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Population dynamics of *Chrysoperla zastrowi sillemi* (Esben-Petersen) fed with different hosts: Prospects for mass rearing and augmentative release

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ABSTRACT: Accurate demographic projections are essential for identifying prey diets that enhance predator efficiency in augmentative biological control. The population of lacewing, *Chrysoperla zastrowi sillemi* (Esben-Petersen) (*CZS*) was projected on four hosts including sterilized and unsterilized *Corcyra cephalonica* eggs, *C. cephalonica* neonates, and *Tribolium castaneum* using TIMING-MSChart program. The largest adult population of *C. zastrowi sillemi* was noted when reared on unsterilized eggs, reaching around 57000 adults after 60 days, compared to 51000 adults when reared on sterilized eggs. Population projection curves confirmed a faster build-up on unsterilized eggs, primarily due to enhanced juvenile survival and early adult fecundity. However, reliance on unsterilized eggs entails cannibalism, biosecurity risks, including pathogen and parasitoid contamination. These findings demonstrate that diet quality decisively shapes predator demography and establish sterilized *C. cephalonica* eggs as the most practical and reliable prey resource for insectary production and augmentative release of *C. zastrowi sillemi*.

Keywords: Augmentative release, *Chrysoperla zastrowi sillemi,* life table, population projection,

INTRODUCTION

The green lacewings, *Chrysoperla* spp. (Neuroptera: Chrysopidae) are among the most important generalist predators used in integrated pest management (IPM) owing to their voracious feeding on soft-bodied insect pests such as aphids, mealybugs, whiteflies, thrips, and lepidopteran eggs (Smith and Jones, 2010; Zhao *et al.,* 2015). Among them, *Chrysoperla zastrowi sillemi* (Esben-Petersen) (*CZS*) has gained prominence in tropical and subtropical horticultural systems due to its strong reproductive capacity, ecological adaptability, and compatibility with sustainable pest management strategies (Kumar *et al.,* 2018; Oliveira *et al.,* 2020). As interest in environmentally friendly alternatives to chemical pesticides rises, augmentative biological control utilizing lacewing predators is becoming ever more important. The success of augmentative programs, however, is critically dependent on the ability to mass-produce predators at low cost, high quality, and in a biosecure manner (Van Lenteren, 2012). Currently, mass rearing of *CZS* largely relies on *Corcyra cephalonica* eggs as the principal factitious diet. Although unsterilized eggs support rapid predator multiplication, they present serious drawbacks such as egg cannibalism, webbing, and contamination by microbial pathogens, parasitoids, and hyperparasitoids, which compromise colony health and sustainability (Patil and Deshmukh, 2013). Alternatives such as *C. cephalonica* neonates and *Tribolium castaneum* are sometimes explored, but their nutritional adequacy and efficiency in supporting predator growth remain poorly understood. Moreover, despite the recognized importance of diet quality, comprehensive demographic assessments quantifying its effect on lacewing performance are still limited.

In this study, we evaluated the life table parameters of *C. zastrowi sillemi* reared on four laboratory prey using the age-stage, two-sex life-table approach with the TWOSEX-MS Chart® software (Chi, 2020). In addition, population projection parameters were estimated with the TIMING-MS Chart® program to forecast predator growth and stage dynamics under different dietary regimes (Chi, 2021). Our integrative approach not only facilitates the identification of the most effective feeding regime for large-scale *C. zastrowi sillemi* rearing but also weighs practical concerns of colony health and biosecurity. Ultimately, the findings aim to inform improved protocols for sustainable mass-production and augmentative deployment of *C. zastrowi sillemi* in horticultural ecosystems.

MATERIALS AND METHODS

Experimental setup

The demographic parameters as well as population projection of *C. zastrowi sillemi* were studied at the Division of Genomic Resources, ICAR- National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru, India. All experiments were conducted under controlled laboratory conditions of 25 ± 1 °C temperature, 65 ± 5% relative humidity (RH), and a photoperiod of 14L:10D. *Corcyra cephalonica* was reared in disinfected boxes (45 × 45 × 5 cm) using standardized artificial diet. While the adults of *C. zastrowi sillemi* were maintained in muslin-lined oviposition chambers and provided with cotton swabs soaked in water, 50% honey solution, a commercial protein supplement (Pfizer Ltd., Mumbai), and a 1:1 yeast-sucrose mixture. Castor pollen grains were placed in small containers at the corners of rearing boxes (20 × 16 cm), and perforated brown paper sheets were used to stimulate egg laying. Eggs were collected at two-day intervals and incubated until hatching.

