

Research Article

Development and Fecundity of *Pseudococcus cryptus* (Hempel) Is Temperature-Dependent

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Abstract

This experiment examines the impact of temperature on the physiology and reproductive output of *Pseudococcus cryptus* (Hempel), a major vector of areca palm yellow leaf disease (APYLD). *P. cryptus*, mealybug, a vector of areca palm velarivirus 1 (APV1), which causes areca palm yellow leaf disease (AYLD), it has a toxic effects on plantations in Hainan, China. Keeping in view, the financial value of areca palms in Hainan, optimal pest management is crucial. An integrated pest management (IPM) strategy such as natural enemies and insecticides and temperature directly affects *P. cryptus* development and reproduction. Research indicates that *P. cryptus* shows the highest average egg production of *P. cryptus* was observed at 25 °C (182 eggs per female), and 30 °C (117 eggs per female), and in the same line the average viability of the entire nymphal was highest at 25-30 °C, outside this range; decline in the two parameters were observed due to thermal stress. The minimum days recorded for female development was 29.9 d at 25 °C, and the female developmental periods extended up to 37.3 d to 44.1 d at 35 °C and 20 °C, respectively, due to a decrease in metabolic rates. This extends larval vulnerability to natural enemies and chemical control. By monitoring temperatures in the 25-30 °C range, agricultural technician can forecast potential pest surges, such as those from the spindle bug or leaf-eating caterpillars common in areca palms, enabling proactive scouting and targeted interventions to curb infestations early.

Keywords

Pseudococcus cryptus, Areca Palm, Fecundity, Survival Rate, Duration of Development

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1. Introduction

Mealybugs are one of the most serious pest of agricultural and horticultural crop [1]. The cryptic mealybug, *Pseudococcus cryptus* (Hempel), belongs to the order Hemiptera, family Pseudococcidae, genus *Pseudococcus* [2, 3]. It can now be found in the tropical and subtropical regions of Africa, Central and South America, East Asia, China, and Japan. The host-plant range of *P. cryptus* includes 51 families and 90 genera. It causes damage to citrus (*Citrus* spp.) and palms (especially areca palm (*Areca catechu*), oil palm (*Elaeis guineensis*) and coconut palm (*Cocos nucifera*)), and other plants such as coffee, lemon, pomegranate, chestnut, pear, apple, tea, oil tea, mango, avocado, banana, ficus, gardenia, jasmine, "pothos" (*Scindapsis* sp.), pittosporum, rhododendron, guava, oleander and persimmon [3-6]. There are 10 species of *Pseudococcus* insects (*P. calceolariae*, *P. comstocki*, *P. cryptus*, *P. longispinus*, *P. maritimus*, *P. odermatti*, *P. saccharicola*, *P. viburni*, *P. philippinicus* and *P. baliteus*) recorded in China [7-9]. The mealybug *P. cryptus* adults and nymphs often cluster on the back of areca palm cracked leaves coated in white mealywax. This damage is due to *P. cryptus* having piercing-sucking mouth parts that use it to extract nutrients from the leaves and stems of the plants. Excess sap directly produces a substance called honeydew, which attracts ants and promotes the growth of black sooty mold fungus, which inhibits the plant's ability to photosynthesize, resulting in distorted and yellowed (chlorotic) leaves, stunted growth, and occasionally death of infested plants or plant parts reducing the economic value of the seplants [10]. At the same time, since the insect begins to secrete wax on its body soon after hatching, a thick white powdery wax gradually forms, covering almost the entire insect body, making it challenging to control. Recently, studies demonstrated that mealybug *P. cryptus* could transmit areca palm velarivirus 1 (APV1), causing the most serious AYLD disease of the areca palm, one of the most economically important crops in Hainan Province, China [11, 12].

