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Influence of different temperatures and diets on the life cycle of invasive species *Conogethes punctiferalis*

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Research Paper

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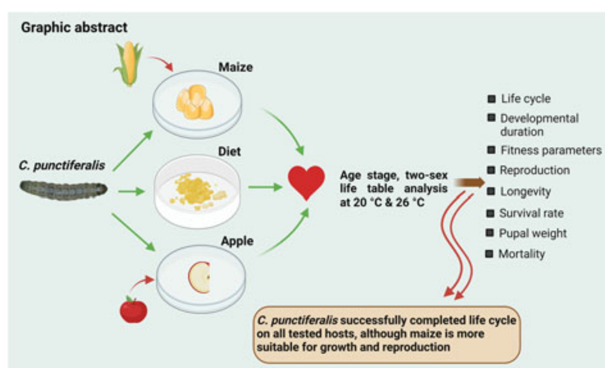
Abstract

Understanding the interactive effects of temperature and diet on insect life cycles is crucial for effective pest management. Here, the influence of different temperatures and diets on the life cycle of *Conogethes punctiferalis* was investigated using the age-stage, two-sex life table analysis. The results support the hypothesis that temperature and diets (maize, apple, and artificial diet) significantly influence the entire life cycle performance of *C. punctiferalis*. The duration of larval development was significantly prolonged, whereas adult lifespan was shortened and showed lower reproductive capacity on apple and artificial diet than maize. The total pre-oviposition period was longer on apples than on maize and artificial diet at both temperatures (20, 26°C). The highest r (0.113 d^{-1}), λ (1.128 d^{-1}), R_0 (57.213), and *GRR* (75.54) of *C. punctiferalis* were found on maize at 26°C, while the highest T (45.062) was found on apples. Similar results were obtained in the age-specific survival curves (s_{xj}), fecundity (m_x), maternity ($l_x m_x$), and reproductive value (v_{xj}) of YPM on different host plants when exposed to 20°C. These findings highlight the need for further research into the complex interactions between temperature, diet, and insect life history traits to develop effective pest management strategies and enhance our understanding of insect ecology in agroecosystems.



Introduction

Understanding the direct effects of temperature fluctuations and host availability is essential to comprehending the dynamics of invasive species. The life cycles of invasive insect pests are greatly impacted by global climate change, which also seriously upsets the equilibrium of ecosystems. These alterations may hasten the global spread of exotic crop pests, resulting in outbreaks that worsen losses to agriculture (Skendžić *et al.*, 2021). Invasive species flourish in changed environments, frequently unopposed by native predators in new habitats, because of their extraordinary capacity for reproduction and adaptability (Ma and Ma, 2022). Although a large variety of plant families are consumed by herbivores, these animals' fitness and performance differ greatly depending on the host plant (Scriber, 2002). Researchers can learn a great deal about the quality of resources and the adaptive mechanisms these versatile insects use to deal with different plant species by observing their eating habits on various hosts (Huang and Chi, 2012; Chen *et al.*, 2018).

Conogethes punctiferalis, Yellow Peach Moth (YPM), is a major polyphagous pest in Southeast Asia, Australia, the United Kingdom, and Europe (Stanley *et al.*, 2009; Haldhar and Maheshwari, 2021). Its impact is evident from its rapid spread across different regions. It is a major pest that attacks crops like maize and fruits such as *Carica papaya*, *Dimocarpus longan*, *Averrhoa carambola*, *Durio zibethinus*, and *Helianthus annuus* in various countries (Wang *et al*., 2006; Kumar *et al*., 2021; Rojas-Sandoval, 2022; Ramzan *et al*., 2024). In China, it severely infests maize, causing ear rot and large production losses (Yang *et al*., 2015; Dong *et al*., 2023; Gao *et al*., 2024).

Due to altered agricultural methods, changing climate patterns, and inadequate pest management strategies, *C. punctiferalis* has become much more prevalent in China, especially in the Huang-Huai-Hai area, in recent years (Chen *et al*., 2019, 2023a; Jeong *et al*., 2021; Jing *et al*., 2021; Shwe *et al*., 2021; Gao *et al*., 2023; Li *et al*., 2023). It is currently the most common pest in maize cultivation, even surpassing *Ostrinia furnacalis* (Lepidoptera: Crambidae), another important maize borer, in both abundance and damage (Wang *et al*., 2006; An *et al*., 2023). In Pakistan, it has recently been reported in mango orchards (Mehdi *et al*., 2024). The life cycle and development of *C. punctiferalis* are critical factors for its impact as an agricultural pest (Du *et al*., 2012; Kumar and Kalkal, 2022; Ganesha *et al*., 2013; Doddabasappa *et al*., 2014; Shashank *et al*., 2015; Umbarkar and Patel, 2017).

The biology of *C. punctiferalis* on different hosts and artificial diets has been previously studied (Luo and Honda, 2015a, 2015b; Du *et al*., 2016). However, the life cycle of *C. punctiferalis*, which varies with different diets and temperatures, needs further study to understand the relationship between population growth and environmental factors. The purpose of this study is to examine the theory that temperature significantly impacts the fitness indices of *C. punctiferalis* when the nutritional conditions of individual host plants are constant. We aim to provide more insight into the development patterns and adaptability of *C. punctiferalis* by assessing these important parameters, which will have important implications for agricultural management and pest control strategies.