Prey treatments

Four prey types were evaluated as larval diets, Sterilized *C. cephalonica* eggs (surface-sterilized with UV light exposure for 30 min), Unsterilized *C. cephalonica* eggs (freshly collected and used directly), *C. Cephalonica* neonates (newly hatched first-instar larvae) *T. castaneum* larvae (early instars (1-2 mm). Each *CZS* larva was provided ad libitum prey daily until pupation. Food was replenished daily, and leftover prey was removed.

Life-table study design

Newly hatched (< 12 h) *C. zastrowi sillemi* larvae were individually reared in plastic vials (4 × 5 cm) lined with moist filter paper to prevent desiccation. For each prey treatment, 120 individuals were monitored from egg hatching until adult death. Vials were checked every 24 h to record survival, developmental duration, and stage transitions (egg, larval instars, pupa, and adult). Daily fecundity, adult longevity, and pre-oviposition periods were recorded until female death.

Population projection

Stage-specific survival and fecundity data obtained from each prey diet were analysed using TIMING-MS Chart® (Chi, 2021) to generate population projection curves. Simulations of population growth and age-stage distribution of *Chrysoperla zastrowi sillemi* were conducted for 60 days under laboratory conditions to compare its long-term demographic performance on different diets. The program (Chi and Liu, 1985) estimates the population size that can be derived from life table parameters, with outputs including the total projected population and the age-stage structure, denoted as P(t) (insect population projection). This approach provides a dynamic visualization of how populations change over time under different diet treatments.

P(t): Insect population projection $P(t) = \sum_{j=1}^{m} \left(\sum_{x=0}^{\infty} c_{xj} n_{xj,t} \right)$

RESULTS AND DISCUSION

The *C. zastrowi sillemi* successfully completed development on all four prey types; however, significant differences were evident in survival and developmental times. Larvae reared on sterilized and unsterilized *C. cephalonica* eggs exhibited the shortest immature durations and highest survival (>85%), whereas those reared on *C. cephalonica* neonates and *T. castaneum* showed prolonged development with reduced survivorship (<60%). Faster development on *C. cephalonica* eggs indicates superior nutritional suitability, consistent with observations by Patil and Deshmukh (2013) that egg-based diets provide balanced nutrients for lacewing growth.

These results corroborate findings of Oliveira *et al*. (2020), who demonstrated that diet quality strongly influences reproductive capacity in *Chrysoperla* species. Enhanced fecundity on eggs reflects their high protein and lipid content, essential for oogenesis (Kumar *et al*., 2018).

Population projection simulations demonstrated a steeper increase in population size on unsterilized eggs, driven by early fecundity and higher juvenile survival. The largest adult population of *CZS* was noted when reared on unsterilized eggs, reaching around 57000 adults after 60 days, compared to 51000 adults when reared on sterilized eggs (Fig. 1 and 2). However, the difference with sterilized eggs diminished over time, suggesting that sterilized eggs can ensure comparable long-term productivity while mitigating risks of cannibalism,

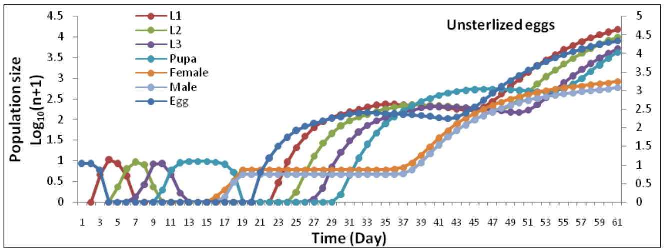

Fig. 1. Population projection of *Chrysoperla zastrowi sillemi* on unsterilized *Corcyra cephalonica* eggs

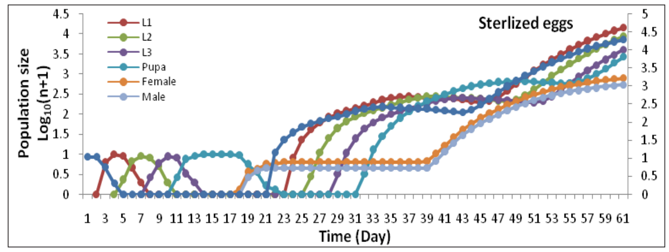

Fig. 2. Population predictions of *Chrysoperla zastrowi sillemi* on sterilized *Corcyra cephalonica* eggs

