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EFFECTS OF TEMPERATURE ON THE DEVELOPMENT OF *STENOMA IMPRESSELLA* (LEPIDOPTERA: ELACHISTIDAE) ON OIL PALM IN COLOMBIA

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ABSTRACT

Stenoma impressella Busck (Lepidoptera: Elachistidae) is an important oil palm pest and its life history and life table parameters were studied at various temperatures, from 16 °C to 40 °C. Females and males developed successfully into adults between 20 °C and 36 °C. However, no eggs were found at 10 °C and all the adults died after exposure to 40 °C. The developmental time from egg to adult was higher (170.5 days) at 15 °C and lower (76.6 days) at 35 °C. Therefore, temperature has a strong effect on the development of *S. impressella* from 15 °C to 35 °C. The reproductive period varied between 15-35 °C with 6.82 to 3.24 days for pre-oviposition, 17.5 to 4.89 days for oviposition, and 5.29 to 0.82 days for the post-oviposition period. Female longevity was longer than that of the male, at all temperatures. The population growth parameters of *S. impressella* net reproductive rate (R_0), intrinsic rate increase (r_m), finite increase rate (λ), mean generation time (T) and doubling time (D) were significantly affected by temperature. Temperature affects *S. impressella* populations by reducing or increasing their possible occurrence in the palm trees. The effect of temperature on the development, survival and reproduction of *S. impressella* can be useful for predicting its long-term population fluctuation as an invasive pest of oil palm plantations.

Key Words: demographic parameters, insect pest, longevity, reproduction, survival, *Stenoma impressella*

RESUMEN

Stenoma impressella Busck (Lepidoptera: Elachistidae) es una plaga importante de la palma de aceite y los parámetros de historia de vida y tabla de vida fueron estudiados a diferentes temperaturas desde 16 °C hasta 40 °C. Las hembras y los machos se desarrollaron exitosamente hasta adultos entre 20 °C y 36 °C. Sin embargo, no se encontraron huevos a 10 °C y todos los adultos murieron después de ser expuestos a 40 °C. El tiempo de desarrollo de huevo hasta adulto fue mayor a 15 °C (170.5 días) y menor a 35 °C (76.6 días). Además, la temperatura tiene un fuerte efecto en la supervivencia de *S. impressella* desde 15 °C hasta 35 °C. El período de reproducción varía entre 15-35 °C con 6.82-3.24 días para la pre-ovoposición, 17.5-4.89 días para la ovoposición y 5.29-0.82 días para la post-ovoposición. La longevidad de la hembra duró más que la del macho, en todas las temperaturas. Los parámetros de crecimiento de la población de *S. impressella* como la tasa reproductiva neta (R_0), tasa intrínseca de incremento natural (r_m), tasa de incremento finito (λ), tiempo medio generacional (T) y tiempo de duplicación (D) fueron afectados significativamente por la temperatura. La temperatura afecta las poblaciones de *S. impressella*, reduciendo o aumentando su posible presencia en las palmas. El efecto de la temperatura sobre el desarrollo, supervivencia y reproducción de *S. impressella* puede ser útil para predecir su fluctuación poblacional a largo plazo como plaga invasora en plantaciones de palma de aceite.

Palabras Clave: insecto plaga, longevidad, parámetros demográficos, reproducción, sobrevivencia, *Stenoma impressella*

Stenoma impressella Busck (Lepidoptera: Elachistidae) is a pest of oil palm (*Elaeis guineensis* Jacquin; Arecales: Arecaceae) with the larvae defoliating the oil palm plantations in Colombia, Costa Rica, Ecuador, Honduras, Panamá, Peru and Venezuela (Genty et al. 1978; Howard et al. 2001; Martínez & Plata-Rueda 2013). The larvae of *S. impressella* are associated with *Pestalotiopsis* (Xylariales: Amphisphaeriaceae) a fungal disease in oil palm plantations from Colombia (Martínez & Plata-Rueda 2013). *Stenoma impressella,* a highly polyphagous caterpillar, is a known pest of *Citrus sinensis* (Osbeck), *Coffea arabica* (L.), *Psidium guajava* (L.), and *Theobroma cacao* (L.) between 0 and 1600 m altitudes and 22-32 ºC (Genty et al. 1978; Zener de Polania & Posada 1992; Martínez and Plata-Rueda 2013).

Environmental conditions play a vital role in the adaptation of the insect pests and cause variations in the rate of development, colonization and distribution in the tropical crops (Gilbert & Raworth 1996; Nechols et al. 1999; Andreadis et al. 2013; Kim et al. 2013). Temperature has a strong effect on the reproduction and development rates of insects (Burke et al. 2005; Noriyuki et al. 2011; Da Silva et al. 2012). In investigating insect pest problems, the life history theory can be used to analyze population structure and stability, estimate the extinction likelihood, predict pest outbreaks, and examine the colonization and invasion probabilities (Jervis & Copland 1996; Vargas et al. 2000). Studies on the insect's life histories would allow for the construction of models to analyze the reproduction, longevity and population dynamics of the pests in the agroecosystems. Studies on the biology and ecology of the oil palm pest defoliators, *Elymnias agondas glaucopis* Staudinger (Lepidoptera: Nymphalidae), *Metisa plana* Walker, *Pteroma pendula* Joannis (Lepidoptera: Psychidae), *Segestes decoratus* Redtenbacher (Orthoptera: Tettigoniidae), *Leucothyreus femoratus* (Coleoptera: Scarabaeidae) and *Demotispa neivai* (Coleoptera: Chrysomelidae) have been used as a starting point for the adoption of control methods and strategies (Young 1985; Merrett 1993; Ibrahim et al. 2013; Martínez et al. 2013a, 2013b).