Despite the importance and invasion potential of *P. cryptus* and temperature remains among the critical environmental factors. It plays an important role in the survival and abundance of mealybugs [13]. Research on the effects of temperature on the development and fecundity of *P. cryptus* in Hainan Province is limited. This study examined the life cycle of *P. cryptus* on the areca palm under six constant temperatures (15, 20, 25, 30, 35, and 40 °C). The results offered information to assess pest infestation risks in subtropical zones. The developmental stages of *P. cryptus* also clarify its life history, thermal tolerance, and susceptibility to natural enemies and insecticides at various temperatures. This information is vital for improving pest management in areca palm groves.

2. Material and Methods

2.1. Sources of Mealybug *Pseudococcus cryptus* for Testing

Mealybug *P. cryptus* females were reared on a non-host plant pumpkin fruits (*Cucurbita moschata*) as food for the mealybug and incubated inside a nylon net cage (50 × 50 × 100 cm) at room temperature (26.0 ± 2.0 °C; 70% ± 5% RH; 12L: 12D photoperiod) [14].

2.2. The Host Plant Source

Seedlings of areca palm (*Areca catechu* L.) were used as host plants for feeding mealybug in a greenhouse in rearing cages, at the Coconut Research Institute of Chinese Academy of Tropical Agricultural Sciences, located in Wenchang, Hainan Province, China. The plants were watered with tap water every six days and maintained under identical natural conditions without fertilizers and chemicals.

2.3. Biological Parameters

The developmental phases of *P. cryptus* was determined at 6 constant temperature incubators: 15, 20, 25, 30, 35 and 40 °C (± 1 °C), relative humidity 70 ± 10%, photoperiod 12 h (L: D=12: 12). Mealybug females were transferred to a plastic box vial size (20 × 13 × 7 cm) covered with a plastic cover of 60-mesh sieve. The plastic contained moist, soaked filter paper. Females were kept inside the box for the development of eggs in an ovisac. *P. cryptus* adults were fed with fresh areca palm leaves and placed in a controlled incubator having the mentioned temperatures. After the females started to lay eggs, 20-30 first instars nymphs were collected with a smooth hair brush. The nymphs were transferred to a plastic box (described as above) containing fresh areca palm leaves for feeding. The areca palm leaves were replaced after every 6 d. The developmental duration for each instar was observed daily under a stereoscopic microscope and the distinction between the three stages of nymphal development of females was made. The average developmental time from hatching till last moult for female nymphs was analysed for every instar using Excel 2010 and SPSS 26.0 software. The lifespan of *P. cryptus* females was calculated as the sum of the duration of each instar and the pre-oviposition period. The overall survival rate from egg to adult female at each temperature treatment was determined by the number of adult females emerged divided by the total number of eggs used in the initial infestation, then multiplied it by 100% [15].

2.4. Statistical Analysis

For statistical analysis, each mean value is given with its standard error (±SEM). The effect of temperature on the development time, oviposition period, and Survival rates of various

population growth parameters of *P. cryptus* were analyzed using one-way ANOVA followed by a post hoc Tukey test to analyse the significant difference among treatments. A p-value of ≤ 0.05 was considered statistically significant.

3. Results

3.1. Fecundity

Within the range of temperatures tested, the yellow coloration eggs of *P. cryptus* were observed in the ovisac and

hatched at 20 °C, 25 °C, 30 °C and 35 °C. All *P. cryptus* females failed to lay eggs at 15 °C and 40 °C, suggesting that these two temperatures were not suitable for the egg-laying. The highest average of egg production of *P. cryptus* was recorded at 25 °C and 30 °C with several numbers, i.e 182 and 117 eggs per female, respectively, suggesting that the female's fertility increased gradually by temperature through a range of 25-30 °C. The lowest average of egg production was shown at the two extremes, indicated that they are extremely vulnerable to high or low temperatures. (Table 1).

Table1. Fecundity of female *P.cryptus* under 6 different constant temperatures.

