Effect of daily temperatural fluctuation on population fitness of *Ophraella communa* in early spring in Langfang, Heibei Province

Lu Kong, Zhongshi Zhou, Lei Yue, Zhibang Liu, Fanghao Wan, Jianying Guo *

State Key Laboratory for Biology of Plant Diseases and Insect Pests, Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing 100193, China

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ABSTRACT

Ophraella communa LeSage (Coleoptera: Chrysomelidae) was accidentally introduced in China, and it is a biological control agent of common ragweed, *Ambrosia artemisiifolia* L. (Asterales: Asteraceae). Life history and life table parameters of *O. communa* were studied in the open field of Langfang city, Hebei province, north China (39°30′42″N, 116°36′07″E) in early spring. Development durations for egg, larva, pupa and entire immature stage of *O. communa* were 13.6, 21.1, 7.9 and 42.8 d, respectively. Adults could survive in 37.41 d, no differences in the longevities between female and male, and fecundity was 713.1 eggs per female. The intrinsic rate of increase (r), finite rate of increase (λ), net reproductive rate (R_0), and mean generation time (T) were 0.0660 d^{-1}, 1.0683 d^{-1}, 73.9 offspring/individual and 63.0 d, respectively. The results of our study can offer valuable insight on the population demography of *O. communa* in early spring in the field. In addition, the effects of temperature fluctuation on the development, survival and fecundity of *O. communa* and the potential of using the beetle for controlling *A. artemisiifolia* are also discussed in the early spring.

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The ragweed beetle, *Ophraella communa* LeSage (Coleoptera: Chrysomelidae), originates from North America [1,2], and it has played an important role in biological control of the invasive common ragweed, *Ambrosia artemisiifolia* L. (Asterales: Asteraceae) [3–5]. In southern China, it had a good control effect on common ragweed [6,7]. However, low temperatures in winter and a sudden decrease of temperature in early spring have been a climatic barrier to prevent *O. communa* migrating from lower latitudes to higher latitudes, which directly lead to the decrease in control effect of the beetle on common ragweed in northern China. However, previous study had deduced that *O. communa* populations showed potential to spread to temperate regions with possessing ecological plasticity towards cold hardiness [8].

Temperature is an important variable for an insect [9,10], and temperature experienced during development profoundly affects many life history traits of an insect [11,12]. In nature, insects have to experience daily periodic variation of temperatures, and the effects of changing temperatures on the development of insects differ significantly from constant temperatures [13]. As a short-term stress factor, the night-time low temperature usually has a powerful effect on the development, survival and fecundity of an insect [14–17]. After suffering from a night-time low temperature, insects meet a day-time temperature stage (relative higher-temperature) that may repair chill injuries accumulated during the cold periods [18–20]. Several studies have shown that survival rate significantly increased when some insect species were exposed to a fluctuating temperature compared with a constant low

temperature, such as *Sarcophaga crassipalpis* (Diptera: Sarcophagidae), *Orchesella cincta* (Collembola: Entomobryidae), *Aphidius colemani* (Hymenoptera: Aphidiidae), *Megachile rotundata* (Hymenoptera: Megachilidae) and *Spodoptera exigua* (Lepidoptera: Noctuidae) [21–25]. Furthermore, the fluctuating temperature experience can enhance cold tolerance of an insect, such as eggs of *Locusta migratoria* (Orthoptera: Acrididae), adults of *Drosophila melanogaster* (Diptera: Drosophilidae) and *Pyrrhocoris apterus* (Hemiptera: Pyrrhocoridae) [26–28]. Previous study had suggested that both development and fecundity of *O. communa* were significantly affected under a short-term low temperature [29].

We hypothesize that the development of *O. communa* when exposed to daily natural changing temperatures in early spring may differ significantly from a constant sub-optimum temperature. To describe the development of *O. communa* in early spring, the survival, development and fecundity of the beetle under natural fluctuating temperatures were studied in the field. In addition, life table was used for analyzing the population development of the beetle via the age-stage, two-sex life table theory. The results could offer valuable insights on the prospects of using the beetle as a biological control agent against common weed in early spring.

1. Material and methods

1.1. Host plants and insects

Seedlings of common ragweed were individually grown in 15-cm diameter plastic pots with loamy clay soil, watered every four days,

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and fertilized with N:P:K at the ratio of 13:7:15 twice a month. The plants were used for experiments when they reached 40 cm in height.

O. communa adults were collected from Langfang Experimental Station of Chinese Academy of Agricultural Sciences (CAAS), Langfang city, Hebei province, north China (39°30′42″N, 116°36′07″E) in late October 2011 and maintained on common ragweed's plants in the greenhouse of CAAS Langfang Experimental Station. Stock colony of O. communa was reared in an air-conditioned laboratory at 25 ± 1 °C, 70 ± 10% RH, and a photoperiod of 14:10 (L:D) during the winter. Newly emerged adults were collected in early April 2012, and females and males were separately held on potted common ragweed's plants in cages (52 cm × 37 cm × 63 cm) in the same above laboratory, at a density of 20 adults per plant and one plant per cage. Two-day-old adults were used for experiments.

