.0018 ± 0.0026 to 1.91 ± 0.38 ind./cm², 0 to 0.005 ± 0.007 ind./cm², 0 to 0.005 ± 0.007 ind./cm², 0 to 0.53 ± 0.58 ind./cm² and 0.01 ± 0.01 to 1.20 ± 0.82 ind./cm² with peaks in February (UL, Logopé, Apédokoé) and March (Zopomahé). Compared to the dry season, the density of mealybugs during the rainy period, is between 0 and 0.11 ± 0.07 ind./cm² (UL), 0.002 ± 0.002 and 0.12 ± 0.03 ind. /cm² (Todman), 0 and 0.04 ± 0.007 ind./cm² (Zopomahé), 0.002 ± 0.001 and 0.77 ± 0.23 ind./cm² (Apédokoé) with peaks in April (UL, Todman) and September (Zopomahé, Apédokoé) (Table 5). Whatever the season, the density of *P. marginatus* is lowest at Logopé.

The average rate of infestation of papaya trees (plants, leaves and fruits) with *P. marginatus* and the population density of the pest on this host in the urban and peri-urban areas of Lomé was relatively higher in the dry season than in the rainy season. These results are consistent with those of Tairas *et al*. [15]. The abundance of the pest in the dry season is probably related to the low relative humidity caused by the scarcity of rainfall and high temperatures during this period. Indeed, Tanwar *et al*. [17], Amarasekare *et al*. [6] showed that temperatures (above 25°C) favoured a harmonious development of *P. marginatus* by ensuring high female fecundity and a long life span of individuals of both sexes. The above-mentioned biological parameters (fecundity, lifespan) favoured by these environmental conditions undoubtedly allowed the proliferation of the pest during the dry season at all surveyed sites. Unlike the dry season, the rainy season, during which rainfall is relatively more abundant, is unfavourable to the development and proliferation of mealybugs [15]. Indeed, the observations made during our surveys just after the rains had fallen, allowed us to notice a leaching of mealybug colonies (especially on fruits) by the pressure of rain drops. This probably led to the death of most colonies and consequently to a drastic reduction in the density of the pest in the study area during this period.

Moreover, a reduction in *P. marginatus* populations could also be linked to the presence of their natural enemies in the environment. Indeed, Saengyot and Burikam [18] showed that several species of beetles (*Exochomus laeviusculus* for example) and neuroptera (*Chrysoperla carnea*) were an important mortality factor for the papaya mealybug. Indeed, Meyerdirk and Kauffman [19] showed a significant reduction in *P. marginatus* density caused by parasitoid hymenopterans (including *Acerophagus papayae*).

The difference in the level of infestation observed at the surveyed sites is probably related to the vegetation found at these sites. The low densities of mealybugs as well as the lowest degrees of infestation of papaya plants recorded at Logopé could be explained by a high plant diversity which can harbour a range of natural enemies (food source and shelter) capable of exerting pressure on the pest compared to other sites. However, at the other sites, the cultivation of maize (during the rainy season) and cassava (all year-round) in Todman could enhance the development of mealybugs as these two (2) plant species are also alternative hosts for the pest [3, 7, 20].

Under our study conditions, papaya leaves are relatively more infested than fruits by *P. marginatus* regardless of the season and survey site. These observations are consistent with those of Tairas *et al*. [15] who observed infestation rates of 49% and 32% in the dry season, 15% and 11% in the rainy season for leaves and fruits, respectively.

Conclusion

This study carried out in the urban and peri-urban areas of Lomé showed that the population density of the papaya mealybug as well as the level of infestation of this host fluctuate with season and survey site. Mealybug populations are higher in dry than in wet periods. *P. marginatus* attacks all external and visible parts of papaya trees. However, its density on a plant does not depend on the biological parameters of the plant (number of leaves and fruits, number of shoots and height). The results obtained provide a basis for future studies on the biology of the pest and the interactions between the pest and its natural enemies.

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