Population parameters are important in the measurement of the population growth capacity of a species under specified conditions. These parameters are also used as indices of population growth rates responding to the selected conditions and as bioclimatic indices in assessing the potential of a pest population growth in a new area (Southwood & Henderson 2000). The research has been directed towards determining the basic biology of the insect pests on selected host plants and selected constant temperatures to develop models of the population dynamics (Kim et al. 2001; Bonato et al. 2007; Park et al. 2010; Panassiti et al. 2013). To develop a process-based mathematical model, descriptions of processes such as adult survival rate, oviposition, longevity and stage-specific development rates and mortalities are necessary (Taylor 1982; Southwood & Henderson 2000; Medeiros et al. 2003a, 2003b).

There is little information on the ecology of *S. impressella*, although populations may be increasing rapidly as oil palm plantations expand to cover larger areas (Howard et al. 2001; Martínez et al. 2013c). The biology and life history of *S. impressella* has been partially studied, primarily on the oil palm under variable conditions; however, these studies were carried out in the 1970s under inconsistent experimental conditions and the details of the life-cycle are not conclusive (Genty 1978; Genty et al. 1978).

In this study, we describe the development rate, survival and fecundity of *S. impressella* on the oil palm, *E. guineensis*, under different temperatures, in order to contribute to the comprehension of the demography of *S. impressella* as a basis for the development of Integrated Pest Management (IPM) programs in oil palm plantations.

MATERIALS AND METHODS

Insects

In the field, 1835 adults of *S. impressella* (♂ = 941, ♀ = 894) were hand captured in a 7-yr-old commercial plantations of the oil palm, in the municipality of Puerto Wilches, Santander, Colombia (N 07° 20' -W 73° 54'), with 28.46 °C average temperature, 75-92% RH, 145-225 sunshine h/yr and 2,168 mm annual rainfall. The insects were placed in metallic boxes (70 cm long × 70 cm wide × 80 cm high) covered with a nylon mesh and transported to the Entomology Laboratory at the Universidad de La Paz, Barrancabermeja, Santander, Colombia. *Stenoma impressella* was reared at 28 ± 1 °C and 75 ± 5% RH under a 12:12 h L:D photoperiod. These insects were used to establish a colony under laboratory conditions. Healthy insects without malformations were used in the bioassays.

Development

Males and females of *S. impressella* were caged in glass containers (30 × 30 × 30 cm) covered with a nylon mesh along with *E. guineensis* leaflets. Eggs were collected daily from the leaflet surfaces and transferred to Petri dishes (90 mm × 15 mm high) with a moistened filter paper at the bottom. The eggs were maintained at 16, 20, 24, 28, 32, 36 or 40 ± 1 °C, 75 ± 5% RH and 12: 12 h L:D.

In the course of the larval and pupal development, the first instar larvae were individualized in glass vials (5 cm × 25 cm high) plugged with cotton and fed daily on 25 cm^2 *E. guineensis* leaflets. The larvae and pupae were maintained at the same temperatures as eggs until adult emergence.

The adults were placed in glass containers (30 × 30 × 30 cm) covered with a nylon mesh and fed daily on a liquid diet (10 mL of sugarcane juice + honey + water, 3:1:1 proportion). The adults were maintained at test temperatures. The life history was determined from the newly laid eggs at seven different constant temperatures. Longevity and survival data from the different developmental stages of *S. impressella* were recorded daily.

Fecundity

A pair of newly-emerged adults of *S. impressella* were isolated and kept in glass containers (30 × 30 × 30 cm) containing *E. guineensis* leaflets as the oviposition site and fed daily on a liquid diet. The leaflets were replaced daily and the eggs on each leaf were collected every 24 h and counted, and egg viability was evaluated for each female. Then pre-oviposition, oviposition and post-oviposition periods were then calculated. Twenty pairs of *S. impressella* adults were evaluated daily until the females died.

Statistics

Developmental time, survival and fecundity (pre-oviposition, oviposition and post-oviposition) were subjected to the one-way analysis of variance (ANOVA). The survival variable was summarized in percentage and the data were transformed by √arcsine. The means associated with temperature for each variable were separated using an LSD test at the 5% significance level, when significant F values were obtained. Based on the age-specific mortality for each temperature, the survival curves for females were calculated for the Kaplan-Meier method and compared using the log-rank test. The data were analyzed with the SAS User v. 9.0 for Windows (SAS Institute 2002).