1.2. Life table experiment

O. communa adults from the above culture were paired, and each pair was placed on a potted fresh common ragweed's plant in cage (see above) for oviposition. The potted plants that had at least 40 O. communa eggs <12-h-old laid at the third day were allocated randomly, and transplanted into the field cage (4 m × 2 m × 2 m) covered using a 350 ∗ 350 μm sieve mesh nylon screening fabric in the late April 2012. Redundant eggs were removed in order to keep a density of 20 eggs per plant, and six plants with eggs per cage. Adjacent plants were separated by a row of unplanted ground (50 cm wide). A humidity & temperature recorder (DSR-THRA; ZOGLAB Data logger for Temperature and Humidity, Zhejiang, China) was placed in one of these cages to record temperature at different times daily. Eggs were checked daily until all hatched. The larvae were kept on the same common ragweed's plant until pupation. Pupae were detached from leaves, then placed in a 5 ml unsealed centrifugal tube individually, and checked daily until adult emerged. Five cages with plants were used as five replications in the field. Larval survival rates and developmental period were recorded and newly emerged adults were sexed for determining the sex ratio.

Seedlings of common ragweed were inserted into plastic bottles (3 cm in diameter and 5 cm in height) filled with water and with a 0.8 cm diameter hole in the lid to hold the seedling. Newly emerged virgin males and females were paired and each pair was placed on a seedling. The seedlings with a pair of the adult beetles were placed in transparent plastic boxes (19 cm × 12 cm × 6 cm) and covered with organdy mesh fabric. These plastic boxes with O. communa adults and ragweed seedlings were also placed randomly in the field cage. O. communa eggs were checked and counted daily until the adults died. If the male died earlier, another newly emerged male was added. Survival, the number of eggs laid, longevity, preovipositional periods and ovipositional period were recorded.

1.3. Data analysis

The collected data were analyzed by the age-stage, two-sex life table theory (Chi and Liu, 1985) and the method described by Chi (1988). The age-stage specific survival rate (s_{xj}) (where x is the age and j is the stage), the age-stage specific fecundity (f_{xj}), the age-specific survival rate (l_x), and the age-specific fecundity (m_x) were calculated from daily records of survival and fecundity of all individuals in the cohort. The population life table parameters were included intrinsic rate of increase (r), finite rate of increase ($λ$), net reproductive rate (R_0), and mean generation time (T). The intrinsic rate of increase was estimated by using the iterative bisection method from the Euler–Lotka formula:
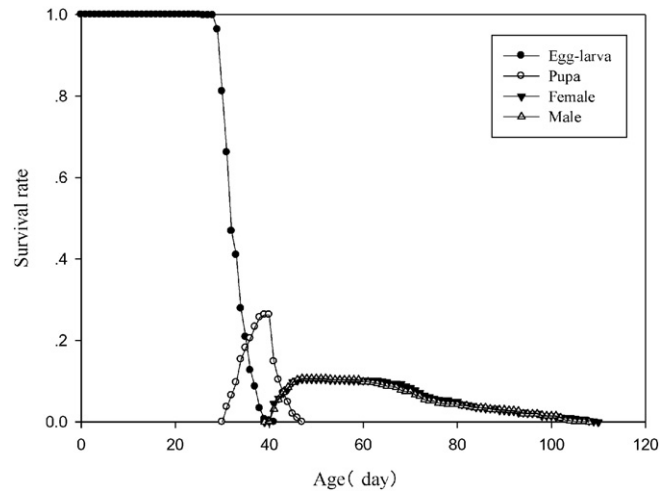
$$\sum_{x=0}^{\infty} e^{-r(x+1)} l_x m_x = 1$$

Fig. 1. Age-stage survival rate (s_{xy}) of O. communa in the field in early spring.

with age indexed from 0 [30]. The mean generation time is defined as the length of time that a population needs to increase to R_0-fold of its size (i.e., $e^{rT} = R_0$ or $λ^T = R_0$) as the stable age distribution and the stable increase rate are reached. Thus, it is calculated as $T = \ln R_0/r$. The means and standard errors of the life table parameters were from the five replications. To facilitate the tedious process of the raw data analysis, we used the TWOSEX-MSChart program [31] to calculate the population parameters (r, R_0, T, and $λ$) and group the raw data. The TWOSEX-MSChart is available at http://140.120.197.173/Ecology/prod02.htm (Chung Hsing University) and at http://nhsbig.inhs.uiuc.edu.tw/www/chi.html (Illinois Natural History Survey).

2. Results

2.1. Survivorship and sex ratio

Because the density of O. communa larvae affected their developments, we divided the life history of O. communa into egg-larva, pupa and adult stages. The age-stage specific survival rate (s_{xj}) of O. communa gave the probability that a newly laid egg survived to age x and stage j. Because of the age-stage, two-sex life table took the variable development rate among individuals into consideration, significant overlapping between developmental stages was observed in Fig. 1. In early spring, survival rate of entire immature stage of O. communa was only 21.3% (Table 1). The probability that a new born egg survives to the adult stage was 0.11 for males and 0.10 for females. Female ratio was 0.49, which was closed to an expected female ratio of 0.5 ($x^2 = 0.901$, $df = 1$, $P > 0.05$).

2.2. Development

Egg, larval and pupal developmental durations lasted for 13.6 d, 21.1 d and 7.9 d, respectively, in early spring. The total developmental time of the entire immature stage of O. communa was 42.8 d (Table 2).

Table 1
Survival rates and female ratio of O. communa in the field in early spring.

Survival rate (%)				Female ratio
Egg	Larva	Pupa	Total preadult	
81.5 ± 4.3	33.6 ± 2.9	78.9 ± 1.5	21.3 ± 2.8	0.49 ± 0.02