Methodology

Insects and hosts

Conogethes punctiferalis larvae were obtained from a stock colony maintained for seven generations on an artificial diet developed by Jing *et al*. (2021) at the State Key Laboratory for Biology of Plant Diseases and Insect Pests, Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing, China. The colony was maintained under controlled conditions of 27 ± 1°C, 60–80% relative humidity (RH), and a 14-light/10-dark photoperiod. Pupation was induced by placing paper inside the lid of a plastic box (31 × 26 × 28 cm), following the method described by Du *et al*. (2016). Newly emerged moths were fed with a 10% honey solution, and an apple wrapped with gauze was provided inside the adult cage for oviposition. Newly laid eggs were collected and used for our experiments. The rearing methodology of Jing *et al*. (2021) was used to maintain the *C. punctiferalis* population. Three host substrates, namely maize, apple, and artificial diet, were utilised in this study.

Life table analysis

To evaluate the impact of host plants/diet and temperatures on the life history parameters of *C. punctiferalis*, *C. punctiferalis* eggs were collected from each host plant/diet at different temperatures. Individual eggs were then carefully removed with forceps without causing any damage and placed separately in Petri dishes. Each treatment consisted of 70 replicates, with each Petri dish containing a single egg. The Petri dishes were covered with lids lined with moistened filter paper until the larvae hatched. The experiments were carried out at two temperatures, 20 and 26 °C on maize, apple, and artificial diet substrates with an RH of 70 ± 5% and a photoperiod of 14:10 (LD) in a climate chamber were maintained. Eggs hatchability was observed daily at 8:30 am and 8:30 pm until hatching with that did not hatch or appeared shrivelled being considered nonviable. Larvae provided fresh food daily and larval instars were divided into two groups: first to second instars (L1–L2) and third to fifth instars (L3–L5) to minimise disturbance. The survival rate of the larvae was monitored daily until pupation. After emergence, adult moths were paired (4 M: 4 F) and placed in nylon mesh cages (35 × 35 × 35 cm) to determine their longevity and fecundity. An apple wrapped with gauze was placed in the adult cage for egg laying and a 10% honey solution was provided for adult feeding. The fecundity was recorded daily until the death of all individuals. All experiments were carried out at 20 ± 1°C and 26 ± 1°C, 70 ± 5% RH, and a photoperiod of 14:10 (LD) hours. The developmental time and mortality rates of each stage of *C. punctiferalis* were observed and recorded twice daily, at 8:30 a.m. and 8:30 p.m. The pre-oviposition, oviposition age, fecundity, and longevity of *C. punctiferalis* were also noted. Preliminary data for all individuals at different temperatures and on different host plants/diets were organised and analysed using an age-stage, two-sex life table approach (Chi and Liu, 1985; Chi, 1988). Population parameters such as means, and standard errors of development time, mortality, pre-oviposition period, total oviposition period, fecundity, and longevity of *C. punctiferalis* were calculated using TWOSEX-MSChart (Chi, 2021), with estimates generated from 100,000 bootstrap replicates. The following formulas were used to get the estimates.

Age-stage specific survival rate (S_{xj}): where x is age and j is the stage

$$S_{xj} = \frac{n_{xj}}{n_{0,1}}$$

Age-specific survival rate (l_x): where x is age.

$$l_x = \sum_{j=1}^{m} S_{xj}$$

where m denotes the number of stages.

Age-specific fecundity (m_x): the number of eggs per female at age x:

$$m_x = \frac{\sum_{j=1}^{m} S_{xj} f_{xj}}{\sum_{j=1}^{m} S_{xj}}$$

Age-stage-specific life expectancy (e_{xj}): the time duration in which an individual of age x and stage y is expected to live:

$$e_{xj} = \sum_{j=1}^{m} \sum_{j=1}^{m} S'_{iy}$$

, where $S'iy$ is the probability that an individual of age x and stage y will survive to age i and stage j.

Age-specific maternity ($l_x \times m_x$): the combination/product of l_x and m_x.

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Age-stage-specific fecundity (f_{xj}): the number of hatched eggs a female adult lay at age x.

$$f_{xj} = \frac{f_{x.total}}{n_{xj}}$$

Age-stage-specific reproductive value (V_{xj}): the contribution of individuals of age x and stage y to the future population:

$$V_{xj} = \frac{e^{-r(x+1)}}{S_{xj}} \sum_{i=x}^{n} e^{-r\,(i+1)} \sum_{j=y}^{m} S'_{ij} f_{ij}$$

Further, five population parameters were obtained by using such formulas:

Intrinsic rate of increase (r):

$$\sum_{x=0}^{\infty} e^{-r\,(x+1)} l_x m_x = 1$$

Finite rate of increase (λ):

$$\lambda = e^r$$

Net reproductive rate (R_0):

$$R_0 = \sum_{x=0}^{\infty} l_x m_x$$

Mean generation time (T):

$$T = \frac{\ln R_0}{r}$$

The gross reproductive rate (GRR) was determined as

$$GRR = \sum\nolimits_x^m$$

Results

Mortality rate

The mortality rates of *C. punctiferalis* reared on different diets at different temperatures are presented in table 1. Significant differences in the mortality of *C. punctiferalis* adults were observed among treatments, whereas no significant differences were recorded in the mortality of larvae, pre-pupa, and pupae.

