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Effect of temperature on the development, reproduction and mortality of the sweetpotato weevil *Cylas brunneus* (Fabricius) (Coleoptera: Brentidae)

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Abstract

The sweetpotato weevil, *Cylas brunneus*, is a serious insect pest of sweetpotato (*Ipomoea batatas* (L.) Lam.) in East and West Africa. Knowledge on the influence of temperature on development, reproduction and mortality of this pest is important in understanding its potential population growth and geographical distribution. Such knowledge is a pre-requisite for developing pest control strategies for different agro-ecological zones. The effect of temperature on the development of immature stages, reproduction and mortality of *C. brunneus* was studied at six constant (15, 20, 25, 30, 35 and 40°C) and at fluctuating temperature range of 22.9 ± 8.7°C. Results obtained indicated that at 15°C and 40°C, there was no development and reproduction of *C. brunneus*. At 35°C, only 46% of eggs hatched after 1.78 ± 0.20 days but the larvae from these eggs did not pupate. Egg-laying was not possible at 15 °C, 35 °C and 40 °C. The developmental period from egg to adultat 15 °C, 20 °C, 30 °C and 35 °C was 59.43 ± 2.17 days, 49.00 ± 0.93 days, 34.70 ± 0.45 days and 28.67 ± 0.46 days, respectively and tended to decrease significantly with increasing temperature. Similar trend was observed for larval and pupae development time. There was 100 % egg mortality at 15°C and 40 °C. Larval mortality was highest (46 %) at 35 °C and lowest (18 %) at 25°C. After emergence, adults had a pre-oviposition period that ranged from 5.73 ± 0.21 days at 30 °C to 16.17 ± 0.91 at 20°C. *C. brunneus* laid the highest number of eggs (93.67 ± 10.54 eggs) at 30°C and least eggs (26.33 ± 2.84 eggs) at 20°C. Based on these life table data, the optimal temperature for *C. brunneus* population growth and development was noted to be 25°C.

Key words: Integrated Pest Management, *Ipomoea batatas,* life-table studies, pest phenology

Introduction

Two species of African sweetpotato weevils, *Cylas brunneus* (Fabricius) and *Cylas puncticollis* (Boheman), are the two most important insect pest of sweetpotato in Africa. *C. brunneus* has been recorded in West, Central and East Africa but the exact distribution and pest status in Southern and Northern Africa is unknown (Smit, 1997; CAB International, 2005). *Cylas brunneus* attacks sweetpotato in the field by feeding on the foliage or roots, and laying eggs in roots or vines. Injuries caused by the adult on foliage reduce photosynthetic activity while larval activities induce terpenoid production in the roots which render them unfit for human consumption (Stathers *et al.*, 2003). In Uganda, yield losses of 56 to 98% due to damage by the two African sweetpotato weevils have been reported in farmers' fields (Ebregt *et al.*, 2004; Muyinza *et al.*, 2007; Okonya and Kroschel, 2013). Yield loss caused by *C. brunneus* alone is however not known since it always co-exists in the field with *C. puncticollis* (Smit, 1997).

The recent fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC) predicts that in Africa, land temperatures will rise faster than the global land average by 3 - 6 °C by 2050 (IPCC, 2013). A temperature increase of even a modest magnitude will have a number of implications on the biology and development of exothermic organisms such as insects and may lead to greater range expansion, abundance and outbreaks of insect pests (Bale *et al.*, 2002). The spread of *Hypothenemus hampei* (Ferrari) and *Anopheles* mosquitoes to formerly cold highland areas in Uganda, Ethiopia and Brazil are two good examples of how global warming is already influencing insect geographical distribution (GoU, 2007; Jaramillo *et al.*, 2013). *Cylas brunneus* will be no exception to this rule.

Knowledge on how temperature influences the development, mortality and reproduction of *C. brunneus* is important in understanding its potential population growth and geographical distribution. Such knowledge could help policy makers to understand the vulnerability of sweetpotato farming systems to this major insect pest in the face of global warming. Such information also may help scientists to develop a cost effective and environmental friendly strategy to adapt integrated pest management (IPM) to this pest. However, very scanty information is available on how temperature affects the development of *C. brunneus* and as such, the aim of this study was to determine the direct effect of temperature on the development and reproduction of this important sweetpotato pest.

