

Research Article

Response of *Ooencyrtus fecundus* (Hym., Encyrtidae) to deprivation of host *Eurygaster integriceps* (Hem., Scutelleridae) eggs**Shahzad Iranipour*, Arezoo Bazavar and Roghaiyeh Karimzadeh**

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Abstract: The common sunn pest, *Eurygaster integriceps* Puton (Hemiptera: Scutelleridae), is a major pest of wheat and barley in Iran. Egg parasitoids (Hymenoptera: Scelionidae and Encyrtidae) represent the most promising natural enemies of this pest. However, these parasitoids often experience host absence early in the season. This study evaluated the effects of different host-deprivation intervals on *Ooencyrtus fecundus* Ferrière and Voegelé (Hymenoptera: Encyrtidae), a widespread egg parasitoid of *E. integriceps*. Experiments were conducted under constant environmental conditions (25 ± 1 °C, $50 \pm 10\%$ RH, and a 16L:8D h photoperiod) with five host-access regimes: continuous access (control), access every other day, every third day, once per week, and full access following a seven-day deprivation period. Parasitism rate decreased as the deprivation interval increased, with the strongest negative effects observed in the once-per-week treatment. Partial compensation occurred during host-access days across all treatments. Females showed substantial recovery when given unlimited access following a long deprivation. Thus, early-season host delays are unlikely to threaten the biological control of the common sunn pest, as *O. fecundus* can compensate for lost opportunities during subsequent access. Nonetheless, intermittent host availability may negatively affect parasitoid performance.

Keywords: Compensation, Parasitism, Enhancement, Environmental constraints, Encyrtidae, Hymenoptera

Introduction

The common sunn pest, *Eurygaster integriceps* Puton (Hemiptera: Scutelleridae), is a key pest of cereal crops across western Eurasia, including the Middle East, the Mediterranean Basin, Russia, the Caucasus, southern Europe, and Central Asia (Radjabi, 2000). The fauna of egg parasitoids associated with this pest is diverse, mainly comprising species of *Trissolcus*, *Telenomus*, and *Gryon* (Hymenoptera:

Scelionidae), as well as *Ooencyrtus* (Hymenoptera: Encyrtidae) (Kozlov and Kononova, 1983; Radjabi and Amir-Nazari, 1989; Doğanlar, 2001; Trissi *et al.*, 2007; Iranipour, 2021; Al-Hadrawi *et al.*, 2023). Among these, *Ooencyrtus fecundus* Ferrière and Voegelé is a widely distributed, perennial species that inhabits wheat fields in Iran. Although parasitism rates in nature are typically low (Iranipour *et al.*, 2011), substantial numbers of *O. fecundus* adults are captured in host-egg

Handling Editor: Yaghoob Fathipour

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Received: 05 October 2024, Accepted: 23 June 2026

Published online: 03 October 2026

traps late in the season (Iranipour, 1996; Nozad-Bonab and Iranipour, 2010; Shafaei *et al.*, 2011), suggesting strong host acceptance. Under laboratory conditions, *O. fecundus* successfully parasitizes host eggs, and its immature stages develop within them (Iranipour *et al.*, 2020; Nassiri *et al.*, 2020), demonstrating strong potential as a biological-control agent despite its modest performance in the field.

Low parasitism levels in the field may be partly explained by temporal asynchrony between the parasitoid and its host. Synchronization between adult parasitoids and the susceptible host stage is crucial for effective parasitism (Ramos Aguila *et al.*, 2023). Several studies report that *Ooencyrtus* spp. are primarily active late in the season (Iranipour, 1996; Nozad-Bonab and Iranipour, 2010; Shafaei *et al.*, 2011), suggesting that host-absence intervals may occur in their annual life cycle. Even in well-synchronized species, early-season host deprivation is likely, as cereals are annual crops and field rotations or fallows force associated insects to relocate between seasons. Both *E. integriceps* and its egg parasitoids leave cereal fields after harvest to overwinter in resting sites. However, the dispersal capacities differ markedly: parasitoids typically disperse ≤ 500 m, whereas the sunn pest may migrate up to 30 km toward nearby mountains (Safavi, 1973; Radjabi, 2000). Consequently, in spring, parasitoids usually recolonize cereal fields from adjacent refuges while the pest undertakes longer flights, often delayed by cold or rainy weather. This migration lag creates a period when parasitoids are active, but their host is absent (Kaitazov, 1968; Safavi, 1973; Iranipour, 1996; Radjabi, 2000).

Differences in thermal requirements between *E. integriceps* and its egg parasitoids further accentuate this asynchrony. The developmental thresholds of parasitoids are typically 7–8 °C lower than those of the host (Popov and Paulian, 1971; Şimşek, 1986; Şimşek and Yaşarakinci, 1990). For example, the thermal threshold for immature development of *E. integriceps* is 18.85 °C (Iranipour *et al.*, 2003), whereas corresponding values for *Trissolcus* spp. and *Ooencyrtus* spp. range from 12–14 °C (Iranipour

et al., 2010, 2015; Kivan and Kilic, 2006; Jalal Kor, 2023). In Türkiye, Şimşek (1986) and Şimşek and Yaşarakinci (1990) observed that *Trissolcus* spp. began flight activity in spring once temperatures reached 13.5 °C, approximately three weeks earlier than the host. Collectively, these findings indicate that parasitoids colonize cereal fields before *E. integriceps* and thus experience host-deprivation periods in nature.