Developmental time, adult longevity, and reproduction

The embryonic period of *C. punctiferalis* across different treatments ranged from 4.07 to 4.30 days and 3.78 to 4.07 days at 20 and 26°C, respectively. The larval period (1st to 2nd and 3rd to 5th) was significantly longer on apples compared to maize and artificial diet at both temperatures ($P < 0.05$). The pupal duration of larvae fed apples was non-significantly impacted by temperatures, but significantly impacted when fed maize and artificial diet ($P < 0.05$). The larval duration of *C. punctiferalis* reared on an artificial diet was 23.99 and 23.91 days, 13.17 and 13.10 days on apples and 15.21 and 13.93 days on maize at 20 and 26°C, respectively (table 2). The significant differences in male and female longevity were recorded on maize and artificial diets ($P < 0.05$), while no differences were recorded on apples at both temperatures. However, adult longevity (male and female) was significantly shorter on apples than on maize and artificial diets ($P < 0.05$). Females longevity was significantly longer on an artificial diet than that on maize (females: 11.12 vs 10.95 days) ($t = 1.140$; $P < 0.05$). Overall, the development time was significantly longer at 20°C and shorter at 26°C ($P < 0.05$). Significant differences in

Table 1. Mortality rates (mean ± standard error) of different developmental stages of *Conogethes punctiferalis* reared on different host plants/diet at various temperatures

	Mortality rate					
	1st–2nd instar larvae			3rd–5th instar larvae		
Temperatures	Maize	Apple	Artificial diet	Maize	Apple	Artificial diet
20̊C	0.00 ± 0.00 aA	0.00 ± 0.00 aA	0.01 ± 0.00 bA	0.17 ± 0.10 aA	0.22 ± 0.11 aA	0.10 ± 0.08 bA
26̊C	0.00 ± 0.00 aA	0.00 ± 0.00 aA	0.02 ± 0.01 aA	0.20 ± 0.18 aA	0.24 ± 0.12 aA	0.11 ± 0.09 bA
Temperatures	Pre-pupa			Pupa		
	Maize	Apple	Artificial diet	Maize	Apple	Artificial diet
20̊C	0.00 ± 0.00 aA	0.00 ± 0.00 aA	0.00 ± 0.00 aA	0.00 ± 0.00 aA	0.00 ± 0.00 aA	0.00 ± 0.00 aA
26̊C	0.00 ± 0.00 aA	0.00 ± 0.00 aA	0.00 ± 0.00 aA	0.00 ± 0.00 aA	0.00 ± 0.00 aA	0.00 ± 0.00 aA
Temperatures	Male			Female		
	Maize	Apple	Artificial diet	Maize	Apple	Artificial diet
20̊C	0.52 ± 0.18 aA	0.52 ± 0.25 aA	0.44 ± 0.12 bB	0.30 ± 0.17 bA	0.32 ± 0.19 aA	0.35 ± 0.11 aA
26̊C	0.47 ± 0.05 aB	0.44 ± 0.24 bB	0.51 ± 0.17 aA	0.32 ± 0.12 aA	0.31 ± 0.17 aA	0.34 ± 0.16 aA

The different lowercase letters (a–c) denote significant differences in the developmental period of *C. punctiferalis* on various hosts at the same temperature. The different capital letters (A–B) indicate significant differences in the developmental period of *C. punctiferalis* on the same host at various temperatures. A paired bootstrap test was used to assess statistical differences in *C. punctiferalis* mortality across different stages across tested host plants or both different temperatures. Standard errors were estimated using 100,000 bootstrap resamples.

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the fecundity and total life cycle of *C. punctiferalis* reared on different diets or hosts were observed at both temperatures (20 and 26°C) ($P < 0.05$). The highest fecundity was recorded on maize (154.95 and 174.13 eggs), followed by artificial diet (123 and 131.04 eggs) and apple (75.39 and 79.95 eggs) at 20 and 26°C, respectively. The total life cycle of *C. punctiferalis* reared on maize, apple, and artificial diet at 20°C was 41.10, 46.87, and 38.32 days, respectively, and 33.72, 47.81, and 37.91 days at 26°C, respectively. The adult male proportion (N_m/N) was higher than females (N_f) at all treatments. N_f was recorded as the highest on an artificial diet at both temperatures. The curves representing the survival rates (S_{xj}) for the pupal and adult stages of *C. punctiferalis* fed on an artificial diet were consistently higher than those observed for the other two natural hosts across different temperatures (fig. 1). Temperature exerted a significant effect on the survival rates (v_x) as well. Notably, females reared on maize at 26°C exhibited higher v_{xj} values compared to moths fed on an artificial diet and apple (fig. 2). Furthermore, both temperature and diet significantly affected the adult longevity of *C. punctiferalis*. The shortest longevity of both males and females of *C. punctiferalis* was recorded at 26°C compared to 20°C when reared on maize. Under the same diet, the shortest lifespan (e_{xj})

Table 2. Duration of the mean (±SE) each developmental stage of *Conogethes punctiferalis* reared on different foods under various temperatures