Materials and methods

The *C. brunneus* specimens used in this study were obtained from a laboratory colony, which was initiated from field collection at the National Crops Resources Research Institute (NaCRRI), Namulonge in Uganda. The effect of temperature on the development of immature life stages, mortality and reproduction of *C. brunneus* was studied at six constant (15, 20, 25, 30, 35 and 40° C) and fluctuating temperatures (mean 22.9±8.7°C). One hundred *C. brunneus* eggs, larvae, and pupae were used to study the development time and mortality of each stage and the longevity of female and male adults, while 30 adult females were monitored for total oviposition.

Eggs

Because *C. brunneus* eggs are laid very close to the skin of the sweetpotato root, it is not possible to know if an oviposition hole contains an egg or not without opening it. Additionally, once the oviposition hole is opened, the egg gets destroyed. In light of this challenge, two sets of sweetpotato root pieces were provided to adult females for oviposition. One set of approximately 100 eggs contained in 133 oviposition holes (number of eggs estimated based on a study of 600 oviposition holes) was destroyed to determine egg to larva development period while the second set of 100 eggs (133 oviposition holes) was not disturbed. The number of days each egg took to hatch and the number of eggs that failed to hatch were recorded.

Larvae

Newly hatched larvae were transferred using a camel hair brush to a new root section of sweetpotato (2 x 2 cm) with 50-60 mm deep hole. The hole was sealed with another root piece. The number of days the larvae took to pupate and the number of larvae that died before pupation was recorded.

Pupae

Pupae were transferred using a camel hair brush to transparent plastic containers of 3.5 cm in diameter and 3 cm height containing tissue paper at the base. The number of days the pupae took to eclosion and the number of pupae that died before eclosion was recorded.

Adults

Emerging *C. brunneus* adults were sexed based on the shape of the distal antennal segment and individually placed in clear plastic containers. Each adult was provided with a 2 x 2 cm fresh sweetpotato root piece which was changed after 1-3 days, depending on the level of feeding. Adult longevity and percent mortality were recorded for each individual.

Oviposition

Thirty newly emerged *C. brunneus* females and males were paired. Each pair was placed separately in a clear plastic container of 3.5cm in diameter and 3cm height containing tissue paper on the base. They were provided daily with a 2 x 2 cm fresh sweetpotato rootpiece with periderm facing up wards. Pre-oviposition, oviposition, post-oviposition periods and the number of eggs laid per female per day were recorded. The study continued until all females died.

Statistical analysis

Data on the development time, adult longevity, pre-oviposition, oviposition period, post-oviposition and total number of eggs per female were subjected to analysis of variance (ANOVA) using SAS software (SAS inc, 2008). Means were separated by Fisher's LSD test. Pearson product-moment correlation coefficient was done to identify the relationship between temperature and other biological parameters. The statistical significance level was set at $P< 0.05$.

Results

Temperature had significant effects on the developmental time of immature stages and adult longevity of *C. brunneus*. Developmental time decreased as the temperature increased from 20- 35°C for the egg and from 20 - 30°C for the larvae and pupae. Egg developmental time ranged from 1.78 ± 0.20 days at 35°C to 6.78 ± 0.25 days at 22.9 ± 8.7 °C (Table 1). At 15 and 40°C, no egg hatching occurred. Larval developmental time ranged from 20.87 ± 0.43 days at 30°C to 37.86 ± 2.13 days at 20°C while pupae development time ranged from 4.64 ± 0.12 to 9.24 ± 0.63 days at 20°C and 30°C, respectively. However at 35°Clarvae did not develop into pupa.

Total developmental time from egg to adult was longest (59.43 ± 2.17 days) at 20°C and shortest (28.67 ± 0.46 days) at 30°C. Adult weevils lived the longest (147.36 ± 9.49 days) at 25°C and this period was not statistically different from that of 131.09 ± 10.56 days at 22.9 ± 8.7°C.