Life table parameters of *S. impressella* were calculated based on the life history data using the Jackknife technique (Meyer et al. 1986; Hulting 1990; Maia et al. 2000). The net reproductive rate (R_0), the intrinsic rate of natural increase (r_m), the finite increase rate (λ), the mean generation time (T) and the doubling time (D) were computed using the SAS User v. 9.0 for Windows (SAS Institute 2002).

Results

Development and Survivorship of Immature Instars

Stenoma impressella completed development at all the temperatures, except at the 16 °C and 40 °C - temperatures, with no oviposition or egg hatching.

Life history parameters of *S. impressella* showed that different temperatures had significant effects on the development time ($F_{1,97}$ = 42.1, P < 0.0001) (Table 1). The developmental time of the egg was 5.12 to 2.18 d ($F_{1,97}$ = 22.3; P < 0.0001), the larval stage was 51.9 to 22.1 days ($F_{1,97}$ = 63.4; P < 0.0001), the pupa was 25.6 to 10.9 d ($F_{1,97}$ = 40.1; P < 0.0001), and the adult was 26.9 to 11.4 days ($F_{1,97}$ = 7.91; P < 0.0001) at temperatures from 20 to 36 °C. At this temperature range, the developmental time decreased as temperature increased, whereas at the higher temperatures the developmental time was faster.

The survival rate of *S. impressella* was affected by temperature ($F_{1,97}$ = 44.6; P < 0.0001) (Table 2).

TABLE 1. DEVELOPMENTAL TIMES OF *STENOMA IMPRESSELLA* STAGES AT CONSTANT TEMPERATURES UNDER LABORATORY CONDITIONS (75 ± 5% RH AND 12:12 H L:D)

	Temperature °C						
Stages Days (mean ± SE)†	20	24	28	32	36	$F_{1,97}$	P
Egg	5.12 ± 0.8 a	4.35 ± 0.7 b	3.57 ± 0.1 c	2.87 ± 0.1 d	2.18 ± 0.5 e	22.35	<0.0001
Larvae	51.9 ± 2.6 a	44.1 ± 1.6 b	36.1 ± 0.6 c	29.7 ± 1.4 d	22.1 ± 1.3 e	63.40	<0.0001
Firth instar	0.89 ± 0.6 a	0.75 ± 9.5 b	0.62 ± 0.3 c	0.51 ± 0.5 d	0.38 ± 1.5 e	12.41	<0.0001
Second instar	2.56 ± 0.4 a	2.17 ± 0.8 b	1.78 ± 0.5 c	1.43 ± 0.5 d	1.09 ± 0.2 e	35.43	<0.0001
Third instar	3.84 ± 0.6 a	3.26 ± 0.7 b	2.67 ± 0.8 c	2.15 ± 0.3 d	1.63 ± 0.9 e	11.72	<0.0001
Fourth instar	5.76 ± 0.9 a	4.91 ± 0.7 b	4.01 ± 0.7 c	3.23 ± 0.3 d	2.45 ± 0.8 e	12.52	<0.0001
Fifth instar	6.41 ± 0.7 a	5.44 ± 0.6 b	4.46 ± 0.4 c	3.58 ± 0.9 d	2.73 ± 0.2 e	16.68	<0.0001
Sixth instar	7.05 ± 0.1 a	5.99 ± 0.1 b	4.91 ± 0.7 c	3.94 ± 0.8 d	3.53 ± 0.5 e	2.12	<0.0001
Seventh instar	7.69 ± 0.2 a	6.53 ± 0.5 b	5.35 ± 0.7 c	4.37 ± 0.1 d	3.27 ± 0.8 e	5.43	<0.0001
Eighth instar	8.33 ± 0.3 a	7.08 ± 0.3 b	5.83 ± 0.5 c	4.66 ± 0.6 d	3.55 ± 0.1 e	4.86	<0.0001
Ninth instar	10.2 ± 0.5 a	8.71 ± 0.4 b	7.14 ± 0.2 c	5.74 ± 0.2 d	4.37 ± 0.1 e	2.87	<0.0001
Pupa	25.6 ± 1.4 a	21.7 ± 0.8 b	17.8 ± 0.5 c	14.3 ± 0.5 d	10.9 ± 0.2 e	40.15	<0.0001
Adult	26.9 ± 1.5 a	22.8 ± 1.5 b	18.7 ± 0.5 c	15.5 ± 0.7 d	11.4 ± 1.5 e	7.91	<0.0001
Egg to adult	109.6 ± 2.3 a	93.1 ± 1.3 b	76.3 ± 0.9 c	61.3 ± 0.7 d	46.7 ± 1.9 e	42.18	<0.0001

†The means followed by different letters in the lines are significantly different (P < 0.05) (LSD). No eggs laid or were laid but did not hatch 16 °C and 40 °C

TABLE 2. SURVIVORSHIP (% ± SE) OF *STENOMA IMPRESSELLA* STAGES AT CONSTANT TEMPERATURES UNDER LABORATORY CONDITIONS (75 ± 5% RH AND 12:12 H L:D).