	Development duration (d)					
	Egg			1st–2nd instar larvae		
Temperatures	Maize	Apple	Artificial diet	Maize	Apple	Artificial diet
20°C	4.21 ± 1.66 aA	4.07 ± 0.07 bA	4.30 ± 1.19 aA	4.70 ± 0.08 bA	5.25 ± 0.11 aA	4.47 ± 0.05 cA
26°C	3.78 ± 1.55 bB	4.07 ± 0.10 bA	3.92 ± 1.24 bB	4.42 ± 0.13 bB	5.22 ± 0.11 bA	4.19 ± 0.33 cB
Temperatures	3rd–5th instar larvae			Total larval period		
	Maize	Apple	Artificial diet	Maize	Apple	Artificial diet
20°C	9.41 ± 4.12 bA	18.74 ± 0.16 aB	8.66 ± 0.14 cB	15.21 ± 0.17 aA	23.99 ± 0.21 bA	13.17 ± 1.25 cA
26°C	9.46 ± 3.00 bA	18.71 ± 0.20 bB	9.43 ± 0.19 cA	13.93 ± 0.24 aB	23.91 ± 0.32 bA	13.10 ± 1.11 cA
Temperatures	Pre-pupa			Pupa		
	Maize	Apple	Artificial diet	Maize	Apple	Artificial diet
20°C	2.51 ± 1.56 aA	2.52 ± 1.80 aA	2.35 ± 1.06 bA	9.77 ± 2.45 aA	9.11 ± 0.21 aA	9.64 ± 0.09 aA
26°C	2.50 ± 1.69 aA	2.51 ± 1.88 aA	1.73 ± 0.16 cB	9.12 ± 2.10 bB	9.11 ± 0.21 aA	8.75 ± 0.15 cB
Temperatures	Male longevity			Female longevity		
	Maize	Apple	Artificial diet	Maize	Apple	Artificial diet
20°C	10.54 ± 4.26 aA	7.95 ± 0.22 cA	10.10 ± 0.11 bA	10.95 ± 0.14 aA	8.03 ± 0.16 cA	11.12 ± 0.14 aA
26°C	10.27 ± 4.81 aB	7.93 ± 0.16 cA	9.44 ± 0.34 bB	10.66 ± 0.15 bB	8.00 ± 0.22 cA	10.37 ± 0.11 bB
Temperatures	APOP			TPOP		
	Maize	Apple	Artificial diet	Maize	Apple	Artificial diet
20°C	2.42 ± 0.12 aA	2.47 ± 0.13 aA	2.40 ± 0.11 aA	33.38 ± 0.24 bA	43.56 ± 0.42 aA	33.56 ± 0.24 bA
26°C	2.30 ± 0.76 cB	2. 40 ± 0.12 aB	2. 37 ± 0.10 bB	32.08 ± 0.18 cB	43.13 ± 0.43 aA	30.87 ± 0.41 cB
Temperatures	Oviposition period			Fecundity		
	Maize	Apple	Artificial diet	Maize	Apple	Artificial diet
20°C	7.23 ± 0.15 aB	4.56 ± 0.18 cA	7.60 ± 0.19 aA	154.95 ± 3.93 aB	75.39 ± 2.03 cB	123.00 ± 2.91 bB
26°C	7.65 ± 0.16 aA	4.59 ± 0.19 cA	7.08 ± 0.13 bB	174.13 ± 5.34 aA	79.95 ± 1.93 cA	131.04 ± 2.46 bA
Temperatures	Female proportion (Nf/N)			Male proportion (Nm/N)		
	Maize	Apple	Artificial diet	Maize	Apple	Artificial diet
20°C	0.30 ± 0.05 cA	0.32 ± 0.13 aA	0.35 ± 0.05 aA	0.52 ± 0.18 aA	0.44 ± 0.12 cA	0.52 ± 0.15 aA
26°C	0.32 ± 0.12 aA	0.31 ± 0.10 cA	0.34 ± 0.09 aA	0.47 ± 0.16 aA	0.44 ± 0.14 cA	0.51 ± 0.17 aA
Temperatures	N_{fr}/N_f ratio			Total life cycle		
	Maize	Apple	Artificial diet	Maize	Apple	Artificial diet
20°C	1.00 ± 0.00 aA	1.00 ± 0.00 aA	1.00 ± 0.00 aA	41.10 ± 1.22 bA	46.87 ± 0.49 aB	38.32 ± 0.29 bA
26°C	1.00 ± 0.00 aA	1.00 ± 0.00 aA	1.00 ± 0.00 aA	33.72 ± 1.48 cB	47.81 ± 0.33 aA	37.91 ± 0.23 cB

The lowercase letters (a–c) represent significant differences in *C. punctiferalis*'s developmental period on various hosts at the same temperature. The capital letters (A–B) represent significant differences in *C. punctiferalis*'s developmental period on the same host at both temperatures. To find statistical differences in *C. punctiferalis* mortality at different stages on tested host plants or both temperatures, a paired bootstrap test was employed. To estimate standard errors, 100,000 bootstrap resampling was used.