Temperature (°C)	Fecundity (The average no. of eggs laid per female)					
	15	20	25	30	35	40
Fecundity	0	115±18.3	182±14.6	117±15.4	90±13.8	0

3.2. Effect of Temperature on the Development of the Female of *Pseudococcus cryptus*

The duration of development of *P. cryptus* females were completed from oviposition to emergence within temperature range of 20 °C, 25 °C, 30 °C and 35 °C (Figures 1, 2 and 3).



Figure 1. The egg formation stage and first instar.



Figure 2. The transition stage from 1st instar to 2nd instar.



Figure 3. The transition stage from 2nd instar to 3rd instar.

In general, an average complete developmental duration of *P. cryptus* female was shorter on areca palm leaves from oviposition to emergence within the defined range of 20 °C to 35 °C. The shortest mean duration occurred at 25 °C with development duration of 29.95 d, whereas the mean longest duration of 44.1 d was observed at 20 °C. The fastest devel-

opmental rate for female 3rd instar nymph occurred at 25 °C, and the slowest pre-oviposition with a duration of 11.5 d. It was evident from the table 2 that the duration of development significantly shortened at 25 °C and increased as temperature increases (Table 2).

Table 2. Developmental duration of individual instars of *P. cryptus* mealybug at different temperatures under laboratory-reared conditions (means $\pm$ SEM).

Temperature (°C)	egg	Female development (d)			Pre-oviposition	Egg to egg
		Nymph				
		1 st instar	2 nd instar	3 rd instar		
15	-					
20	6.0 $\pm$ 0.2a	8.5 $\pm$ 0.2a	10.5 $\pm$ 0.3a	7.6 $\pm$ 0.1a	11.5 $\pm$ 0.4a	44.1 $\pm$ 2.1a
25	3.9 $\pm$ 0.3b	5.3 $\pm$ 0.4b	7.8 $\pm$ 0.5b	4.8 $\pm$ 0.2b	8.2 $\pm$ 0.4b	29.9 $\pm$ 2.8c
30	4.3 $\pm$ 0.2bc	6.5 $\pm$ 0.1c	8.3 $\pm$ 0.3c	5.2 $\pm$ 0.2b	9.2 $\pm$ 0.2c	33.5 $\pm$ 1.8d
35	5.0 $\pm$ 0.4bc	6.7 $\pm$ 0.3c	9.7 $\pm$ 0.3d	5.6 $\pm$ 0.5b	10.3 $\pm$ 0.1d	37.3 $\pm$ 2.2b
40	-					

The shorter developmental rate for female 1st and 2nd instar nymphs occurred at 25 °C and increased with increase in temperature. The relationships between temperature and developmental rate at different stages are shown in Figure 4 and Table 2.

