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Effect of Temperature on Life Cycle Traits of *Callosobruchus* spp. Infesting Stored Mungbeans

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Abstract: Bruchid beetles are primary pests of stored pulses, causing significant post-harvest losses. *Callosobruchus maculatus* (F.) and *Callosobruchus chinensis* L. are the most common species in tropical and subtropical regions, often co-occurring in storage. This study aimed to evaluate the temperature-dependent life cycle parameters of *C. maculatus* and *C. chinensis* infesting mungbean (*Vigna radiata* L.) seeds. The life cycle of both species was observed under two different conditions: controlled (27 ± 1°C, 65 ± 5% RH) and room temperature: uncontrolled (34 ± 4°C, 70 ± 5% RH). Three experimental sets were maintained, each with 10 replicates in completely randomized design. Life cycle duration was recorded, and data were analyzed using descriptive statistics to determine mean durations. Under controlled conditions, *C. maculatus* and *C. chinensis* completed their life cycles in 33.40–39.80 days (mean 36.84 ± 1.61) and 31.30–36.70 days (mean 34.20 ± 1.23), respectively. At room temperature, development accelerated, with durations of 28.53–32.70 days (mean 30.84 ± 1.17) and 26.30–31.80 days (mean 29.32 ± 1.55), respectively. Higher temperatures shorten the life cycle of both beetle species, potentially increasing infestation rates. These findings highlight the need for temperature management and timely monitoring in stored mungbean to reduce bruchid damage and improve storage outcomes.

Keywords: Bruchid, *Callosobruchus chinensis*, *Callosobruchus maculatus*, Life cycle, Mung bean, Pulse beetle.

Introduction

Pulses are a vital source of protein, minerals, and dietary fiber, especially for vegetarian populations. They contribute to household food security, soil fertility through nitrogen fixation, and provide economic stability for smallholder farmers. Globally, pulses support sustainable agriculture and are integral to human nutrition and livelihoods. India is the largest producer and consumer of pulses globally, contributing approximately 25% of production and 27% of consumption (Shukla and Mishra, 2020).Among pulses, mungbean (*Vigna radiata* L.) accounts for 10% of production and 16% of cultivated area, with domestic demand projected to reach 2.75 million tonnes by 2030 (Singh & Gangwar, 2013). India leads global mungbean production, contributing roughly 65% of acreage and 54% of output (Baraki et al., 2020).

Insect pests, particularly bruchid beetles (*Callosobruchus* spp., Coleoptera: Chrysomelidae), represent a major constraint to stored mungbean. These beetles primarily infest seeds during storage, causing qualitative and quantitative losses such as seed perforation, reduced weight, diminished market value, and decreased germination capacity (Mishra et al., 2018; Tripathi et al., 2016). Economic losses can range from 30–40% within six months, potentially reaching total seed destruction if left unmanaged (Akinkurolere et al., 2006; Sharma et al., 2011). Both *C. maculatus* and *C. chinensis* are the most prevalent species across tropical and

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subtropical regions, and their coexistence in storage amplifies the risk of infestation (War et al., 2017; CABI, 2021).

Understanding the life cycle of bruchid beetles, particularly *C. maculatus* and *C. chinensis*, is essential for effective management of stored pulses. The rate of development and reproductive potential of these pests directly determines the speed and severity of infestation, with significant implications for seed quality and market value. Life cycle parameters, including egg-to-adult duration and survival rates, provide critical information for predicting population growth under varying storage conditions. Moreover, identifying vulnerable stages within the life cycle allows for the targeted timing of control measures, such as chemical treatments, biological agents, or physical interventions.

Although several studies have documented bruchid damage and general biology, detailed comparative information on the life cycle traits of co-occurring *C. maculatus* and *C. chinensis* under varying storage conditions remains limited. Understanding these biological parameters is essential for developing targeted management strategies. Differences in development under varying temperatures and humidity highlight the increased risk of rapid infestations in tropical and subtropical storage environments, where multiple bruchid species often coexist. Comparative life cycle studies of co-occurring species help prioritize management strategies by revealing which species develop faster or cause greater damage. The present study aims to evaluate the life cycle traits of *C. maculatus* and *C. chinensis* on stored mungbean, providing novel insights into their temperature-dependent development. The findings are expected to address the effective storage and pest management practices, reducing post-harvest losses and sustaining the seed quality.