	Temperature °C						
Stages	20	24	28	32	36	$F_{1,97}$	*P*
Egg	93.1 ± 0.3 d	97.6 ± 0.2 c	100 ± 0.0 a	99.4 ± 0.1 b	97.2 ± 0.1 c	31.91	<0.0001
Firth instar	92.8 ± 0.1 e	96.5 ± 0.5 c	98.7 ± 0.2 a	97.7 ± 0.0 b	95.9 ± 0.1 d	19.42	<0.0001
Second instar	92.5 ± 0.8 e	95.5 ± 0.4 c	97.4 ± 0.6 a	96 ± 0.6 b	94.6 ± 0.1 d	6.94	<0.0001
Third instar	90.6 ± 0.5 d	92.9 ± 0.6 c	94.3 ± 0.8 b	95.8 ± 0.5 a	92.9 ± 0.6 c	5.36	<0.0001
Fourth instar	88.3 ± 0.1 d	89.2 ± 0.5 c	91.7 ± 0.3 b	92.6 ± 0.4 a	88.7 ± 0.5 d	32.89	<0.0001
Fifth instar	81.3 ± 0.9 e	87.6 ± 0.8 c	88.5 ± 0.6 b	89.2 ± 0.2 a	82.4 ± 0.3 d	6.99	<0.0001
Sixth instar	79.3 ± 0.7 d	82.6 ± 0.3 c	86.5 ± 0.5 a	84.2 ± 0.1 b	79.9 ± 0.5 d	26.51	<0.0001
Seventh instar	77.6 ± 0.9 d	80.1 ± 0.2 b	81.8 ± 0.4 a	79.2 ± 0.2 c	75.3 ± 0.1 e	5.78	<0.0001
Eighth instar	74.5 ± 0.6 d	79.2 ± 0.1 a	79.6 ± 0.8 a	78.1 ± 0.3 b	75.1 ± 0.6 c	63.25	<0.0001
Ninth instar	71.6 ± 0.7 d	76.9 ± 0.2 a	75.3 ± 0.1 b	75.8 ± 0.5 b	72.4 ± 0.9 c	8.65	<0.0001
Pupa	68.5 ± 0.3 c	72.5 ± 0.3 a	71.4 ± 0.4 b	68.2 ± 0.7 c	64.6 ± 0.8 d	36.93	<0.0001
Egg to adult	65.9 ± 0.6 d	66.3 ± 0.2 c	69.8 ± 0.5 a	67.5 ± 0.8 b	63.7 ± 0.1 e	44.67	<0.0001

Either no eggs laid or those that were laid did not hatch at 16 °C and 40 °C. The percentages followed by different letters in the lines are significantly different ($p < 0.05$) (LSD).

The survival from the egg to adult ranged between 65.9% at 20 °C up to 69.8% at 28 °C. From 20 °C to 32 °C, the survival increased with low temperature and declined when the temperature increased to 36 °C with 63.7%. The survival rate was higher at 24, 28 and 30 °C.

Adult Longevity and Reproduction

Temperature also had an effect on the reproduction and longevity of *S. impressella* (Table 3). The reproductive period of *S. impressella* varied at temperatures from 20 and 36 °C, with pre-oviposition from 6.26 to 1.63 d ($F_{1,17}$ = 5.29; P < 0.0005), oviposition from 17.6 to 10.2 d ($F_{1,17}$ = 8.08; P < 0.0001), and post-oviposition period from 4.33 to 0.55 d ($F_{1,17}$ = 2.17; P < 0.0001).

The female longevity was longer than that of the males ($F_{1,17}$ = 20.4; P < 0.0001) ($F_{1,17}$ = 16.6; P < 0.0001). Age-specific survival showed that *S. impressella* females were susceptible at temperatures from 20 to 36 °C (χ^2 = 4.165; P = 0.091; Fig. 1). Female longevity varied from 28.2 to 12.4 days, whereas male longevity lasted from 22.9 to 9.75 days. The longevity of the females and males increased at 20 °C and declined gradually when the higher temperatures were reached.

The viable eggs throughout the lifespan of *S. impressella* at different temperatures were different, with peaks between days 9 and 10 at 20 °C; an earlier peak (days 8, 9 and 10) at 24 °C, a peak on day 7 at 28 °C, a peak between days 5 and 6 at 32 °C and a peak on day 7 at 36 °C. The oviposition rate declined gradually at all the temperatures (Fig. 2).

Population Growth Parameters

The population growth parameters of *S. impressella* such as R_0, r_m, λ, T and D were affected by temperature (Table 4). The net reproductive rate (R_0) was altered at all temperatures according to the following pattern: 28 > 24 > 33 > 36 > 20 °C ($F_{1,97}$ = 7.08; P = 0.0001). The intrinsic

TABLE 3. OVIPOSITION PERIOD AND LONGEVITY ADULTS OF *STENOMA IMPRESSELLA* AT CONSTANT TEMPERATURES UNDER LABORATORY CONDITIONS (75 ± 5% RH AND 12:12 H L:D)