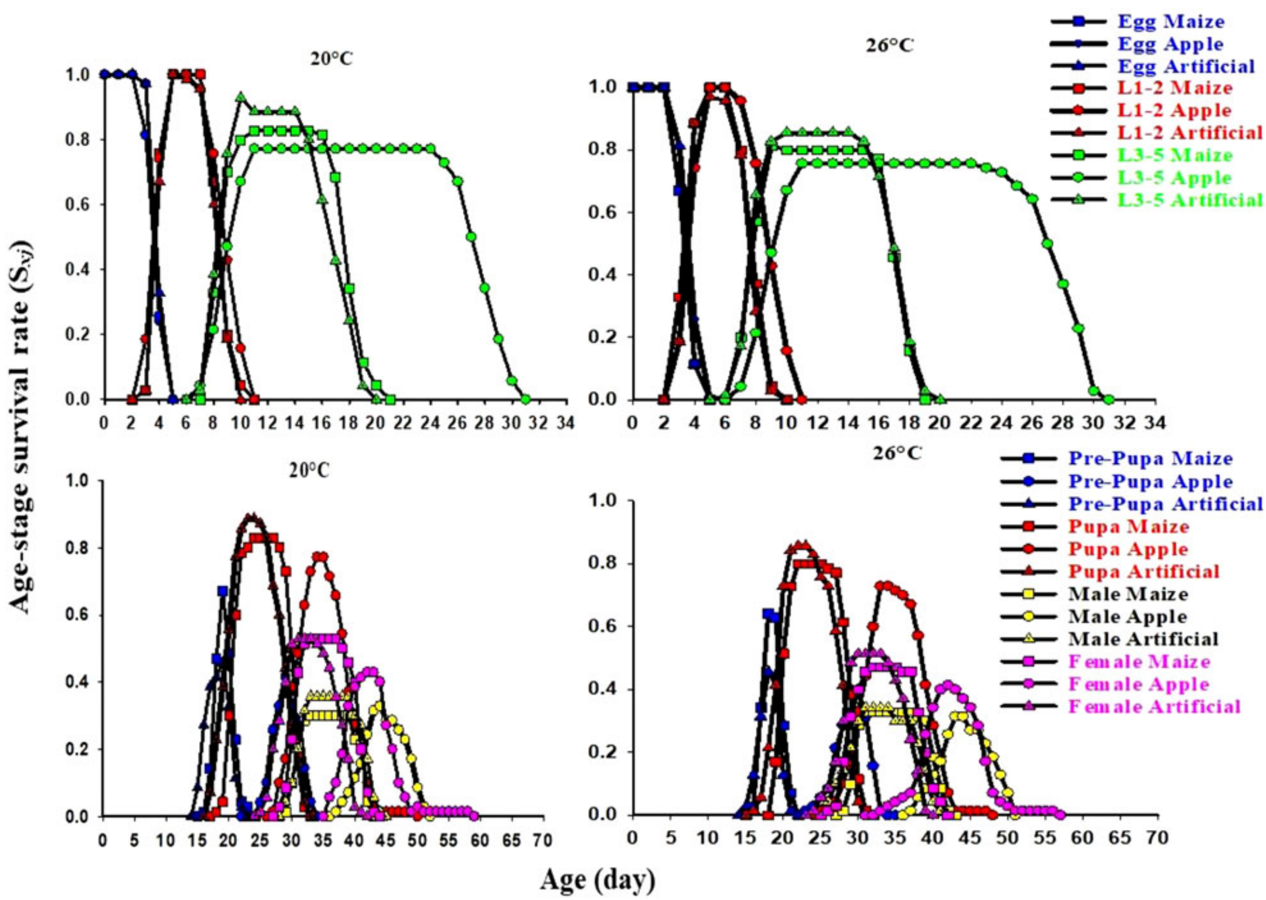

Figure 1. Age-stage specific survival rate (S_{xj}) of each developmental stage of *Conogethes punctiferalis* feeding different diets at different temperatures.

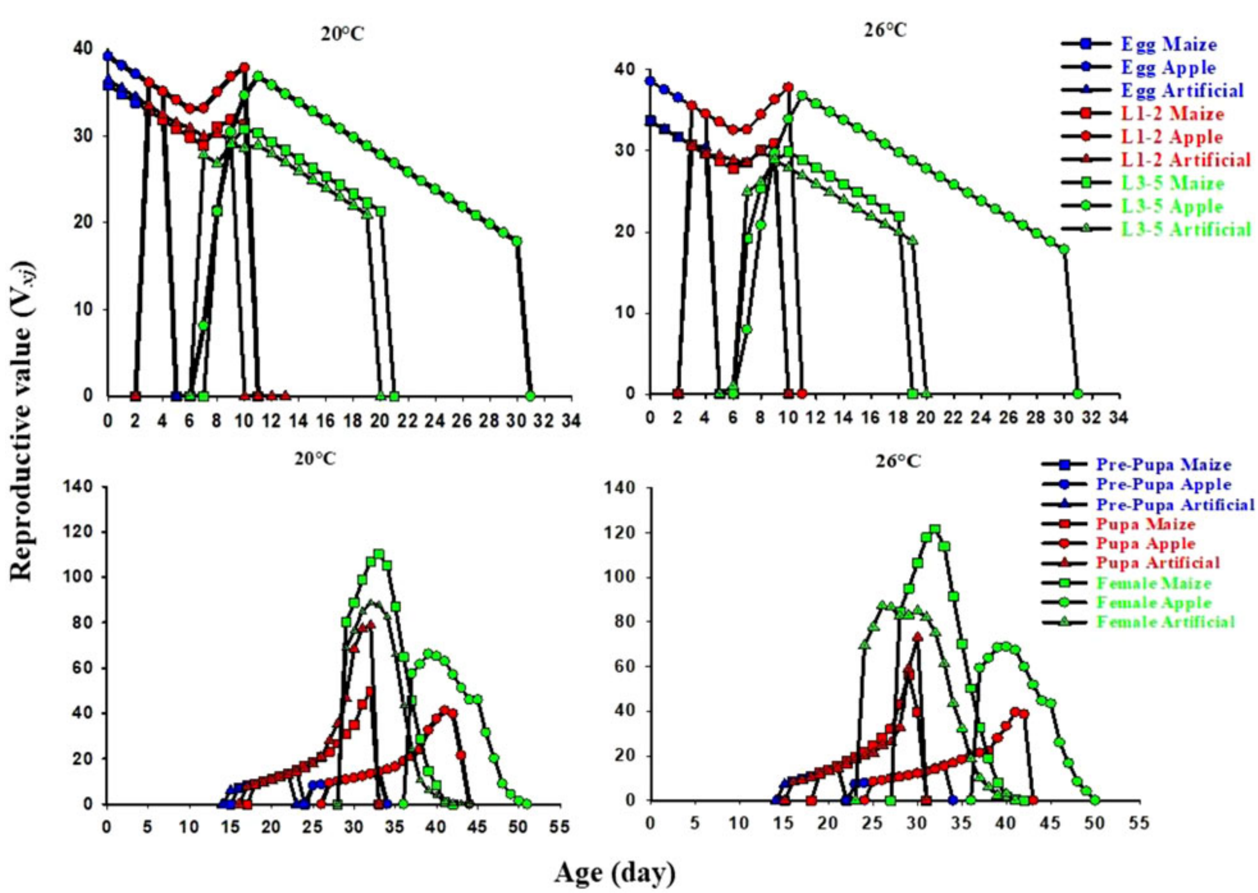

Figure 2. Age-stage reproductive value (V_{xj}) of each developmental stage of *Conogethes punctiferalis* feeding different diets at different temperatures.