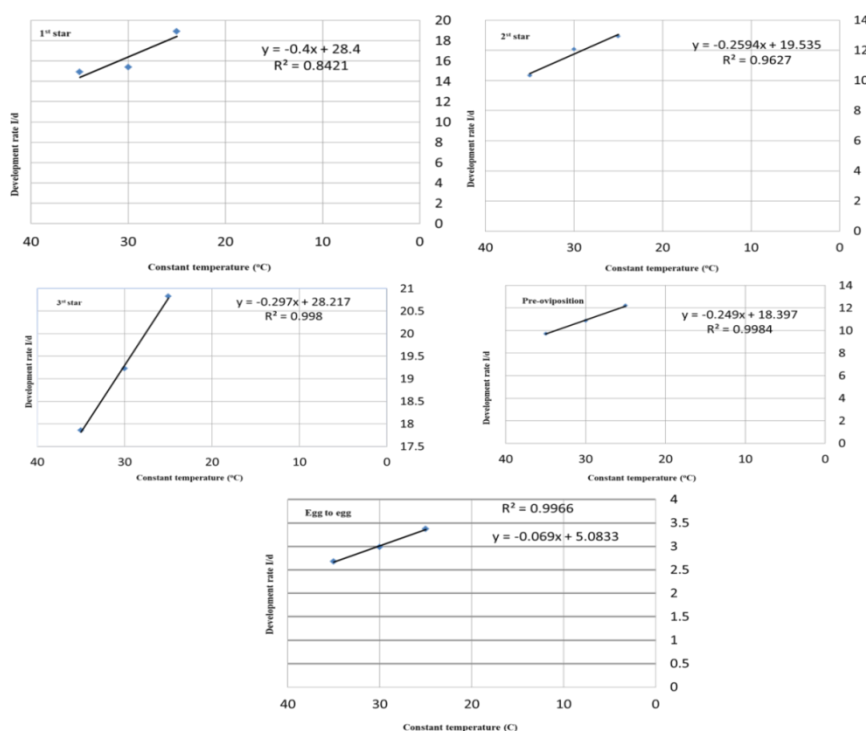


Figure 4. Development rates for nymph and adult pre-oviposition of female *P. cryptus* reared under constant temperatures (25, 30, and 35 °C) in the laboratory. Circled data points were included in linear regression.

3.3. Survival Rates

The viability of the *P. cryptus* nymphal stage was relatively high at first and third instars within all temperature ranges despite some minor differences (Table 3).

Table 3. Survival rates of individual instars of *P. cryptus* mealy bug at different temperatures.

Temperature (°C)	Viability (%)			
	Nymph			Egg to adult
	Egg+ 1 st instar	2 nd instar	3 rd instar	
20	95.4±1.3	82.3±1.8	90.2±1.0	35.4±2.0
25	97.5±2.0	93.4±1.3	95.1±1.6	32.2±1.9
30	93.4±1.9	85.3±2.1	91.6±1.3	40.3±2.1
35	90.3±1.4	80.2±1.8	90.3±2.0	43.2±2.8

The average viability of the entire nymphal was highest within three stages reared at 25 °C. The lowest viability of nymphs in the second instar when compared to first and third instars nymph, especially at lowest and highest temperatures, suggested that they are highly susceptible to extreme temperatures.

4. Discussion

The areca palm (*Areca catechu*), one of the most economically important crops in the Hainan province of China, is severely attacked by the mealybug *P. cryptus*. It is responsible for the transmission of APV1 [12]. The fast developmental nature of mealybug along with lack of management at early stages, increased its high survival rate in the tropical and subtropical regions worldwide [15, 16].

P. cryptus is temperature-dependent, and it is considered an important ecological factor affecting fecundity, development, survival and reproduction. The highest average egg production of *P. cryptus* was observed at 25 °C (182 eggs per female), and 30 °C (117 eggs per female), and the fertility decreased above and below these two temperatures, indicating that they are extremely vulnerable to high or low temperatures. This is in line with the results of the previous research [8], where it is reported that the fertility rate decreases at low temperatures. Since the gonads and egg formation was dependent on hormone secretion in insects which was ultimately affected by change in temperature. These observations are consistent with the findings by [17] who observed *P. cryptus*, feeding on pumpkin, produced higher offspring (111 eggs per female) when exposed to 28 °C temperature, which decreases to 102.7 eggs per female at 32 °C. They also observed that the total number of eggs laid by *P. cryptus* female varied between 59 to 152, influenced by temperature and the species of host plant

[17-19]. Furthermore, another research [19] demonstrated that the highest hatching rate of *P. citri* eggs on grapefruit leaves was obtained at 25/30 °C, and the lowest one was at 20 °C. However, no hatching was observed at 35 °C.