Materials and Methods

Experimental site

The experiments were conducted in the Department of Entomology, Banda University of Agriculture and Technology, Banda during July to October, 2023. The coordinates of Banda are 24°53' to 25°55' North Latitudes and 80°07' to 81° 34' East Longitudes in Uttar Pradesh (India).

Experimental Population and Unit

Pure cultures of *Callosobruchus maculatus* and *C. chinensis* were obtained from the Indian Council of Agricultural Research (ICAR) – Indian Institute of Pulses Research (IIPR), Kanpur. The experimental population consisted of newly emerged, healthy adult beetles. Adult beetles were sexed based on morphological characters: females were larger, with a pointed abdomen and darker coloration, whereas males were smaller, brown, and had an obtuse abdomen. Adults were introduced to polypropylene boxes (250 ml) containing freshly harvested mungbean seeds, allowing mating and oviposition. Seeds with freshly laid eggs were subsequently transferred to individual 1.5 ml tubes to monitor the development of virgin adults. The experimental unit was defined as a plastic tube (10 × 5 cm) containing 50 g of mungbean seeds and five pairs of newly emerged adult beetles (five males and five females).

Experimental Design

A completely randomized design (CRD) was employed with three independent experimental sets, each comprising ten replicates per treatment. Treatments consisted of two environmental conditions: controlled and uncontrolled. Random allocation of experimental units to treatments ensured unbiased representation.

Rearing Conditions

Two rearing conditions were taken to study the various biological parameters of *C. maculatus* and *C. chinensis*. Controlled condition: Insect growth chamber maintained at 27 ± 1°C and 65 ± 5% relative humidity (RH). Uncontrolled condition: Room temperature at 34 ± 4°C and 70 ± 5% RH.

Data Collection

The following life cycle parameters were recorded daily:

- Number of eggs laid per female (fecundity)
- Egg hatchability (%)
- Pre-oviposition and oviposition periods
- Incubation, larvaland pupal, and total developmental periods (egg to adult)
- Adult emergence and longevity (male and female)
- Total life cycle duration

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- Sex ratio of adults

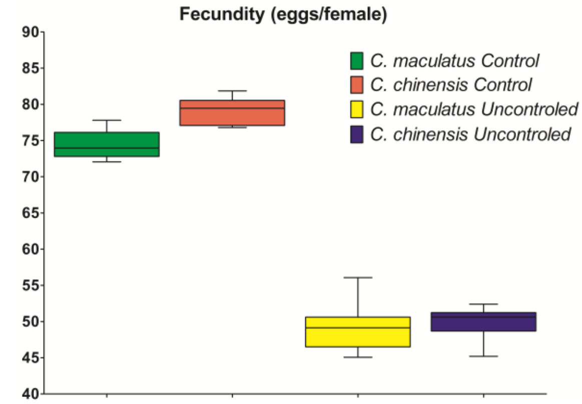
All observations were recorded under both controlled and uncontrolled conditions using standardized entomological procedures (Southgate, 1979).

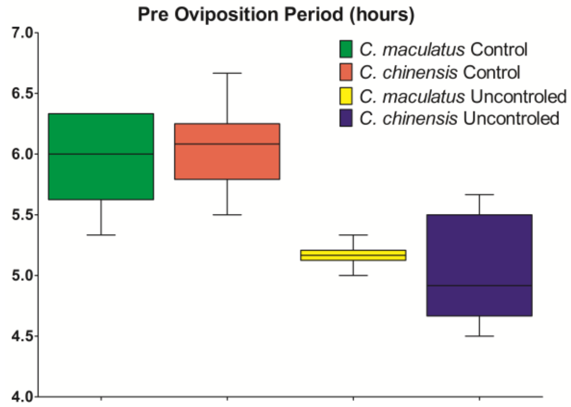
Statistical Analysis

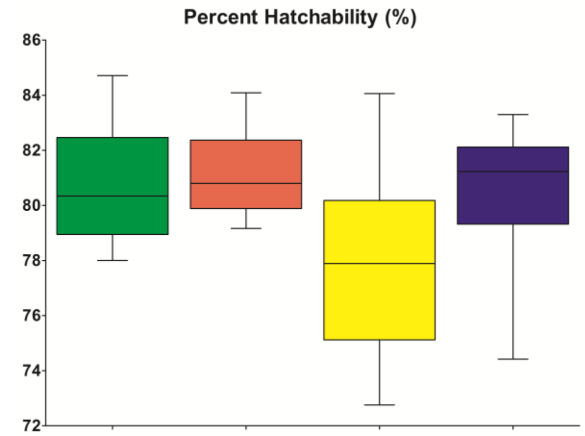
Data were subjected to analysis using the online statistical analysis tool OPSTAT (Developed by Chaudhary Charan Singh Haryana Agriculture University, Hisar, India).

