Journal of Oil Palm Research Vol. 37 (4) December 2025 p. 627-634
DOI: https://doi.org/10.21894/jopr.2024.0046

LIFE CYCLE, FOLIAR CONSUMPTION RATE, NATURAL ENEMIES AND POPULATION FLUCTUATION OF *Phobetron hipparchia* CRAMER, 1777 (LEPIDOPTERA: LIMACODIDAE): AN EMERGING PEST OF OIL PALM IN COLOMBIA

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ABSTRACT

Phobetron hipparchia *is an occasional pest in oil palm plantations in the Colombian Caribbean zone. Its life cycle and foliar consumption rate were determined under laboratory conditions; additionally, the population fluctuation in an oil palm lot was recorded through sampling carried out every 20 days for two years. Subsequently, the population dynamics of* P. hipparchia *were correlated with the climatic variables: Precipitation, relative humidity (RH), temperature and natural biological control. The life cycle of* P. hipparchia *under laboratory conditions (27.3 ± 3.8°C, 85 ± 15% RH) lasted 74.3 ± 8.2 days, with the developmental phases distributed as follows: Egg: 6.3 ± 0.7 days, larva: 49.1 ± 5.3 days passing through nine instars, pupa: 14.4 ± 0.9 days and adult 4.5 ± 1.3 days. The larvae of* P. hipparchia *consumed 682.9 ± 103.6 cm² of the leaf blade. No correlation was found between the population dynamics and the climatic variables recorded. However, a correlation was found between the population dynamics of the larvae of* P. hipparchia *and the biological control caused by* Baryceros *sp. (ρ = 0.685;* $p<0.0001$*) and* Cordyceps *sp. (ρ = 0.505;* $p<0.001$*). This information enables the recognition of* P. hipparchia *in oil palm plots and emphasises the importance of natural control in regulating defoliating insect populations.*

Keywords: *Baryceros*, climate, *Cordyceps*, herbivory, leaf-eating.

Received: 19 September 2023**; Accepted:** 9 July 2024**; Published online:** 20 September 2024.

INTRODUCTION

The cultivation of oil palm *Elaeis guineensis* Jacq., 1,763 is one of the main agro-industries in Colombia, with 595,722 ha currently planted, of which 111,790 ha are planted in the Colombian Caribbean, mainly in the departments of Magdalena and Cesar (Fedepalma, 2022). *Elaeis guineensis*, being an introduced species, is susceptible to pathogenic organisms or insect pests that initially fed on native palms and have migrated as well as adapted to feeding on oil palms (Hernández-Lambraño et al., 2014; Mexzón et al., 1996; Plata-Rueda et al., 2020).

In Colombia, the main pests that attack oil palm crops belong to the order Lepidoptera, which are mostly defoliators for example *Opsiphanes cassina* Felder, 1862; *Stenoma impressella* Busck, 1914 and *Euprosterna elaeasa* Dyar, 1906 (Escalante et al., 2010; Hernández-Lambraño et al., 2014). The severity of the damage caused by defoliating insects depends on specific aspects of each insect pest species, such as the length of their life cycle, the rate of foliar consumption, and their association with pathogens that cause foliar necrosis (Calvache, 2004). Most of the defoliating insects that affect oil palm plantations in Colombia belong to the Limacodidae family, and their larvae are commonly known as

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slimy caterpillars; they are characterised because they are generally colourful, with a variety of shapes and sizes (Zaspel et al., 2016), they have an elastic abdomen, small thoracic legs, a retractile head capsule and usually have stinging hairs on the body (Epstein, 1996; Lill et al., 2006).

Most of the species in this family have a short life cycle (Syed, 1994); for example, the life cycle of *E. elaeasa* Dyar, 1906 is 63.0 days, *Sibine megasomoides* Walker, 1866 is 90.4 days and *Acharia fusca* Stoll, 1781 is 63.7 days (Alvarado et al., 2014; Martínez et al., 2014; Mexzón et al., 1996). However, in many species (e.g., *Phobetron hipparchia* Cramer, 1777) belonging to this family, basic aspects such as their life cycle, natural enemies and foliar consumption rate are unknown. This species has been recorded to cause severe defoliation in oil palm plantations located on the Colombian Caribbean coast but also has been recorded to cause damage to eucalyptus (Pereira et al., 2001) and macadamia crops (Villegas, 2005). Due to the above and considering that the knowledge of the life cycle and the rate of foliar consumption is necessary to know the economic impact that a pest insect can have on its host (Pozo et al., 2005) and the establishment of integrated pest control management program, this study was carried out to determine the life cycle and foliar consumption rate of *P. hipparchia*, as well as its population fluctuation in oil palm plots and its natural enemies.