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of *C. punctiferalis* was recorded at 26°C compared to 20°C (fig. 3). Figure 4 illustrates the l_x, m_x, and $l_x m_x$ curves of *C. punctiferalis* reared on different diets at various temperatures. At 26°C, the highest daily egg production (f_x) values were 33.06, 23.21, and 19.01 on maize, artificial diets, and apple, respectively, while at 20°C, these values were 28.38, 21.12, and 15.03 on maize, artificial diets, and apple, respectively (fig. 4). The $l_x m_x$ reached its maximum values at 26°C on maize and minimum at 20°C on apple (fig. 5).

Life table parameters

The diets and temperatures significantly influenced the life table parameters of *C. punctiferalis* (table 3). Among life table parameters of *C. punctiferalis*, only R_0 and *GRR* showed a significant increase with rising temperature ($P < 0.05$) showed a significant increase with rising temperature on each diet except λ. The highest values for *r*, λ, R_0, and *GRR* of *C. punctiferalis* were observed on maize at 26°C, while the highest value for *T* was observed on apples compared to the other two diets under both temperatures. *T* was significantly different on maize at both temperatures ($P <$ 0.05).

Discussion

The temperature and quality of the host plant significantly affect the population dynamics of herbivorous insects. Traditionally, this relationship has been attributed to metabolic rate effects and changes in energy needs. However, recent data suggest a more intricate relationship between temperature, host plant quality, and life-history traits that affect insect fitness. (Sedighi *et al.*, 2017; Chen *et al.*, 2023b). The fitness parameters of herbivores, including *C. punctiferalis,* are closely tied to the nutritional value of the host plant. Host plant phenology and pest developmental physiology are intricately linked and influenced by abiotic factors, particularly temperature (Chen *et al.*, 2022; Karuppannasamy *et al.*, 2023). This study investigated how different diets affect the life cycle of *C. punctiferalis* at various temperatures. *C. punctiferalis* completed life cycle on castor oil plants, cardamom, and ginger in approximately 28, 31, and 32 days, respectively, under controlled conditions (Stanley *et al.*, 2009). The results of this study differ from Stanley *et al.* (2009) study because the current study did not test ginger, castor oil plants, and cardamom. The results revealed significant differences among treatments, indicating that *C. punctiferalis* successfully completed its life cycle on all diets (maize, apple, and artificial) at both temperatures. However, the developmental duration of each stage varied, with stages being shorter on maize and longer on apples at both temperatures. The duration of *C. punctiferalis* development is primarily determined by food availability and suitable habitats. Diets with higher nutrient concentrations can support higher metabolic rates in herbivores, leading to increased growth and reproductive potential. Conversely, low-nutrient diets may result in decreased fitness and lower metabolic rates. The shorter developmental time of pest fed maize indicates the suitability of maize for *C. punctiferalis* at 26°C. Insects have a longer time to complete their life cycle in perennial crops like apples