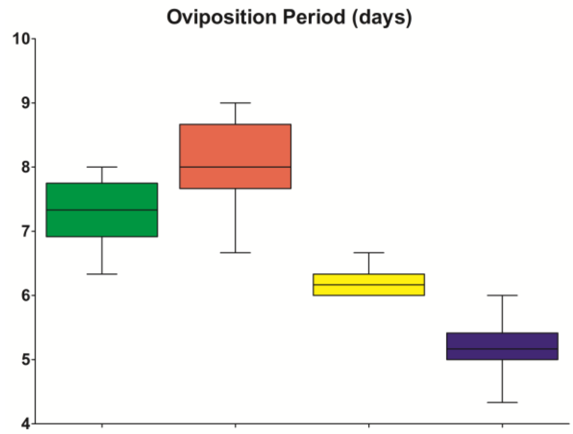
Results and Discussion

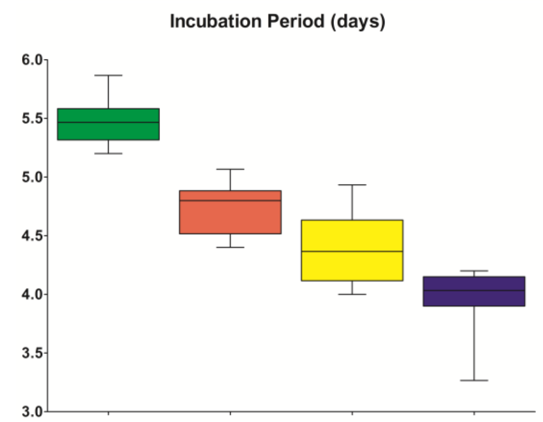
Studies on the life cycle traits of the bruchid beetles (*C. maculatus* and *C. chinensis*) in mung bean showed the promising results. Freshly laid eggs of *C. maculatus* and *C. chinensis* were tiny, oval to spindle shaped, whitish, smooth and translucent in appearance. The eggs were laid individually by females on the surface of the seed. A comparative analysis of the obtained data sets are presented in Figures 1-13.