Parameter	Temperature °C						
(Mean ± SE)† days	20	24	28	32	36	$F_{1,17}$	P
Pre-oviposition period	6.26 ± 0.6 a	4.43 ± 0.7 b	2.75 ± 0.1 c	2.68 ± 0.6 d	1.63 ± 0.8 e	5.29	<0.0005
Oviposition period	17.6 ± 0.8 b	21.3 ± 0.9 a	21.2 ± 0.7 a	15.3 ± 0.3 c	10.2 ± 0.9 d	8.08	<0.0001
Post-oviposition period	4.33 ± 0.4 a	3.46 ± 0.7 b	1.47 ± 0.1 c	1.17 ± 0.6 d	0.55 ± 0.3 e	2.17	<0.0001
Female longevity	28.2 ± 1.1 b	29.3 ± 0.8 a	25.5 ± 0.3 c	19.2 ± 0.4 d	12.4 ± 0.7 e	20.41	<0.0001
Male longevity	22.9 ± 1.2 a	20.1 ± 1.0 b	18.1 ± 0.2 c	11.4 ± 0.5 d	9.75 ± 0.9 e	16.67	<0.0001

†The means followed by different letters in the lines are significantly different (P < 0.05) (LSD). No eggs laid or were laid but did not hatch 16 °C and 40 °C

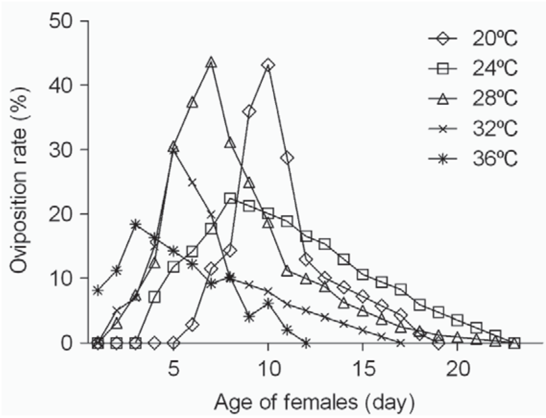

Fig. 1. Survivorship curves for life span of *Stenoma impressella* reared at various constant temperatures determined using the Kaplan-Meier method and compared using the log-rank test (χ^2 = 4.165; P = 0.091)

rate of increase (r_m) also differed according to the pattern 32 > 28 > 24 > 36 > 20 °C ($F_{1,97}$ = 16.23; P = 0.0001). The finite increase rate (λ) differed according to the pattern 32 > 28 > 24 > 36 > 20 °C ($F_{1,97}$ = 9.23; P = 0.0001). The mean generation time (T) decreased with temperature increase between 32 and 36 °C ($F_{1,97}$ = 22.46; P = 0.0001). Doubling time (D) was significantly changed with temperature (F = 91.2; P = 0.000), with a shorter doubling time at 36 °C. The results of R_0, r_m, λ, T and DT showed that the population density of *S. impressella* showed extinction at 15 and 40 °C.

Discussion

Similar to other studies on the Elachistidae biology and ecology, this work showed that different temperatures affected the development, fecundity, longevity and survival of *S. impressella*. Under controlled conditions, *S. impressella* completed their development from 20 to 36 °C, without any eggs hatching at 16°C and 40 °C, indicating that temperature gradients < 20 °C and > 36 °C are unfavorable to the development of this insect. Extreme temperatures may be detrimental to insect development (Logan et al. 1976; Briere et al. 1999; Keena 2006). In our study, development was fast at high temperatures between 20 and 36 °C with the life cycle getting shortened at more than half the time. Peak developmental times of the *S. impressella* stages were from 28 °C to 32 °C. *Stenoma impressella* is commonly found in 3 to7-year-old palms, where the size and number of leaves is smaller when compared with palms over 10 years of age and young palms where the temperature is high and may favor the development of this insect. This is because the immature stages of *S. impressella* have been found in the lower leaves of the canopy and hence are likely benefit from the relatively stable conditions in the palm trees (Genty et al. 1978; Mexzón-Vargas et al. 1996; Howard et al. 2001).

Survival was high in the egg and larval stages. The survival rate can be changed in different insects, at ideal or different temperatures (Nylin & Gotthart 1998; Bowler & Terblanche 2008). Several morphological and behavioral alterations, including cocoon secretion, lack of larvae feeding and movement, were also observed. For instance, the larvae of *S. impressella* did not move at 20 °C, possibly because of the changes in their metabolism or as an attempt to save energy. Some lepidopteran species such as *Anticarsia gemmatalis* Hübner (Noctuidae), *Eriogaster lanestris* L. (Lasiocampidae) and *Stenoma catenifer* Walsingham (Elachistidae) respond to thermal changes by modifying their behavior and inducing metabolism alterations (Ruf & Fiedler 2002; Nava et al. 2005; Da Silva et al. 2012).