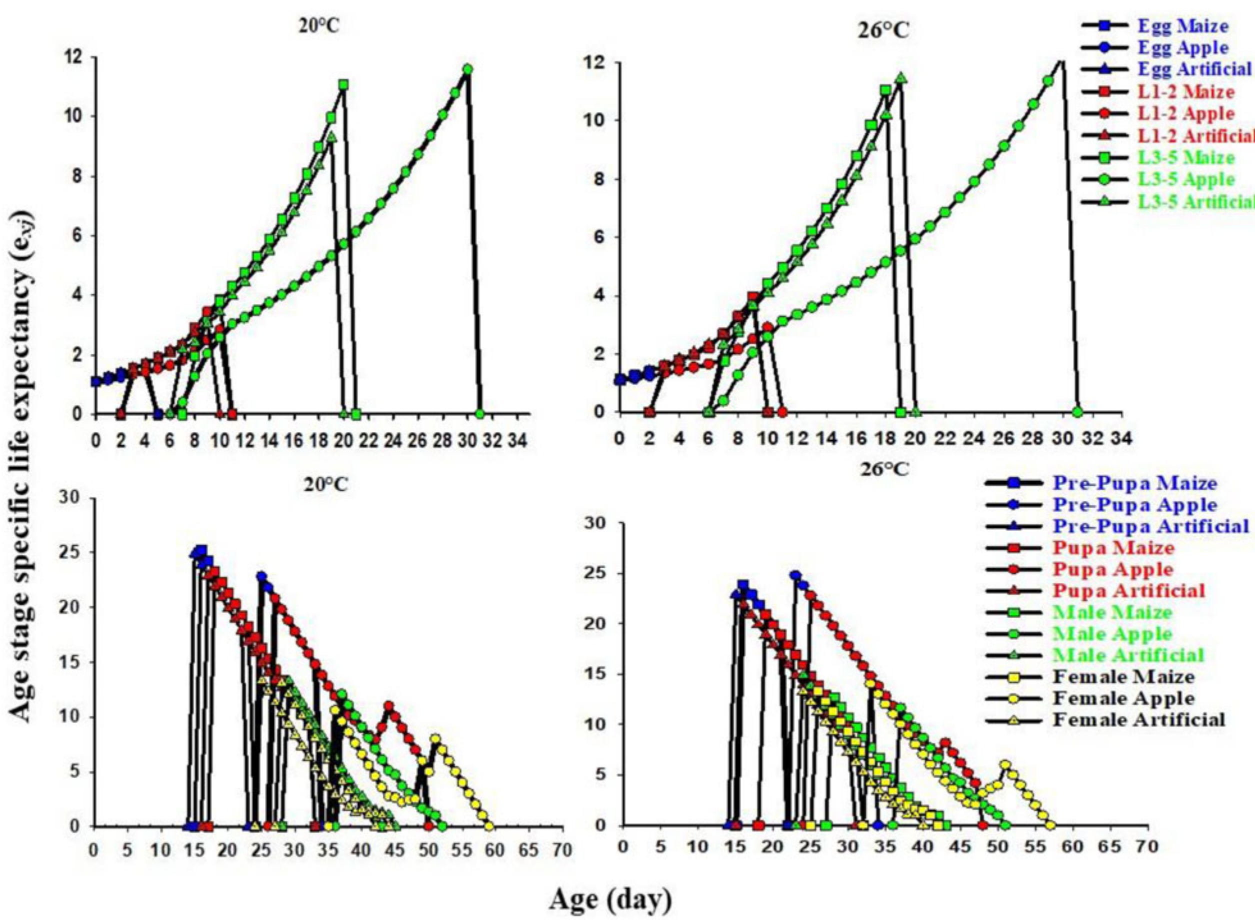

Figure 3. Age-stage specific life expectancy (E_{xj}) of each developmental stage of *Conogethes punctiferalis* feeding different diets at different temperatures.

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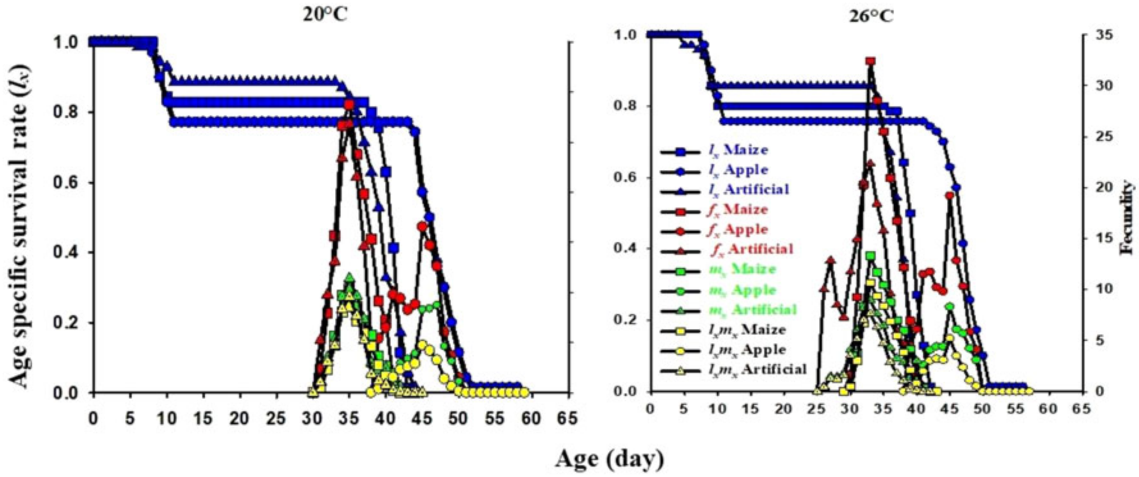

Figure 4. Age-stage specific survival rate (l_x), female age-specific fecundity (f_x), age-specific fecundity (m_x), and maternity (l_xm_x) of *C. punctiferalis* feeding different diets under different temperatures.

because they contain compounds that slow down larval growth or because they lack certain nutrients. This is further corroborated by the fact that the larvae on apples spent a significantly longer time overall on apples than on maize or an artificial diet. The higher survival rate of larvae on maize and lower on apples is consistent with previous findings (Li *et al.*, 2015). At 26°C, the pupal period was shorter than at 20°C, suggesting that higher temperatures could accelerate the pupae's transition into adult moths. This pattern held for all diets, emphasising how temperature affects pupal development. The substantial variations in male and female lifespans between diets and temperatures show how these two variables interact to influence adult survival. Many

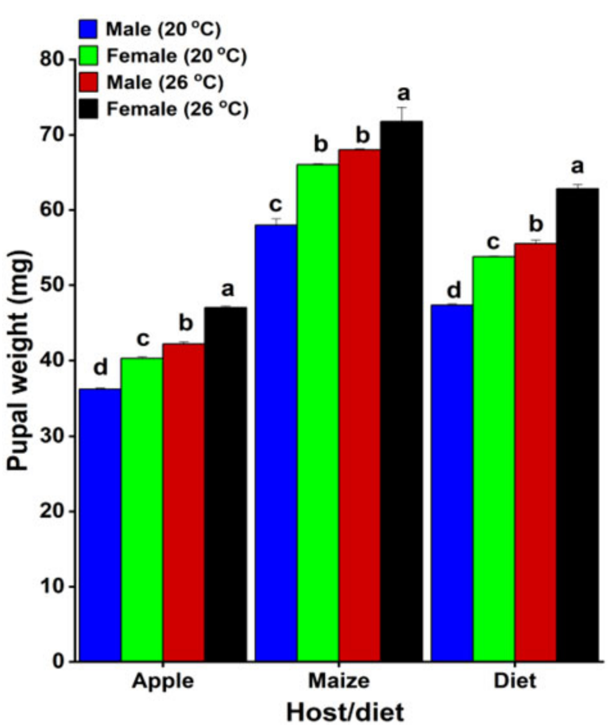

Figure 5. Pupal weight on different hosts/diet under different temperatures. Bars represent means ± SE. Significant differences among different hosts are indicated by different letters on each bar (Tukey-HSD test after ANOVA, $P < 0.05$).