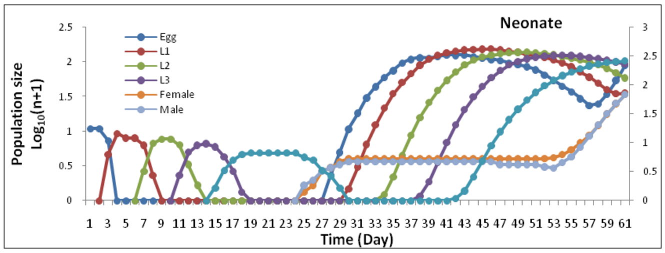

Fig. 3. Population predictions of *Chrysoperla zastrowi sillemi* on *Corcyra cephalonica* neonates

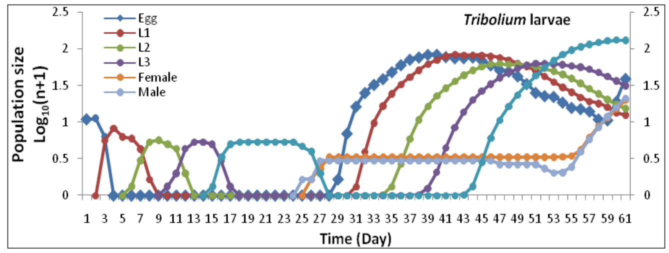

Fig. 4. Population predictions of *Chrysoperla zastrowi sillemi* on *Tribolium castaneum*

webbing, and contamination of unsterilized eggs. The lowest adult population was noted when reared on neonates of *Corcyra* and *T. castaneum* reaching around 600 and 300 adults after 60 days. The slower growth on neonates and *T. castaneum* highlights their unsuitability for large-scale rearing (Fig. 3 and 4).

Our population projection simulations revealed that (*CZS*) populations increased more rapidly when reared on unsterilized *C. cephalonica* eggs compared to sterilized eggs, largely due to higher juvenile survival and earlier fecundity. This trend is consistent with earlier studies on *Chrysoperla* spp., which repeatedly identified *C. cephalonica* eggs as the most suitable prey for mass rearing (Ramakrishnan *et al*. 1992; Balasubramaniam *et al*. 2001; Henry *et al*. 2010). Similar to our results, Harbi *et al*. (2025) reported that females reared on unsterilized *C. cephalonica* eggs exhibited higher fecundity than those reared on other prey sources. Although unsterilized eggs supported the highest adult population (57,000 after 60 days), our projections indicate that the difference with sterilized eggs (51,000) diminished over time. This suggests that sterilized eggs, despite initially reducing reproductive performance, can sustain comparable long-term productivity.

This observation agrees with findings of Atlihan and Chi (2008), who emphasized that prey quality strongly influences early growth trajectories but long-term fitness may stabilize across different diets. Moreover, using sterilized eggs has the practical advantage of reducing cannibalism, webbing, and contamination, a problem highlighted in mass-rearing facilities (Singh and Varma, 1986; Ghosh *et al*. 2016). Thus, our results support the recommendation that sterilized eggs are more suitable for large-scale and hygienic production systems. In contrast, the poorest performance was recorded on neonate larvae of *C. cephalonica* and *T. castaneum*, with adult populations reaching only 600 and 300 individuals, respectively, by day 60. The slower population growth on these diets corroborates earlier reports that chrysopids reared on neonates or flour beetle larvae experience prolonged development, reduced survival, and lower fecundity (Tauber *et al*. 2000; Chandran *et al*. 2018). The present results reinforce the conclusion that neonates and *T. castaneum* are unsuitable for large-scale rearing due to their poor nutritional quality and high handling costs. Overall, our findings strengthen the evidence that *C. cephalonica* eggs, particularly when sterilized, remain the most reliable food source for mass production of *CZS*, balancing biological performance with practical rearing considerations.

In conclusion, Sterilized *C. cephalonica* eggs provide a balanced solution for large-scale mass production of *CZS*, sustaining high demographic performance while minimizing risks of cannibalism, contamination, and handling challenges. Their practicality and reliability make them the most suitable prey resource for efficient insectary multiplication and augmentative biological control programs.

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