MATERIALS AND METHODS

Life Cycle and Morphology of *P. hipparchia*

During 2022, *P. hipparchia* larvae were collected in plots from the Palmas Sicarare plantation, located in the Agustín Codazzi municipality, Cesar, Colombia, 09°55′41″N, 73°18′17″W. The collected larvae were transferred in styrofoam cellars to the Entomology Laboratory located in the Palmar de la Sierra Experimental Field (Banana Zone, Magdalena, d Colombia). In the laboratory i.e. temperature and relative humidity (RH) (27.3 ± 3.8°C, 85 ± 15% RH), the larvae were individualised in Petri dishes, which contained a piece of absorbent paper moistened with sterile water and a 5 x 5 cm piece of palm leaflet collected from leaf 17 of oil palm cultivar IRHO. Every two days, the piece of leaflet and the piece of absorbent paper were replaced. The larvae were maintained under these conditions until they reached the pupal stage when the moistened paper and piece of palm leaflet were permanently removed. When the adults emerged from the pupae, they were transferred to an entomological cage (50 x 50 x 50 cm) made with a muslin cloth. Pieces of leaflets were placed inside the cage for the female's oviposition. The eggs were individualised in Petri dishes, and the time from oviposition to the emergence of the larvae was recorded. The larvae were maintained using the same methodology as those from the field, their development was monitored daily with recordings on the date of instar change until the pupal stage, after which, the adults were placed in the oviposition cages to determine their longevity. The morphological description was made, and the length of 30 specimens of each stage of development was measured using an Olympus SZ61® stereoscope and an Olympus EP50® camera (Tokyo, Japan).

Foliar Consumption

The leaf area consumed by 30 *P. hipparchia* larvae from the first to the last instar was quantified. The larvae were kept individually in pieces of leaflets; for each leaflet piece, the area was measured through photography and image analysed with the Imagen® 1.47 program (National Institutes of Health, Maryland, USA). The leaf was replaced every two days, and consumption was estimated by calculating the difference between the leaf area before and after feeding. Data analysis was done using descriptive statistics.

Population Dynamics of *P. hipparchia*

In studying the population dynamics of *P. hipparcia*, the Casanare 1 lot belonging to the Palmas Sicarare plantation, located in the Agustín Codazzi municipality, Cesar, Colombia, (09°55′41″N, 73°18′17″W), was selected to determine its natural enemies as well as its interaction with its surroundings. The plot of 13.8 ha was planted in 2008 with a cultivar *Elaeis guineensis* (IRHO). In this lot, 5 x 5 sequential samplings were carried out (one palm every five palms every five lines) every 20 days from December 12, 2020 to February 7, 2023. At each sampling event for every selected palm, the total number of live larvae of *P. hipparchia* present on frond 17 was recorded. The parasitised specimens were brought to the laboratory and placed into individual Petri dishes until the emergence of parasitoids. Individuals with signs of infection by an entomopathogen were transferred to the Cenipalma Laboratory of Entomopathogenic Microorganisms, located in the Palmar de las Corocoras Experimental Field (Paratebueno, Cundinamarca, Colombia) for their isolation, identification, and storage. The climatic variables were recorded with the Vantage Pro 2® weather station (Davis Instruments, Haywards, CA, USA) located approximately 0.5 km from the lot, at coordinates 9°55′58″N, 73°15′46″W. The population dynamics of *P. hipparchia* were correlated with climatic factors: Precipitation, average temperature, and, as well as with the percentage of biological control registered on each sampling date through Spearman's correlation coefficient.