Information on the effects of host deprivation on the egg parasitoids of *E. integriceps* is limited. Only a few studies have addressed *Trissolcus grandis* (Thomson) (Hem., Scelionidae) (Tarla, 2011; Bazavar *et al.*, 2015), whereas most knowledge of host-deprivation responses derives from other parasitoid–host systems, particularly *Trichogramma* spp. (Fleury and Bouletreau, 1993; Li *et al.*, 1993; Garcia *et al.*, 2001; Hohmann *et al.*, 2001; Hougardy *et al.*, 2005; Hougardy and Mills, 2006; Karimi-Malati *et al.*, 2006; Legult *et al.*, 2013; Martel and Sforza, 2021). Understanding how *O. fecundus* responds to such constraints is essential for designing agroecosystems and implementing conservation and enhancement measures. Therefore, the objective of this study was to examine the effects of varying host-deprivation regimes on *O. fecundus* reproductive effort, longevity, and population-growth rate, and to assess its ability to compensate for missed oviposition opportunities when later provided with continuous host access.

Materials and Methods

Insect cultures

Adult *E. integriceps* were collected in May 2013 from Qaramalek (38.09° N, 46.21° E) and Kujubar (38.06° N, 46.13° E) villages near Tabriz, East Azerbaijan Province, northwestern Iran. The insects were transferred to the greenhouse facilities of the Department of Plant Protection, University of Tabriz, and reared in rectangular Plexiglas containers (30×15×10 cm). Twenty-five adults were placed in each container and fed wheat kernels (cv. Omid) and water-soaked cotton balls. Folded paper sheets

served as oviposition substrates. Containers were ventilated via 3×6 cm openings covered with 50-mesh cloth. The cultures were maintained at 26 ± 2 °C, $50 \pm 10\%$ RH, and a 16L:8D h photoperiod. Host eggs were collected daily and either used immediately in experiments or stored at 4 °C for later use (Bena Molaei et al., 2015).

Immature *O. fecundus* were obtained from *E. integriceps* egg traps deployed at the same collection sites. Each trap consisted of a rectangular yellow cardboard (8 × 12 cm) folded into a Π shape, with three clusters of *E. integriceps* eggs (14 eggs per cluster) affixed to the inner surface. Twenty traps were installed weekly, suspended by thread from wheat plants at 3 m intervals. Emerged *O. fecundus* adults were isolated from the parasitoid assemblage and transferred to 1.5 × 10 cm glass vials provisioned with honey droplets applied to paper strips. Vials were held in an incubator under constant environmental conditions (25 ± 1 °C, $50 \pm 10\%$ RH, and a 16L:8D h photoperiod) until adult emergence. The F₂ generation was used for all experiments.

Experimental design

The effects of host deprivation on *O. fecundus* were assessed under controlled environmental conditions (25 ± 1 °C, $50 \pm 10\%$ RH, and a 16L:8D h photoperiod). Pairs of one-day-old adult parasitoids were confined in glass vials (1.5×10 cm), and <24 h-old *E. integriceps* eggs were supplied *ad libitum* at designated intervals. The number of eggs offered was determined as the maximum daily attack rate (MAR) of *O. fecundus* multiplied by the deprivation interval (Iranipour et al., 2020).

Five host-access regimes were established, each with 15 replicates:

- i) **Control (C):** Continuous access to host eggs throughout the parasitoid's lifespan. ii) **C/2:** Access to host eggs every other day (deprivation on alternate days). iii) **C/3:** Access every third day (two days of deprivation between exposures). iv) **C/7:** Access once per week. v) **-7C:** Continuous access following a seven-day deprivation period.

The design allowed deprived females to compensate for missed oviposition opportunities when subsequently provided with hosts. All reproductive and survival events were recorded until the female's death.

Parameter estimation and data analysis

Data were analyzed using a fecundity–life table framework. Life expectancy, survival rate, and population growth parameters, including gross reproductive rate (*GRR*), net reproductive rate (*R*₀), intrinsic rate of increase (*r*), finite rate of increase (*λ*), generation time (*T*), doubling time (*DT*), birth rate (*b*), and death rate (*d*), were estimated following Iranipour et al. (2025). Confidence intervals and standard errors were obtained via bootstrap resampling (Meyer et al., 1986) using a Microsoft Excel macro developed by Iranipour (2018).

Entropy was calculated as an indicator of survivorship-curve type (Demitrius, 1978). One-way ANOVA was used to compare mean longevity and total fecundity across treatments, and Tukey's HSD test ($\alpha = 0.05$) was applied for mean separation (SAS Institute, 2009). Stable population growth parameters were compared pairwise based on randomly paired bootstrap estimates.

