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Biology and fertility of *Hypothenemus hampei* (Ferrari, 1867) (Coleoptera: Curculionidae) at 16 °C under laboratory conditions

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ABSTRACT

The coffee berry borer (CBB) *Hypothenemus hampei* (Ferrari, 1867) (Coleoptera: Curculionidae) is one of the main insect pests of coffee crops worldwide. The present research determined the biological parameters of CBB at 16 °C under laboratory conditions. Development time (egg to adult) was 119.3±1.02 days, with 41% survival, and 20.37 eggs.female-1 for a period of 120 days. The biological aptitude of CBB is negatively affected to 16 °C, when compared with temperatures between 18–28 °C.

Key words: Coffee berry borer; life cycle; thermal conditions.

1 INTRODUCTION

Commercial coffee plantations are located in areas with optimal mean temperatures for coffee production, between 18 and 22 °C; temperatures below 12 °C and above 24 °C are unsuitable (Pereira; Camargo; Camargo, 2008). Coffee, an important crop in Colombia, Brazil and other countries, is affected by climate change (Jaramillo, 2018), as are the insects associated with coffee crops. Temperature, the primary abiotic factor affecting insects, controls the annual number of generations (Yamamura; Kiritani, 1998), the duration of the reproductive period and life cycle (Kiritani, 2013), the range of spatial distribution and ecological zones where insects can develop (Milanez; Parra, 2000), and population dynamics (Kiritani, 2013).

The coffee berry borer *Hypothenemus hampei* (Coleoptera: Curculionidae) (CBB) is a serious insect pest in coffee plantations worldwide (Benavides et al., 2013; Vega; Infante; Johnson, 2015). Studies of the thermal requirements of CBB(Jaramillo et al., 2009; Giraldo-Jaramillo; Garcia; Parra, 2018; Hamilton et al., 2019; Azrag et al., 2020) indicate a strong correlation between insect development and abiotic factors, especially temperature, where the development time is inverse to temperature in the range between 18 and 32 °C (Giraldo-Jaramillo; Garcia; Parra, 2018). The CBB did not develop at 15 °C (Jaramillo et al., 2009).

In some countries coffee producers, have commercial coffee areas in subtropical region, in these coffee-growing areas, some months the year, can present the lowest mean temperatures of the year (<18 °C), which is consequently the period with the least development of the coffee berry borer (Hamilton et al., 2019). This is also the period of rest and senescence for the coffee plant, since the harvest has finished (Pereira; Camargo; Camargo, 2008). After the harvest, coffee berries remaining on the plants and the ground can serve as a reservoir for future CBB infestations (Bergamin, 1944).

In the present research, we evaluated the development time of the egg, larval and pupal stages, and determined the fecundity of CBB at 16± 1 °C.

2 MATERIAL AND METHODS

The study was carried out at the Department of Entomology at Cenicafé (National Center for Coffee Research), Manizales, Caldas, Colombia. CBB females were obtained from coffee plantations in Chinchiná, Caldas, Colombia (04°58'46" N, 075°39'25" W). The CBB stock colony was reared on parchment of fee berries (*Coffea arabica* var. Caturra)and kept at a temperature of 25±2 °C, 65±10% relative humidity (RH), and 0:24 h (L:D) photoperiod.

The effect of temperature (16±1 °C) on CBB development was evaluated by using a climate-controlled chamber with a photoperiod of 0:24 (L:D) and 60±10% RH. Females were maintained on an artificial diet made with *C. arabica* var. Caturra. Eggs were collected within ~12 h after they were laid. According to the method of Giraldo-Jaramillo, Garcia and Parra (2018), the eggs were placed on 24-well culture plates (TPP Techno Plastic® ref.920024) containing 3–4 mL of artificial diet per well. Each well contained one egg, for a total of 600 eggs on 25 plates. Each well was inspected daily to record the development and survival of the insects until the adults emerged.

To evaluate the fertility of CBB at 16 °C, parchment coffee berries var. Caturra with 60% ± 10% water content were infested with CBB females approximately 35 days old, obtained from the laboratory colony. The parchment coffee berries were

placed individually in the same type of culture plates used for the artificial diet. The total number of fruits established was 600 parchment coffee berries. Fifty samples of parchment coffee berries were removed from the plates every 40 days and dissected under a Zeiss® Stemi SV¨6 stereomicroscope, to count the immature stages of CBB. The evaluations concluded when adults (F_1) were found.

A descriptive analysis was carried out for each variable evaluated: measures of central tendency using the meanand measures of variation (standard error of the mean, SEM), by means of the statistical program R core-team 3.6.1 (R Core-Team, 2019).