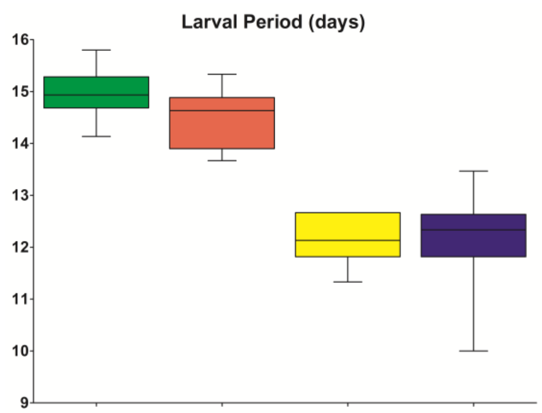












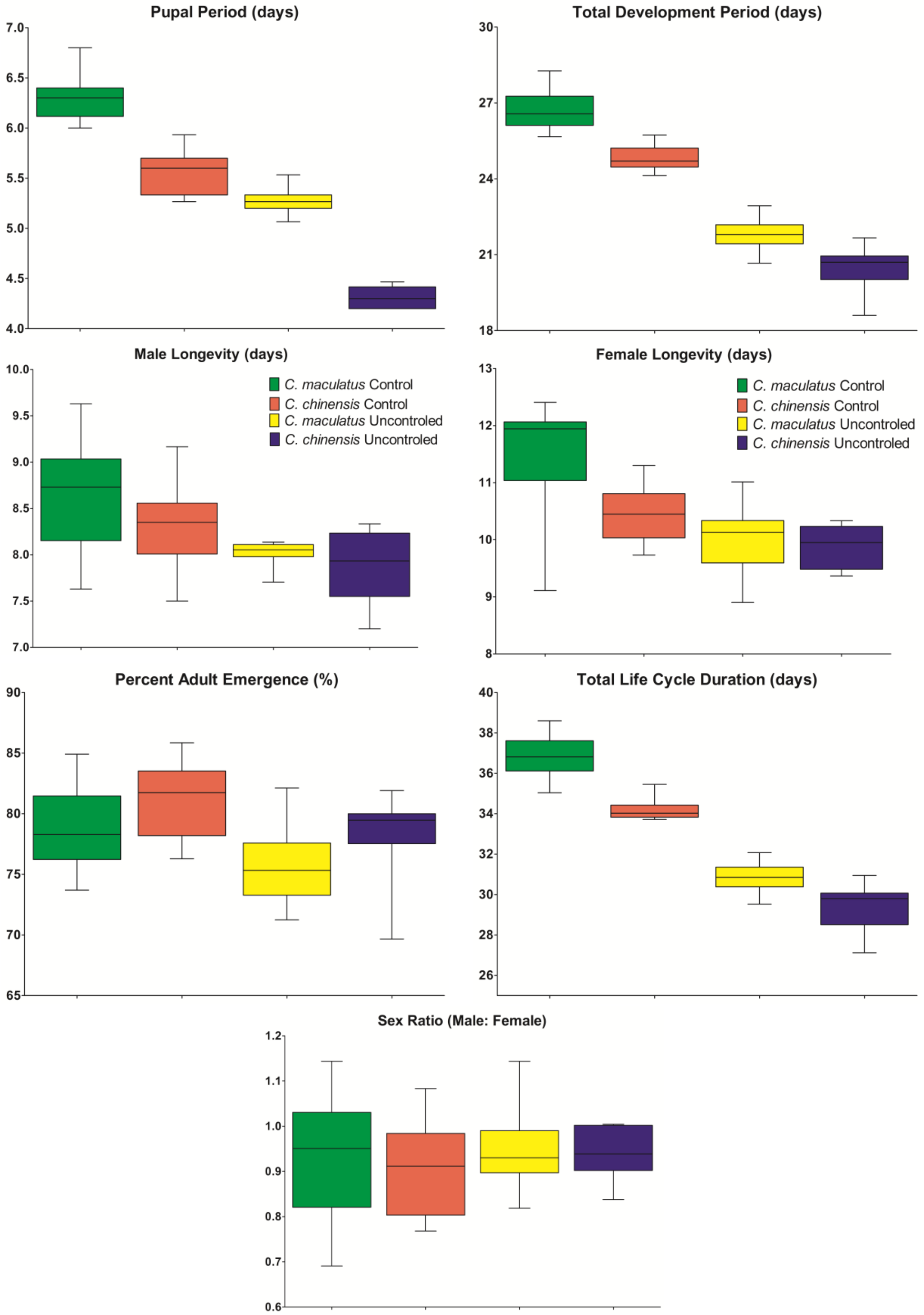


Figure 1-13. Comparative observations of certain life cycle traits of *C. maculatus* and *C. chinensis* in controlled and uncontrolled storage conditions

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Fecundity and Reproductive Traits

Under controlled conditions (27 ± 1°C, 65 ± 5% RH), *C. chinensis* exhibited slightly higher average fecundity (about 79 eggs/female) than *C. maculatus* (about 75 eggs/female), although both species showed considerable individual variation. The pre-oviposition period was short and comparable between species (about 6 hours), indicating rapid initiation of egg-laying after adult emergence. *C. chinensis* displayed a marginally longer oviposition period than *C. maculatus*, which may contribute to its slightly higher total egg production. Egg hatchability remained high for both species (>80%), reflecting favorable survival of early developmental stages under stable conditions.

In uncontrolled conditions (34 ± 4°C, 70 ± 5% RH), fecundity of both species decreased markedly, with averages of approximately 49 eggs/female, suggesting that elevated temperature negatively affects reproductive output. Despite this reduction, egg hatchability remained relatively stable (about 78–80%), indicating that early embryonic development is less sensitive to moderate thermal stress. The pre-oviposition period slightly shortened under higher temperatures, suggesting accelerated reproductive readiness.