RESULTS AND DISCUSSION

Life Cycle and Morphology of *P. hipparchia*

The taxonomic identity of *P. hipparchia* was confirmed by Dr. Marc E. Epstein, a specialist in the taxonomy of the family Limacodidae of the California Department of Food and Agriculture. The taxonomic identification was made via images photographed of the larval and adult stages. The life cycle of *P. hipparchia* was 74.3 ± 8.2 days, including adult longevity under laboratory conditions (27.3 ± 3.8°C, 85 ± 15% RH). Eggs are circular, flattened, 1.2 ± 0.2 mm in diameter and yellow in colour (*Figure 1a*). The larvae are typical of the Limacodidae family, with a retractable hypognathous head, reduced thoracic legs, without the presence of pseudolegs (Epstein, 1996), recently emerged, measuring 1.1 ± 0.3 mm in length, presenting a large number of simple setae grouped in 12 projections of the body of the larva. As the larva grows these setae increase in size, covering the larva and offering a similar appearance to a spider (*Figure 1b*), fully developed larvae measure 32.0 ± 7.0 mm in length and are brown. The total life cycle time of 66.10% is devoted to the larval stage, during which *P. hipparchia* goes through nine larval instars (*Table 1*).

The larvae that are about to pupate stop feeding and generate a brown cocoon, which remains attached to the palm leaves. It has a lid at its end through which the adult emerges. Cocoons measure, on average, 18.0 ± 3.3 mm. Adults present sexual dimorphism; females are larger than males with a wingspan of 28.1 ± 2.1 mm, while in males, it is 24.1 ± 2.7 mm. Additionally, females have forewings mottled with different shades of orange, yellow and red, while, males mottled are black, grey and yellow (*Figure 2*).

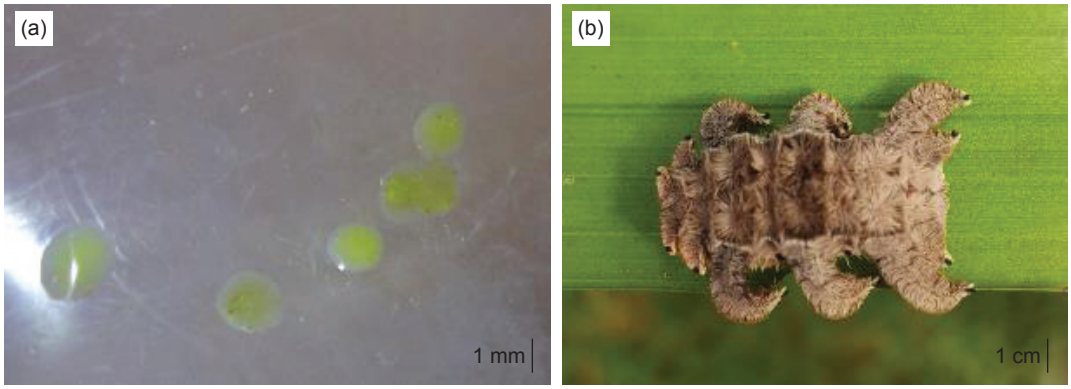

Figure 1. (a) Eggs, and (b) larvae of P. hipparchia *on oil palm leaflets.*

TABLE 1. THE LIFE CYCLE OF *P. hipparchia* UNDER LABORATORY CONDITIONS (27.3 ± 3.8°C, 85.0 ± 15.0% RH)

Stage	n	Average ± SD (days)	Min-Max (days)
Egg	91	6.3 ± 0.7	5-8
Larva I instar	71	4.9 ± 0.4	4-6
Larva II instar	67	4.8 ± 0.4	4-6
Larva III instar	67	4.3 ± 0.5	3-5
Larva IV instar	64	5.4 ± 0.9	4-6
Larva V instar	64	4.7 ± 0.8	4-6
Larva VI instar	63	5.1 ± 0.7	4-6
Larva VII instar	63	6.0 ± 0.6	5-7
Larva VIII instar	63	6.5 ± 0.5	6-7
Larva IX instar	63	7.4 ± 0.5	7-8
Total larva		**49.1 ± 5.3**	**41-57**
Pupa	72	14.4 ± 0.9	13-16
Adult	72	4.5 ± 1.3	3-9
Total life cycle		**74.3 ± 8.2**	**62-90**

Figure 2. Adults of P. hipparchia *on oil palm leaflets note the different colours corresponding to sexual dimorphism between adults: (a) Male, and (b) female.*

Foliar Consumption

The average consumption of the leaf blade during the larval stage of *P. hipparchia* was 682.9 ± 103.6 cm² of leaf area; 69.0% was consumed in the last two instars (*Table 2*).