3 RESULTS

All CBB immature stages were able to complete their development at the test temperature (16 °C). Survival of the development stages (egg-pupa) was 74–90%. The duration of the cycle was 119 days and the total survival from egg to adult was assessed in 41% of CBB colony units (Table 1).These values are lower than those obtained in other studies of the effect of temperature on the CBB life cycle over the range of 18 to 30 °C. In general, the higher the temperature, the shorter the life-cycle duration and the higher the survival and fertility (Jaramillo et al., 2009; Giraldo-Jaramillo; Garcia; Parra,2018; Azrag et al., 2020).

For females of *H. hamperi* in the parchment coffee berries, the total fecundity (mean number of eggs laid per female) was 20.37±1.02 eggs for 120 days, until the F_1 females emerged. Other investigators have reported on the reproductive potential of CBB in different temperatures; Jaramillo et al. (2009) and Hamilton et al. (2019) found that the best reproductive performance of CBB was between 20 and 27 °C. However, below 20 °C and above 28 °C, the reproductive potential decreased (Jaramillo et al., 2009).

For the CBB, the lowest threshold temperatureis between 10 and 18 °C,as reported by many authors(Jaramillo et al., 2009, Ruiz-Cárdenas; Baker, 2010, Giraldo-Jaramillo; Garcia; Parra, 2018). In the present study, all CBB stages completed their development at 16 °C.Some authors, such as Jaramillo et al. (2009) and Azrag et al. (2020) have reported that the CBB life cycle was not completed at 15 °C.

4 DISCUSSION

Geographical regions with temperatures that fall below a mean annual temperature of 17 °C are considered unsuitable for coffee (*C. arabica)* production (Jaramillo et al., 2018; Pereira; Camargo; Camargo, 2008). Besides, coffee trees grow more slowly in regions where temperatures drop to about 15 °C, since there is a reduction in the photosynthetically active area (Coste, 1989). According to Pereira, Camargo and Camargo (2008), this temperature affects the duration of the phenological cycle, which impacts the induction of floral buds that would negatively affect the next harvest.

For example, coffee-growing areas in the State of São Paulo in Brazil may have temperatures between 16–17 °C during June through August (Alvares et al., 2013; Giraldo-Jaramillo; Garcia; Parra, 2018), so the coffee berries remaining on the plants and on the ground would serve asa reservoir for future CBB infestation (Castaño; Benavides; Baker, 2005). As Johnson et al. (2019) stated, old coffee berries are widely acknowledged as CBB reservoirs, and they emphasized the importance of whole-farm sanitation in coffee berry borer management by demonstrating the negative impact that poor postharvest control can have on the following season's crop.Coffee-growing areas where low temperatures (below 18 °C) occur in the inter-harvest season are not sufficiently cold for CBB populations to decrease, since according to the present study, the insects can survive even at these temperatures.

Coffee-growing areas exposed to temperatures around 16 °C during the harvest and resting coffee seasons will have suitable conditions for CBB survival. The insects will slowly reproduce and can persist for up to 120 days, developing from egg to adult and surviving in coffee berries left on the tree and the ground. Once the new coffee berries are growing in the next season, CBB populations will increase as the temperature rises and fruits become available to host new CBB colonizing populations. These results explain the findings of Bergamin (1944) and emphasize the importance of carrying out the so-called "repasse", which consists of sanitizing coffee crops by removing all remaining coffee berries from the trees and ground once the harvest is complete.

Table 1: Mean development time and survival of eggs, larvae, prepupae, pupae and adult stages (±SE) of *Hypothenemus hampei* grown in artificial diet at a temperature of 16±1 °C, RH 60±10% and 24 hours scotophase.

Parameters	Stages of *Hypothenemus hampei*									
	N	Egg	N	Larvae	N	Prepupae	N	Pupae	N	Egg-adult
Development time (days)	600	21.3±0.04	443	37±0.09	360	31.9±0.08	272	29.7±0.11	245	119.3±1.02
Survival (%)		74		81		76		90		41

The number of repetitions is given by the N value. Egg-adult period was calculated by summing the mean period of each stage (eggs, larvae, prepupae and pupae).

5 CONCLUSION

The biological aptitude of CBB is negatively affected to 16 °C, since the cycle duration is very long, with low survival and low fertility compared with temperatures between 18–28 °C. These findings can explain the permanence of remained populations of CBB between harvests (years) in coffee growing regions when that temperature is lowest to 17 °C.

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