Developmental Duration

Egg and Larval Stages

Under controlled conditions, the incubation period of *C. maculatus* (about 5.5 days) was longer than that of *C. chinensis* (about 4.7 days), indicating faster embryonic development in the latter. Larval duration followed a similar pattern, with *C. maculatus* larvae taking slightly longer (about 15 days) than *C. chinensis* (about 14.5 days). Morphologically, larvae were apodous, stout, and C-shaped, with yellowish-white bodies and black heads. During larval development, eggs exhibited color changes due to frass accumulation, indicating active feeding inside seeds. At room temperature, both species showed a significant reduction in incubation and larval periods. Incubation decreased to about 4.4 days in *C. maculatus* and about 4.0 days in *C. chinensis*, while larval periods shortened to about 12.1 days for both species. These reductions highlight the temperature-dependent acceleration of immature development.

Pupal Stage

Pupal duration was slightly longer in *C. maculatus* (about 6.3 days) than *C. chinensis* (about 5.6 days) under controlled conditions. Pupae were initially light cream, gradually darkening to brown, and were exarate with appendages held close to the body. Under uncontrolled conditions, pupal development shortened in both species, particularly in *C. chinensis* (about 4.3 days), reflecting faster metamorphosis at higher temperatures.

Total Developmental Period and Life Cycle Duration

The total egg-to-adult development period was longer in controlled conditions, with *C. maculatus* averaging about 26.8 days and *C. chinensis* about 24.8 days. In uncontrolled conditions, elevated temperatures accelerated development, reducing the total developmental period to about 21.8 days in *C. maculatus* and about 20.5 days in *C. chinensis*. This demonstrates that both species can complete multiple generations more rapidly under warmer storage environments.

Total life cycle duration (from egg to natural adult death) also reflected these trends. Under controlled conditions, *C. maculatus* averaged about 36.8 days, while *C. chinensis* averaged about 34.2 days. At room temperature, life cycle duration decreased to about 30.8 days in *C. maculatus* and about 29.3 days in *C. chinensis*. These reductions suggest that temperature elevation accelerates both developmental and adult phases, increasing the potential for rapid population growth.

Adult Longevity and Emergence

Adult longevity under controlled conditions was higher for females than males in both species. Female longevity averaged about 11.5 days for *C. maculatus* and about 10.5 days for *C. chinensis*, while males lived slightly shorter (about 8.7 days and about 8.3 days, respectively). Percent adult emergence was moderately high (about 79% in both species), indicating successful transition from pupae to adults under favorable conditions. Under uncontrolled conditions, adult longevity decreased for both sexes, with females averaging about 10 days and males about 8 days, reflecting the stress of higher temperatures. Adult

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emergence percentages slightly declined (about 75–77%), indicating that elevated temperatures may marginally affect pupal survival.

Sex Ratio

Across both conditions, the sex ratio was slightly male-biased in both species, with approximately 1 male to 0.91–0.94 females. This pattern remained consistent across temperature treatments, suggesting a stable sex ratio regardless of environmental conditions.

Comparative Analysis

It is evident from the Figures 1 and 2 that *C. chinensis* completed development faster than *C. maculatus*, particularly under elevated temperatures, indicating a competitive advantage in warmer storage. In contrast, *C. maculatus* produced slightly more eggs under controlled conditions, reflecting species-specific reproductive strategies. The data collectively suggest that storage temperature critically influences developmental rate, fecundity, and longevity, which are key parameters determining infestation potential.

Discussion

The present study demonstrates clear temperature-dependent variation in the life cycle traits of *C. maculatus* and *C. chinensis*, with higher temperatures accelerating development while reducing fecundity and adult longevity. Such thermal plasticity is a well-recognized adaptive trait in stored grain bruchids, enabling rapid population build-up under favorable storage conditions (Małek & Czarnoleski, 2021). The shorter developmental period observed at elevated temperature suggests increased infestation potential in inadequately managed storage environments. Faster generation turnover at warmer conditions can lead to exponential population growth, increasing the risk of severe quantitative and qualitative losses in mungbean seeds.

Fecundity and Reproductive Traits

The present study demonstrates that fecundity in *C. maculatus* and *C. chinensis* is strongly influenced by environmental conditions. Under controlled conditions, *C. chinensis* exhibited marginally higher egg production than *C. maculatus*, consistent with previous reports that *C. chinensis* tends to have slightly higher reproductive output under optimal storage conditions (Prajapati *et al*., 2022; Kumari *et al*., 2020; Sharma *et al*., 2016; Chudasama (2015); Pokharkar & Mehta, 2011; Varma & Anandhi, 2010; Singh & Kumari, 2000).