The temperatures between 24 °C and 28 °C were the better settings for *S. impressella* oviposition with low egg viability at 20 °C, perhaps due to the lower mating activity, which might impair egg fertilization. However, the pre-oviposition, oviposition and post-oviposition periods gradually increased according to the temperature. The longevity of the females was higher with respect to the longevity of the males and declined gradually when the higher temperatures (32-36 °C) were reached. These results suggest that the adults of *S. impressella* experienced a response of adaptation or dependence, according to the temperature increase. Reproduction and longevity of the different species show different types of adaptation or dependence for the environmental variables (Boggs 1986; Banno 1990; Eckelbarger 1994; Da Silva et al. 2012; Appiah et al. 2013). A short developmental time could be beneficial in the nonseasonal environments, because it reduces the risk of death before reproduction (Nylin & Got-

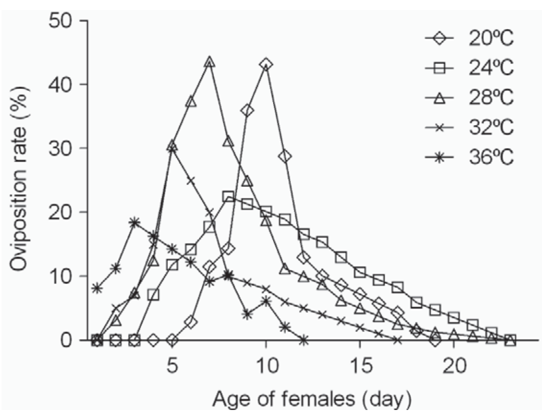

Fig. 2. Age-specific fecundities of *Stenoma impressella* reared at various constant temperatures.

TABLE 4. POPULATION GROWTH PARAMETERS OF *STENOMA IMPRESSELLA* AT CONSTANT TEMPERATURES UNDER LABORATORY CONDITIONS (75 ± 5% RH AND 12:12 H L:D)

Parameter (Mean ± SE)† days	Units	Temperature °C 20	24	28	32	36
Net reproductive rate (R_0)	♀ /Gen	6.938 ± 0.01 d	18.13 ± 0.15 b	35.33 ± 0.01 a	14.22 ± 0.15 c	7.595 ± 0.02 d
Intrinsic rate of increase (r_m)	1/day	0.053 ± 0.03 e	0.119 ± 0.85 c	0.192 ± 0.06 b	0.202 ± 0.15 a	0.104 ± 0.06 d
Finite rate of increase (λ)	1/day	1.058 ± 0.12 e	1.129 ± 0.05 c	1.213 ± 0.48 b	1.223 ± 0.51 a	1.116 ± 0.05 d
Mean generation time (T)	Day	35.07 ± 0.06 a	24.31 ± 0.01 b	17.75 ± 0.85 c	13.21 ± 0.05 d	11.63 ± 0.05 e
Doubling time (D)	Day	17.32 ± 0.09 b	5.725 ± 0.03 c	3.531 ± 0.15 d	3.411 ± 0.14 d	83.93 ± 0.11 a

†The means followed by different letters in the lines are significantly different ($P < 0.05$) (LSD)

thart 1998; Bowler & Terblanche 2008; Andreadis et al. 2013). In this case, the temperature effects on *S. impressella* can impact this invasive pest of *E. guineensis,* even for a short time between generations. In natural conditions, Genty *et al*. (1970) observed that the life-cycle duration of *S. impressella* was lower in seasonally dry period and higher by in rainy season period between 24-36 °C temperatures range, but not provide details of high/low populations of this insect. Our studies suggest that the reduction of development time *S. impressella* for thermal changes can increase the generation number, the emergence peaks in a given year, and the duration of individual developmental stage.

The life table parameters for *S. impressella* varied at all the temperatures evaluated. The net reproductive rate of *S. impressella* rose higher to 28 °C > 24 °C than 36 °C > 20 °C, although the intrinsic and finite rates of population increase rose higher to 32 °C > 28 °C, due to the low immature survival on the former, suggesting that temperatures between 20 °C and 36 °C favor the *S. impressella* population growth and immature survival is probably the most sensitive indicator. Temperature increase results in higher growth rates and shorter developmental times of *S. impressella*. The population dynamics of the oil palm pest under different temperatures have been studied in some species such as *Elymnias agondas glaucopis* Staudinger (Nymphalidae: Satyrinae), *Metisa plana* Walker and *Pteroma pendula* Joannis (Lepidoptera: Psychidae) to develop models that can be incorporated into the phenology of the commercial plantations (Merrett 1993; Basri & Kevan 1995; Ibrahim et al. 2013).

Our findings show that temperature affects the *S. impressella* populations, either by reducing or increasing their occurrence in the oil palm crops.

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REFERENCES CITED

ANDREADIS, S. S., KAGKELARIS, N. K., ELIOPOULOS, P. A., AND SAVOPOULOU-SOULTANI, M. 2013. Temperature-dependent development of *Sesamia nonagrioides*. J. Pest. Sci. 86: 409-417.

APPIAH, E. F., EKESI, S., SALIFU, D., AFREH-NUAMAH, K., OBENG-OFORI, D., KHAMIS, F., AND MOHAMED, S. A. 2013. Effect of temperature on immature development and longevity of two introduced opiine parasitoids on *Bactrocera invadens*. J. Appl. Entomol. 137: 571-579.

BANNO, H. 1990. Plasticity of size and relative fecundity in the aphidophagous lycaenid butterfly, *Taraka hamada*. Ecol. Entomol. 15: 111-113.