Table 1. Mean developmental time of immature life stages and adult longevity of *Cylas brunneus* at different temperatures

Temperature (°C)	Development time in days (mean ± SE)				
	Egg(n)	Larva(n)	Pupa(n)	Egg to Adult(n)	Adult Longevity(n)
15	-	-	-	-	-
20	6.27 ±0.45a (100)	37.86±2.13a (28)	9.24±0.63 a (21)	59.43±2.17a (21)	106.57±15.03 b (21)
22.9±8.7*	6.78 ±0.25 a (100)	33.26±0.86 b (62)	7.60±0.22 b (58)	49.00±0.93 b (58)	131.09±10.56 ab (58)
25	4.03±0.14 b (100)	24.59±0.38 c (73)	5.83±0.20 c (70)	34.70±0.45 c (70)	147.36±9.49 a (70)
30	2.30± 0.14 c (100)	20.87±0.43 d (47)	4.64±0.12 d (45)	28.67±0.46 d (45)	65.60±8.06 c (45)
35	1.78±0.20 c (100)	-	-	-	-
40	-	-	-	-	-

*Under natural fluctuating temperature conditionsin a screen house. Figure in parentheses is the number of individuals that developed at that temperature starting from 100 eggs? A dash (-) indicates that no development was possible at that temperature. Means followed by the same letter in the same column are not significantly different at $P \geq 0.05$.

Both high and low temperatures had direct effects on the mortality of the three developmental stages of *C. brunneus*. One hundred percent egg mortality occurred at 15°C and 40°C while the lowest egg mortality of 9 % was recorded at 25°C (Fig. 1). Mortality of larval stages ranged from 18 % at 25 °C to 46 % at 35. Pupal mortality was generally low being highest (7 %) at both 20°C and 22.9 ± 8.7°C, and lowest (2 %) at 30°C. Overall, mortality was lowest at 25°C and highest at 15, 35 and 40°C.

After adult emergence, females took 5.73 ± 0.21 days at 30°C to 16.17 ± 0.91 at 20°C before they could lay their first egg (Table 2). Temperature had no significant effect on the oviposition period which ranged from 54.47 ± 6.47 days to 58.30 ± 6.05 days. Post oviposition periods were also not very much affected by temperature. The number of eggs laid by an individual female was observed to increase with increasing temperatures. The highest number of eggs produced per female (93.67 ± 10.54 eggs) was recorded at 25°C but these numbers of eggs were not statistically different from those laid at 30°C. The lowest numbers of eggs (26.33 ± 3.1 eggs) were laid at 20°C.

Correlations between temperature and other biological parameters

Temperature was observed to significantly and negatively influence all biological parameters of *C. brunneus* (Table 3). The developmental time for the egg, larval and pupal stages were inversely related to temperature. Of the fecundity parameters, number of eggs laid per female was the least affected by temperature (r = -0.15800) while pre-oviposition time was the most (r = -0.84571) affected parameter.

Discussion

Temperature is an important factor for development and population growth of any insect (Bale *et al.*, 2002; Auad and Moraes, 2003). Sweet potato is grown in a wide range of climates in Africa as a whole ranging from warm lowland areas to cold highland areas. Sweetpotato root damage by *Cylas* species has also been

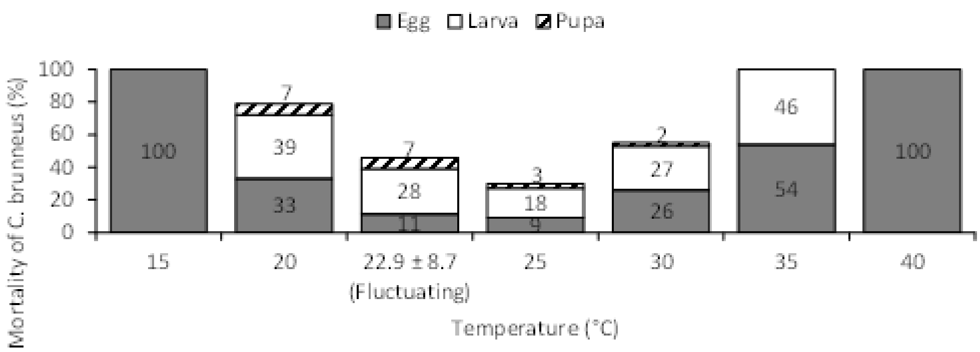

Figure 1. Mortality (%) of life stages of *Cylas brunneus* at different temperatures.