The reduced fecundity observed at higher, uncontrolled temperatures aligns with known thermal sensitivity of reproductive physiology in bruchids, where heat stress can suppress ovarian development and egg-laying capacity (Baur *et al*., 2023; Mona *et al*., 2015). The observed pre-oviposition periods were short for both species, highlighting their capacity for rapid reproduction once adults emerge, a trait that underlies the potential for explosive population growth in storage systems. Egg hatchability remained relatively high across both temperature regimes, suggesting that early embryonic development is less susceptible to moderate thermal fluctuations. This stability in hatchability, despite reduced fecundity under elevated temperatures, implies that even under suboptimal conditions, both species can sustain viable populations, posing continued risks to stored pulses.

Developmental Rates and Temperature Effects

Developmental duration, encompassing incubation, larval, and pupal periods, varied significantly between species and environmental conditions. *C. chinensis* consistently completed development faster than *C. maculatus*, particularly under warmer, uncontrolled conditions. This accelerated development is consistent with the general ectothermic response, where higher temperatures increase metabolic rates, shorten developmental periods, and reduce generation time. In contrast, controlled conditions allowed for longer developmental durations, which may reflect near-optimal but less stressful conditions. The larval period represents the most destructive stage, as larvae feed within the seeds. Although both species exhibited similar larval morphology, the slightly longer larval period in *C. maculatus* under controlled conditions suggests greater seed damage potential per individual (Prajapati *et al*., 2022; Mehta & Negi, 2020; Hosamani *et al*., 2018; Rana, 2014; Singh & Borah, 2001). Shortened larval development at elevated temperatures may reduce individual seed damage per larva but allows multiple overlapping generations, potentially increasing overall infestation intensity.

Life Cycle Duration and Adult Longevity

The total life cycle duration and adult longevity are key parameters for understanding population dynamics and infestation potential. Both species exhibited reduced life cycle duration at higher temperatures, enabling more generations per season. Female longevity exceeded male longevity across conditions, reflecting greater investment in reproductive output. High adult emergence percentages under controlled conditions indicate that near-optimal storage conditions favor population establishment, while moderately lower emergence under elevated temperatures indicates some physiological stress, though not sufficient to prevent population growth. The slight male-biased sex ratio observed in both species remained stable across conditions (Prajapati *et al*., 2022; Sekar *et al.*, 2021; Kumari *et al*., 2020; Jaiswal *et al*., 2018 & 2019; Varma & Anandhi, 2010; Patel *et al.*, 2005).

Comparative Biology and Ecological Implications

Comparative analysis indicates that *C. chinensis* is likely to become dominant under warmer storage conditions due to faster development, whereas *C. maculatus* may exert higher per-capita seed damage under optimal conditions due to slightly higher fecundity. Both species coexisting in storage containers can lead to overlapping generations, resulting in sustained infestation pressure. These findings underscore the ecological advantage of *C. chinensis* in tropical and subtropical storage systems, where elevated temperatures prevail.

The study highlights several practical implications. Reducing storage temperatures can slow bruchid development, decreasing generation turnover and cumulative seed damage. Short life cycle durations, especially in *C. chinensis*, necessitate frequent inspection to prevent rapid population buildup. Combining temperature control with resistant seed varieties or natural enemies could effectively limit bruchid infestation. Knowledge of species-specific developmental rates can inform predictive models for infestation dynamics in different storage environments. While the study provides valuable insights into biology of *Callosobruchus* spp., the studies may be undertaken in future to see the develeopmental rates in other pulses, the interaction between two species of bruchids under co-infestation. Future studies incorporating a wider range of environmental conditions, host varieties, and long-term population dynamics would strengthen predictive understanding of bruchid infestations.

Conclusion

The growth and development parameters of bruchids under different storage conditions will give a clue on the population build up. Interestingly, the understanding of the biological features of *C. maculatus* and *C. chinensis*, are of particular importance because of the coexistence of ecologically similar species. Our comprehension in life cycle traits of bruchid beetles will expand additional research in the field of interaction in coexistence.

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