BASRI, M. W., AND KEVAN, P. G. 1995. Life history and feeding behavior of the oil palm bagworn, *Metisa plana* Walker (Lepidoptera: Psychidae). Elaeis 7: 18-34.

BOGGS, C. L. 1986. Reproductive strategies of female butterflies: variation in and constraints on fecundity. Ecol. Entomol. 11: 7-15.

BONATO, O., AMANDINE, L., CLAIRE, V., AND JACQUES, F. 2007. Modeling temperature-dependent bionomics of *Bemisia tabaci* (Q-biobiotype). Physiol. Entomol. 32: 50-55.

BOWLER, K., AND TERBLANCHE, J. S. 2008. Insect thermal tolerance: what is the role of ontogeny, ageing and senescence? Biol. Rev. 83: 339-355.

BRIERE, J. F., PRACROS, P., ROUX, A. P., AND PIERRE, J. S. 1999. A novel model of temperature-dependent development for arthropods. Environ. Entomol. 28: 22-29.

BURKE, S., PULLIN, A. S., WILSON, R. J., AND THOMAS, C. 2005. Selection for discontinuous life-history traits along a continuous thermal gradient in the butterfly *Aricia agestis*. Ecol. Entomol. 30: 613-619.

DA SILVA, D. M., HOFFMANN-CAMPO, C. B., FREITAS BUENO, A., FREITAS BUENO, R. C. O., OLIVEIRA, M. C. N., AND MOSCARDI, F. 2012. Biological characteristics of *Anticarsia gemmatalis* (Lepidoptera: Noctuidae) for three consecutive generations under different temperatures: understanding the possible impact of global warming on a soybean pest. Bull. Entomol. Res. 102: 285-292.

ECKELBARGER, K. J. 1994. Diversity of metazoan ovaries and vitellogenic mechanisms-implications for life history theory. Proc. Biol. Soc. Wash. 107: 193-218.

GENTY, P. 1978. Morphologie et biologie d'un lepidoptere defoliateur du palmier a huile en Amerique latine, *Stenoma cecropia* Meyrick. Oléagineux 33: 421-427.

GENTY, P., DESMIER DE CHENON, D., AND MORIN, J. 1978. Ravageurs du palmier á huile en Amérique Latine. Oléagineux 33: 325-419.

GILBERT, N., AND RAWORTH, D. A. 1996. Insect and temperature, a general theory. Canadian Entomol. 128: 1-13.

HOWARD, F. W., MOORE, D., GIBLIN-DAVIS, R. M., AND ABAD, R. G. 2001. Insects on palms. CABI Publ. Intl., U.K.

HULTING, F. L. 1990. A computer program for calculation and statistical comparison of intrinsic rates of increase and associated life table parameters. Florida Entomol. 73: 601-612.

IBRAHIM, Y., TUCK, H. C., AND CHONG, K. K. 2013. Effects of temperature on the development and survival of the bagworms *Pteroma pendula* and *Metisa plana* (Lepidoptera: Psychidae). J. Oil Palm Res. 25: 1-8.

JERVIS, M. A., AND COPLAND, M. J. W. 1996. The life cycle. Insect Natural Enemies, Practical Approaches to Their Study and Evaluation (eds. M. Jervis & N. Kidd), pp. 63-161. Chapman and Hall, London.

KEENA, M. A. 2006. Effects of temperature on *Anoplophora glabripennis* (Coleoptera: Cerambycidae) adult survival, reproduction, and egg hatch. Environ. Entomol. 35: 912-921.

KIM, D-S., LEE, J-H., AND YIEM, M-S. 2001. Temperature-dependent development of *Carposina sasakii* (Lepidoptera: Carposinidae) and its stage emergence models. Environ. Entomol. 30: 298-305.

KIM, T., AHN, J. J., AND LEE, J-H. 2013. Age and temperature-dependent oviposition model of *Neoseiulus californicus* (McGregor) (Acari: Phytoseiidae) with *Tetranychus urticae* as prey. J. Appl. Entomol. 137: 282-288.

LOGAN, J. A., WOLLKIND, D. J., HOYT, S. C., AND TANIGOSHI, L. K. 1976. An analytic model for description of temperature dependent rate phenomena in arthropods. Environ. Entomol. 5: 1133-1140.

MAIA, A. H. N., LUIZ, A. J. B., AND CAMPANHOLA, C. 2000. Statistical influence on associated fertility life table parameters using jackknife technique: computational aspects. J. Econ. Entomol. 93: 511-518.

MARTÍNEZ, L. C. AND PLATA-RUEDA, A. 2013. Lepidoptera vectors of Pestalotiopsis fungal disease: first records in oil palm plantations from Colombia. Intl. J. Trop. Insect Sci. 33: 239-246.

MARTÍNEZ, L.C., PLATA-RUEDA, A., ZANUNCIO, J. C., AND SERRÃO, J. E. 2013a. *Leucothyreus femoratus* (Coleoptera: Scarabaeidae): feeding and behavioral activities as an oil palm defoliator. Fla. Ent. 96: 55-63.