TABLE 2. CONSUMPTION RATE OF THE DIFFERENT LARVAL INSTARS OF *P. hipparchia* UNDER LABORATORY CONDITIONS (27.3 ± 3.8°C, 85 ± 15% RH)

Instar	Average ± SD (cm²)	Intervals Min-Max (cm²)
I Instar	1.4 ± 0.4	0.7-2.3
II Instar	2.1 ± 0.4	1.4-3.1
III Instar	3.8 ± 0.7	1.6-5.1
IV Instar	13.2 ± 1.9	9.7-17.0
V Instar	29.7 ± 3.7	23.4-37.6
VI Instar	48.9 ± 4.3	39.4-59.3
VII Instar	112.7 ± 14.6	86.0-141.0
VIII Instar	181.9 ± 37.3	134.0-301.0
IX Instar	289.1 ± 40.2	189.0-401.0
Total	**682.9 ± 103.6**	**485.2-967.4**

During the first three instars, the larvae of *P. hipparchia* only consume the superficial part of the leaf blade, and from the fourth instar onwards, they consume the leaf blade completely, leaving only the midrib (*Figure 3*).

Population Fluctuation of *P. hipparchia*

The monitoring of the population fluctuation of *P. hipparchia* shows that during 2021 there were two population peaks, the first in the months of January-February, when 131 larvae were recorded, and a second population peak in the months of September-October where 97 larvae were recorded, this population peak reappeared during 2022, registering on this occasion 162 larvae (*Figure 4*).

During the samplings, different natural enemies of *P. hipparchia* were recorded; among them, the wasp *Baryceros* sp. (Hymenoptera: Ichneumonidae) was observed parasitising 169 larvae of the 557 registered during the monitoring of the population fluctuation, which is equivalent to 30.3% of natural control. The parasitised larvae showed a yellow colouration (*Figure 5*), in contrast to the brown healthy larvae.

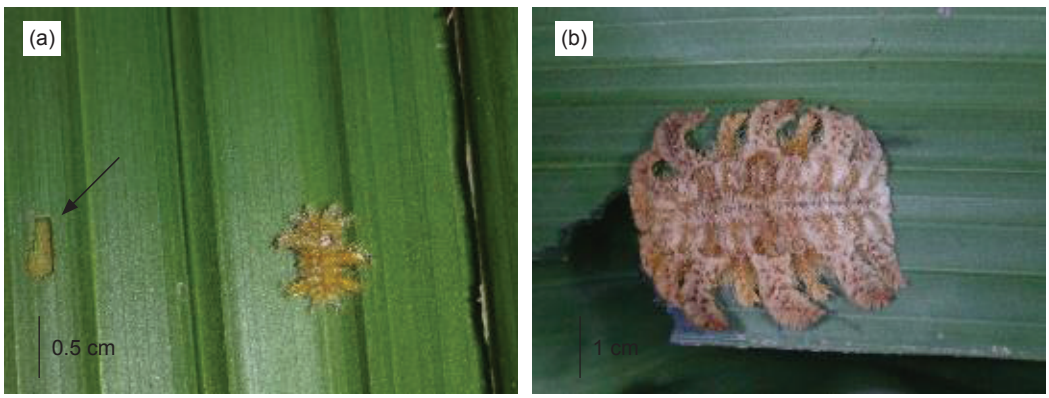

Figure 3. Larvae of P. hipparchia*: (a) Third instar feeding on the superficial part of the leaf blade (indicated with the arrow), and (b) eighth instar larva consuming the entire leaf blade.*