Table 2. Female fecundity (pre-oviposition, oviposition, post-oviposition periods and total number of eggs per female) of *Cylas brunneus* (mean ± SE) different temperatures

Temperature (°C)	Pre-oviposition period (n=30)	Oviposition period(n=30)	Post-oviposition period (n=30)	Number of eggs per female (n=30)
15	-	-	-	-
20	16.17 ±0.91a	56.07±5.64 a	15.80±3.35 a	26.33±2.84 c
22.9±8.7*	9.77 ±0.44 b	57.77±4.67 a	8.47±1.96b	52.93±4.64 b
25	6.80±0.15 c	54.47±6.47 a	5.50±1.25 b	93.67±10.54 a
30	5.73±0.21 d	58.30±6.05 a	11.00±3.15 ab	86.23±10.00 a
35	-	-	-	-
40	-	-	-	-

*Under natural fluctuating temperature conditions in a screen house. A dash (-) indicates that no egg laying was possible at that temperature. Means followed by the same letter in the same column are not significantly different at $P \geq 0.05$.

Table 3. Pearson correlation coefficient between temperature and other biological parameters

Biological parameters	Pearson correlation coefficient	P value
Egg developmental time	-0.58050	<0.0001
Larval developmental time	-0.67135	<0.0001
Pupal developmental time	-0.62312	<0.0001
Egg to adult developmental time	-0.81111	<0.0001
Adult longevity	-0.24937	0.0005
Pre-oviposition period	-0.84571	<0.0001
Oviposition period	-0.49029	<0.0001
Post-oviposition period	-0.28897	0.0003
Number of eggs per female	-0.15800	0.0535

shown to decrease with increasing altitudes (Okonya and Kroschel, 2013). It is therefore important to obtain life history parameters under different temperature regimes for this key insect pest to better understand its temperature requirements when designing suitable control strategies.

Results from this study indicate that the developmental time of all immature life stages and adult longevity of *C. brunneus* declines with increasing temperature. This inverse relationship between development time and temperature has been observed for a number of insect species (Auad and Moraes, 2003; Emana, 2007; Tamil *et al.*, 2012). At fluctuating temperature conditions, the development period from egg to adult of 34.70 ± 0.45 days recorded in this study is within the range of 32 -41 days recorded at laboratory conditions of 27°C (Smit, 1997). However, a similar developmental time at 25°C has been also observed by Ocano *et al.* (1990) for *Cylas formicarius* (Fabricius).

At optimal temperature conditions of 25°C, a female *C. brunneus* laid on average four times more eggs than at

20°C. Temperatures of 25 - 30°C have been shown to be conducive for egg laying in other tropical insect species such as *Cotesia flavipes* (Cameron) (Emana, 2007). For most insect species, high fecundity and short development periods result in high populations and increase in crop damage. Results of this study are therefore useful in explaining why in cold highlands (11-25°C) at 2,373 m asl, relatively small yield losses of (6 - 28 %) are caused by *Cylas* spp. compared to upto 100 % yield losses in warmer lowland areas at 1100 - 1200 masl (Muyinza *et al*., 2007; Okonya and Kroschel, 2013).

Conclusion

Temperature has significant effects on immature life stage development, reproduction and mortality of *C. brunneus.* Additionally, *C. brunneus* is highly sensitive to extreme temperatures and cannot develop, survive or reproduce at temperature conditions <15°C and >35°C. Optimal temperature conditions for development and fecundity occur between 25°C and 30°C. These life table data will be used to develop a phenology model for this species as well as risks maps for predicting its potential distribution and abundance under current and future climatic conditions. Knowledge of how long adult *C. brunneus* can live under different conditions helps scientists decide the suitable crop rotation duration that farmers can adopt depending on daily mean temperature of the agro-ecological zone.

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