The development of *P. cryptus* on areca palm is influenced by temperature, varying from 30 to 44.1 d, and the longest development duration recorded from egg to adult of *P. cryptus* nymphs was 44.1 d at 20 °C. Whereas the minimum days recorded to insect development was 29.9 d at 25 °C. At 20 °C, the female developmental periods extended up to 44.1 d due to decrease in metabolic rates. Furthermore, at lower temperatures, the immature mealybugs have extended developmental periods and produce thin waxy secretion [15]. Moreover, the female development period is shortest at 25 °C and increases with an increase in temperature. This may be due to the nutrient supply of the host plant changing under high temperatures, the reason for delayed development of female mealybug or female nymphs of *P. cryptus* could diapause [20]. The results, are in line with the findings of [21] who reported total development duration of *P. cryptus* nymphs reared on citrus leaves (Satuma Mandarin cultivar) were shorter at temperatures between 25 °C (25.3 d) and 27.5 °C (21.6 d), whereas longer developmental durations (41.6 d) were recorded at 20.0 °C. Also, it was reported that the total development time of *P. cryptus* was shorter at 28 °C (17.4 d) and slightly increased to 19.3 d at 32 °C [9]. The results showed that optimum development temperature for *P. citri* to complete its life cycle was 25/30 °C [18]. The effect of five constant temperatures (15, 20, 25, 29 and 35 °C) on vine mealybug, *P. minor* at 60±10% RH and constant light were studied, the result revealed that there was no development at 15 and 35 °C [21]. It was evident from the research that the longest development from egg to adult of the nymph was 48.8 d at 20 °C and declined to 30.8 and 26.9 d at 25 and 29 °C, respectively. The

influence of temperature on the development of *P. longispinus* in coffee was studied, verifying the longest survival of the nymphal stage at 20 °C and the optimal temperature for insect development was 25 °C [22]. Extreme and constant temperatures at 15 and 35 °C did not allow the development of *P. longispinus*. The total developmental period of different stages of the female *P. vovae* was shortest at 26 °C (27.00 d), with the longest developmental duration of females at 20 °C [23].

Results of this study indicated that the nymphal viability of *P. cryptus* was low under 20 °C and reached a highest peak at 25 °C then was decreased again with increased temperature indicating that neither high temperature nor low temperature is conducive to the survival of various insect states of *P. cryptus*. This result was consistent with that of Heidari [17] who similarly identified previously that 22–26 °C is the best temperature for the highest *P. comstocki* on potato sprouts viability and the lowest at 30 °C. The findings of this study further emphasize the potential of *P. cryptus* to spread as a pest across tropical regions, especially during the summer growing season.

5. Conclusion

Current findings might support different developmental stages of *P. cryptus*, as it offers deeper insights into its life history and ability to survive at various temperatures. Furthermore, this study also established a life table of an experimental population of mealybug *P. cryptus* under constant temperature conditions of 15 to 40 °C and found that at 25 °C, *P. cryptus* become swiftly, grown in less time. This study not only provides an important source for quantifying their attack risk in subtropical regions but also help us to determine the stage that increases their exposure to natural enemies and insecticides. Understanding how environment conditions affect *P. cryptus*'s growth, life cycle, and reproduction is key to managing infestations and preventing associated diseases like areca palm yellow leaf disease.

6. Highlights

The experiment examines the impact of temperature on the physiology and reproductive output of *P. cryptus*, a major vector of APYL disease.

The results indicated that the optimum temperature range for population growth is 25 to 30 °C. These findings highlight the importance of temperature management as a key factor in integrated pest management strategies for areca palm plantations.

Abbreviations

APV1	Areca Palm Velarivirus 1
AYLD	Areca Palm Yellow Leaf Disease
IPM	Integrated Pest Management

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Author Contributions

H.A.A. Gouda and S. Jan contributed equally to this work as first co-authors. They were responsible for conceptualization, methodology, data analysis, and writing the original draft. N.N. Wang, W.W. Song, X.L. Meng, Z.W. Lin, and S.M. Rasheed contributed as second co-authors, assisting with investigation, validation, data curation and formal analysis. W.Q. Qin*, S.C. Huang*, and Q.H. Tang* supervised the study, provided critical revisions, and approved the final manuscript as corresponding authors (*).

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Data Availability

Data will be made available upon the request.

Conflicts of Interest

The authors declare no known conflicts of interest that could influence the work reported in this paper.

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