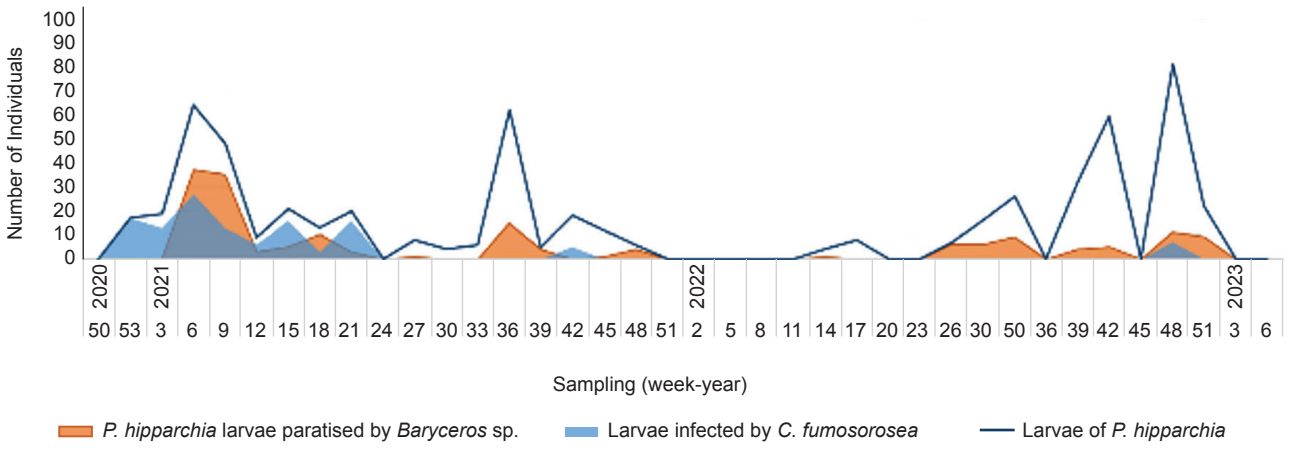

Figure 4. The number of healthy larvae of P. hipparchia*, infected larvae with* C. fumosorosea *and larvae parasitised by* Baryceros *sp. registered on each sampling date of oil palms in the municipality of Agustín Codazzi, Cesar, Colombia.*

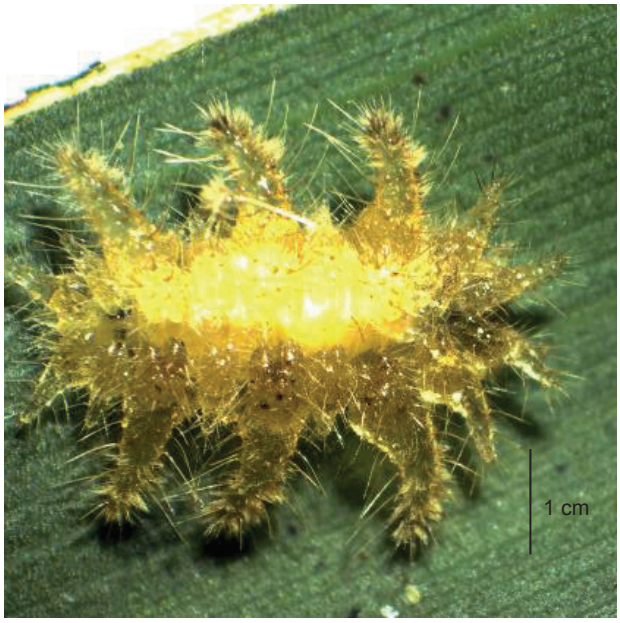

Figure 5. Phobetron hipparchia *larva parasitised by* Baryceros *sp., where it is possible to observe the larva of the parasitoid developing inside the host.*

The second most important mortality factor of larvae is the infections caused by fungus *Cordyceps fumosorosea* (Hypocreales: Cordycipitaceae), which was observed infecting 95 larvae of the 557 registered during the monitoring of the population fluctuation, which is equivalent to 17.0% of the larvae collected. This strain of *C. fumosorosea* was conserved in the collection Entomopathogenic Microorganisms Associated with the Oil Palm (MEAPA for its acronym in Spanish) and was encoded as MEAPA0295, for future use in biological control studies.

No association was registered between the population fluctuation of *P. hipparchia* larvae and the environmental factors studied (*Table 3*), but a strong association was registered between the population fluctuation of *P. hipparchia* larvae and the biological control caused by *Baryceros* sp. (ϱ = 0.685; p<0.0001) and by *C. fumosorosea* (ϱ = 0.505; p<0.001).