lepidopteran species have a common trait where females live longer than males. This trait may be related to the female reproductive roles, which require a longer lifespan for egg-laying. Shorter adult life expectancy at higher temperatures may be caused by higher metabolic rates that accelerate energy breakdown (Klepsatel *et al.*, 2019). Life table parameters indicated that 26°C was the most conducive temperature for the growth and development *of C. punctiferalis*. Maize was identified as the most suitable host for *C. punctiferalis*, corroborating earlier research (Chen *et al.*, 2018; Xie *et al.*, 2021). The intrinsic rate of increase (r), finite rate of increase (λ), net reproductive rate (R_0), and gross reproductive rate (GRR) were highest on maize at 26°C, while the generation time (T) was shorter on apples than on the other two diets under both temperatures. These findings align with previous studies (Pang *et al.*, 2022) and underscore the importance of temperature and diet in shaping the life cycle of *C. punctiferalis*. The observed variations in developmental durations on different hosts highlight the significance of host plant quality in influencing insect fitness. There is an optimal temperature range beyond which negative effects can occur, as evidenced by the higher fecundity and fertility on maize at 26°C compared to 20°C. In contrast to apple and artificial diets, it was suggested that the volatile chemicals released by maize might provide more alluring cues for oviposition. The current findings are closely consistent with the results reported by Li *et al.* (2015), who also found that host plant choice significantly influences the development and reproduction of *C. punctiferalis*. Du *et al.* (2016) also reported similar findings about the ovipositional behaviour of *C. punctiferalis* on different cultivars of chestnut. They reported that among tested cultivars, Huaijiu was most suitable for the oviposition of *C. punctiferalis*. It indicates that plant volatiles can affect the reproductive potential of *C. punctiferalis*. How temperature and diet affect survival and reproduction is shown by the l_x, m_x, and l_xm_x curves. The greatest recorded daily egg production (f_x) on maize was at 26°C, indicating that this temperature maximises reproductive potential. When it comes to diet and temperature, the maximum l_xm_x values on maize at 26°C suggest that this combination provides the best conditions for the overall fitness of *C. punctiferalis*. The development rates of *C. punctiferalis* increased with increasing temperatures. In the previous study, it was observed that temperatures (24–27°C) significantly affected the

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Table 3. Life table parameters of *Conogethes punctiferalis* reared on different foods under different temperatures

	Intrinsic rate of increase (r) (d^{-1})			Finite rate of increase (λ) (d^{-1})		
Temperatures	Maize	Apple	Artificial diet	Maize	Apple	Artificial diet
20°C	0.106 ± 0.033 aA	0.090 ± 0.002 bB	0.078 ± 0.070 bB	1.116 ± 0.091 aA	1.043 ± 0.031 bA	1.119 ± 0.025 aA
26°C	0.113 ± 0.035 aA	0.117 ± 0.011 aA	0.106 ± 0.021 aA	1.128 ± 0.094 aA	1.076 ± 0.051 bA	1.129 ± 0.073 aA
Temperatures	Net reproductive rate (R_0)			Mean generation time (T)		
	Maize	Apple	Artificial diet	Maize	Apple	Artificial diet
20°C	46.481 ± 8.573 aB	24.772 ± 4.263 bB	43.923 ± 7.100 aB	36.291 ± 0.231 bA	45.444 ± 0.442 aA	35.882 ± 0.271 cA
26°C	57.213 ± 9.931 aA	25.121 ± 4.504 bA	44.920 ± 7.461 aA	33.350 ± 0.183 bB	45.062 ± 0.421 aA	35.354 ± 0.453 cA
Temperatures	Gross reproductive rate (GRR)					
	Maize	Apple	Artificial diet			
20°C	57.54 ± 10.08 aB	44.41 ± 6.42 bB	57.28 ± 7.97 bB			
26°C	75.54 ± 11.85 aA	47.99 ± 6.80 bA	61.37 ± 9.62 bA			

The lowercase letters (a–c) represent significant differences in *C. punctiferalis*'s developmental period on various hosts at the same temperature. The capital letters (A–B) represent significant differences in *C. punctiferalis*'s developmental period on the same host at both temperatures. A paired bootstrap test was employed to find statistical differences in *C. punctiferalis* mortality at different stages on tested host plants or both temperatures. To estimate standard errors, 100,000 bootstrap resampling was used.

sex ratio of *C. punctiferalis* population (Pang *et al.*, 2022). The number of generations, survival rate, and developmental time that increase the probability of pest establishment could all be increased by an ideal temperature (Plessis *et al.*, 2020). Overall, this study contributes valuable insights into the complex interplay between temperature, host plant quality, and the life cycle of *C. punctiferalis*. Understanding these dynamics is crucial for developing effective pest management strategies in agricultural systems.

Conclusion

Our study reveals the effects of host plant quality and temperature on the developmental dynamics of *C. punctiferalis*. Maize is the most favourable nutritional source for *C. punctiferalis*, exhibiting improved developmental time, survival rates, and fecundity compared to apple and artificial diets across various temperature regimes. Through a comprehensive analysis of life-table indicators, we demonstrate that populations reared on maize display enhanced performance and fitness, with higher intrinsic growth rates and reproductive capacity. Particularly noteworthy is the keen reproductive potential observed in populations thriving at 26°C on maize, indicating increased susceptibility to outbreak conditions. Our findings underline the importance of further investigating the fundamental mechanisms driving the varying fitness and performance of *C. punctiferalis* across different host plants and temperature conditions. By exploring deeper into insect–plant interactions and adaptation processes, we can enhance our understanding of pest ecology and develop more targeted pest management strategies in agriculture. This comparative examination of temperature and diet effects on the life cycle of *C. punctiferalis* provides valuable insights for the development of sustainable pest control measures and crop protection strategies.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S000748532400083X

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