MARTÍNEZ, L.C., PLATA-RUEDA, A., ZANUNCIO, J. C., LEITE, G. L. D. AND SERRÃO, J. E. 2013. Morphology and morphometry of *Demotispa neivai* (Coleoptera: Chrysomelidae) adults. Ann. Ent. Soc. Am. 106: 164-169.

MARTÍNEZ, O. L., PLATA-RUEDA, A., AND MARTÍNEZ, L. C. 2013c. Oil palm plantations as an agroecosystem: impact on integrated pest management and pesticide use. Outlooks Pest Mgt. 24: 225-229.

MEDEIROS, R. S., RAMALHO, F. S., ZANUNCIO, J. C., AND SERRÃO, J. E. 2003a. Estimate of *Alabama argillacea* (Hubner) (Lepidoptera, Noctuidae) development with nonlinear models. Brazilian J. Biol. 63: 589-598.

MEDEIROS, R. S., RAMALHO, F. S., ZANUNCIO, J. C., AND SERRÃO, J. E. 2003b. Effect of temperature on life table parameters of *Podisus nigripinus* (Het., Pentatomidae) fed with *Alabama argillacea* (Lep., Noctuidade) larvae. J. Appl. Entomol. 127: 209-213.

MERRETT, P. J. 1993. Life history of *Elymnias agondas glaucopis* (Nymphalidae: Satyrinae), a pest of oil palm in Papua New Guinea. J. Lep. Soc. 47: 229-235.

MEYER, J. S., INGERSOLL, C. G., MCDONALD, L. L., AND BOYCE, M. S. 1986. Estimating uncertainly in population growth rates: jackknife vs. bootstrap techniques. Ecology 67: 1156-1166.

MEXZÓN-VARGAS, R. G., CHINCHILLA-LÓPEZ, C. M., AND SALAMANCA, D. 1996. Biología de *Sibine megasomoides* Walker (Lepidoptera: Limacodidae): observaciones de la plaga en palma aceitera en Costa Rica. ASD Oil Palm Papers 12: 1-10.

MEXZÓN, R. G., AND CHINCHILLA, C. M. 2004. El gusano túnel, *Stenoma cecropia* Meyrick en palma aceitera en América. ASD Oil Palm Papers 27: 27-31.

NAVA, D. E., HADDAD, M. L., AND PARRA, J. R. P. 2005. Exigências térmicas, estimativa do número de gerações de *Stenoma catenifer* e comprovação do modelo em campo. Pesq. Agropec. Brasileira. 40: 961-967.

NECHOLS, J. R., TAUBER, M. J., TAUBER, C. A., AND MASAKI, S. 1999. Adaptations to hazardous seasonal conditions: dormancy, migration, and polyphenism, pp. 159-200 *In* C. B. Huffaker and A. P. Guttierez [eds.], Ecological Entomology. Wiley, New York.

NORIYUKI, S., AKIYAMA, K., AND NISHIDA, T. 2011. Life-history traits related to diapause in univoltine and bivoltine populations of *Ypthima multistriata* (Lepidoptera: Satyridae) inhabiting similar latitudes. Entomol. Sci. 14: 254-261.

NYLIN, S., AND GOTTHARD, K. 1998. Plasticity in life-story traits. Annu. Rev. Entomol. 43, 63-83.

PANASSITI, B., BREUER, M., MARQUARDT, S., AND BIEDERMANN, R. 2013. Influence of environment and climate on occurrence of the cixiid planthopper *Hyalesthes obsoletus*, the vector of the grapevine disease 'bois noir'. Bull. Entomol. Res. 103: 621-633.

PARK, C-G., KIM, H-Y., AND LEE, J-H. 2010. Parameter estimation for a temperature dependent development model of *Thrips palmi* Karny (Thysanoptera: Thripidae). J. Asia Pacific Entomol. 13: 145-149.

RUF, C., AND FIEDLER, K. 2002. Tent-based thermoregulation in social caterpillars of *Eriogaster lanestris* (Lepidoptera: Lasiocampidae): behavioral mechanisms and physical features of the tent. J. Therm. Biol. 27: 493-501.

SAS INSTITUTE. 2002. The SAS System for Windows, release 9.0. SAS Institute, Cary, NC.

SOUTHWOOD, T. R. E., AND HENDERSON, P. A. 2000. Ecological Methods (3rd Edition). Blackwell Science, Oxford. 575 pp.

TAYLOR, F. 1982. Sensitivity of physiological time in arthropods to variation of its parameters. Environ. Entomol. 11: 573-577.

VARGAS, R. I. WALSH, W. A., KANEHISA, D. T., STARK, J. D., AND NISHIDA, T. 2000. Comparative demography of three Hawaiian fruit flies (Diptera: Tephritidae) at alternating temperatures. Ann. Entomol. Soc. America 93: 75-81.

YOUNG, G. R. 1985. Observations on the biology of *Segestes decoratus* Redtenbacher (Orthoptera: Tettigoniidae), a pest of coconut in Papua New Guinea. Gen. Appl. Entomol. 17: 57-64.

ZENER DE POLANIA, I., AND POSADA, F. J. 1992. Manejo de insectos, plagas y benéficos de la palma africana. Produmedios, Colombia.