The duration of the life cycle of *P. hipparchia* was similar to that registered for other species of the Limacodidae family that are also pests of oil palm

TABLE 3. SPEARMAN'S CORRELATION COEFFICIENT RELATING THE FLUCTUATION OF THE *P. hipparchia* POPULATION WITH CLIMATIC FACTORS AND THE NATURAL CONTROL IN AN OIL PALM LOT

	Precipitation	Temperature	Relative humidity	*Baryceros* sp.	*C. fumosorosea*
P. hipparchia	0.052	-0.041	0.295	0.685	0.502
Sig.	0.756	0.805	0.072	0.0001**	0.001**
Baryceros sp.	0.044	0.111	0.082		
Sig.	0.794	0.505	0.626		
C. fumosorosea	-0.276	0.379	-0.279		
Sig.	0.093	0.019*	0.090		

Note: * - Significant at α = 0.05; ** - Significant at α = 0.01.

crops, such as *E. elaeasa* Dyar, 1906, *S. megasomoides* Walker, 1866 and *A. fusca* Stoll, 1781 under similar conditions (Alvarado et al., 2014; Martínez et al., 2014; Mexzón et al., 1996). Morphologically, the different stages of development are typical of specimens of the Limacodidae family (Epstein, 1996); however, unlike other species such as *A. fusca*, *E. elaeasa*, *S. megasomoides* and *A. extensa* Schaus, 1896 (Alvarado et al., 2014; Martínez & Plata-Rueda, 2013; Pacheco-Flores et al., 2006), the setae that present the larvae and those that cover the cocoons of *P. hipparchia* are not urticating.

The foliar consumption of the larvae of *P. hipparchia* (682.9 ± 103.6 cm^2 of leaves) is much higher than that recorded for other species of defoliating insects of the oil palm that are considered a pest of economic importance to the oil palm plantations in Colombia such as *E. elaeasa* (66.0 cm^2 of leaves), *A. fusca* (402.3 cm^2 of leaves) *S. impressella* Busck, 1914 (36.7 cm^2 of leaves), and *Opsiphanes cassina* Felder, 1862 (294.4 cm^2 of leaf) (Alvarado et al., 2014; Barrios et al., 2014; Martínez et al., 2014; Salles, 2016). This high rate of consumption implies that *P. hipparchia* has the potential to generate heavy defoliation in oil palms and could easily and quickly reach the status of an economically important pest. For this reason, their populations must be kept under permanent monitoring, especially during the second period of the year, when the highest population densities occur. Estimating the foliar consumption of defoliating insects is necessary information for determining economic damage thresholds (Salles, 2016), so this information can be used in the future for this purpose.

Similarly, the study of population fluctuation shows the existence of a strong correlation between the presence of *P. hipparchia* larvae and the presence of the natural enemies *Baryceros* sp. and *C. fumosorosea*; these organisms had already been recorded as important natural enemies of larvae of other species of the Limacodidae family (Gates et al., 2012; Vera, 2020). Other investigations have recorded that viruses of the Polihedrovirus type are one of the main regulators of the populations of larvae of the Limacodidae family (Sambiran et al., 2017; Zeddam et al., 2003); however, in the present investigation, no *P. hipparchia* larvae with symptoms of viral infections were recorded. In turn, other studies carried out on oil palm show the importance of natural control in the regulation of pest insect populations such as *S. cecropia* and *E. elaeassa* (Alvarado et al., 2014; Sendoya & Bustillo, 2016). Monitoring the population dynamics of *P. hipparchia* shows that this insect was not permanently recorded in the oil palm plot, but rather that its presence is associated with the decrease of its natural enemies, due to this it should be considered as an occasional pest of the oil palm in the Colombian Caribbean, concluding that maintaining adequate natural control, it is possible to keep the populations of these insect pests at levels that do not cause economic damage to the crop and reducing dependence on chemical insecticides.

CONCLUSION

Phobetron hipparchia has a short life cycle and its larvae are voracious and consume a high amount of oil palm leaf blade, which could cause severe defoliation that could affect the productivity of the oil palm, due to this, its populations should be monitored especially during the second semester, when the highest population peaks occur. On the other hand, the registered natural enemies seem promising to be used in biological control plans for *P. hipparchia*.

ACKNOWLEDGEMENT

The authors want to express their gratitude to the technical and administrative staff of the Palmas Sicarare Plantations for providing their facilities for this research and to the Government of Cesar that co-financed this research through the Sistema General de Regalías contract No. 2019-02-1363, Prodesarrollo and the Oil Palm Research Center Corporation and Dr. Marc E. Epstein for his support in the taxonomic identification of *P. hipparchia*.

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