Results

Survival rate and life expectancy

The survivorship curve of *O. fecundus* was convex (Type I) across all treatments, indicating that most mortality occurred at senescence (Fig. 1). Entropy values ranged from 0.0816 to 0.1220, confirming curve convexity. Life expectancy at birth was 19.6, 19.3, 19.8, 21.3, and 19.6 days for treatments C, C/2, C/3, C/7, and -7C, respectively (Fig. 1).

Longevity

Adult longevity did not differ significantly among deprivation regimes ($F = 1.89$; $df = 4, 70$; $P = 0.12$). Mean longevity ($\pm$ SE) was 29.9 ± 1.41 , 30.9 ± 1.15 , 31.7 ± 1.37 , 34.3 ± 1.11 , and 29.3 ± 1.97 days for C, C/2, C/3, C/7, and -7C, respectively.

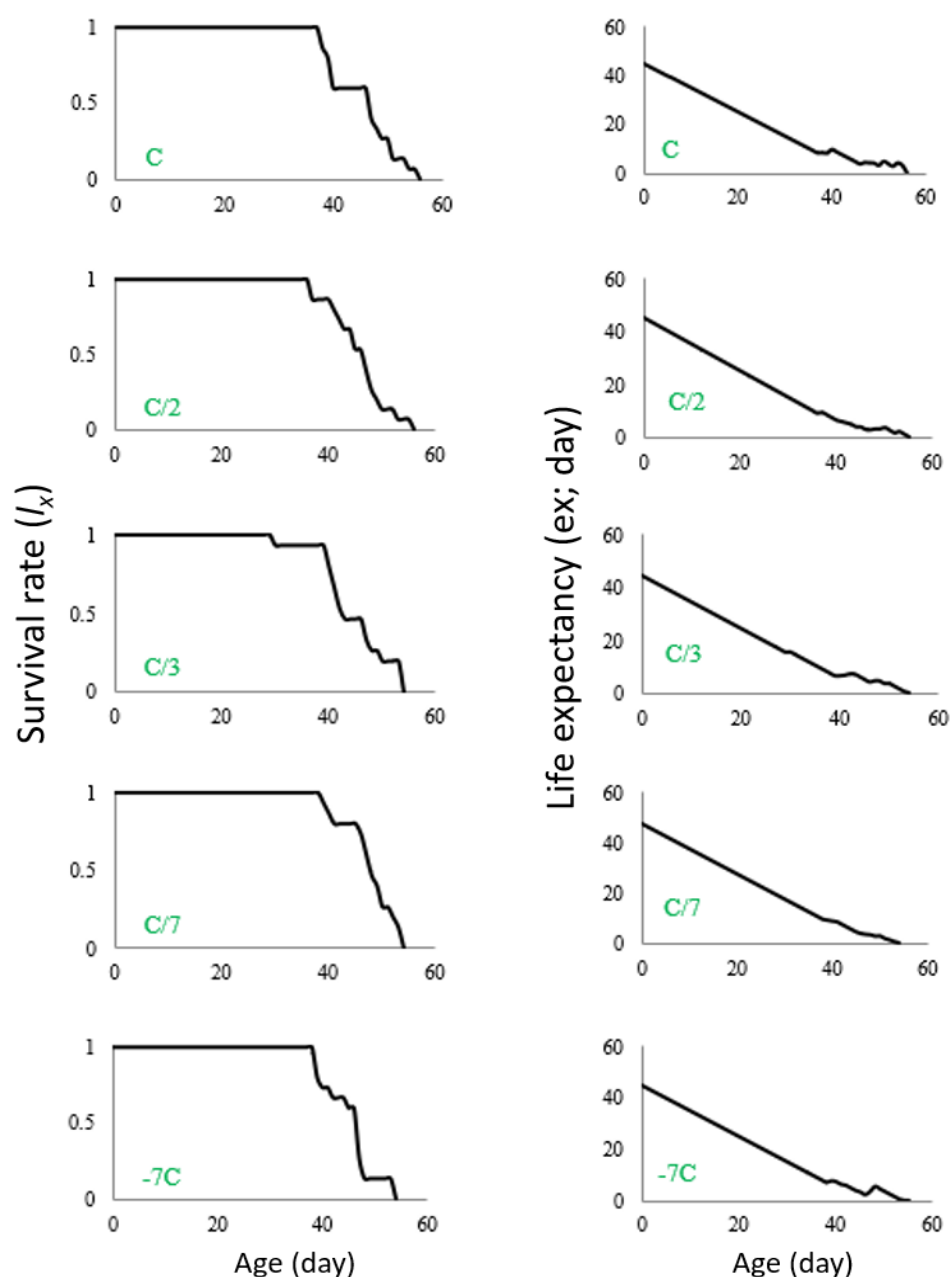


Figure 1 Survivorship curves (left) and life expectancies (right) of *Ooencyrtus fecundus* at different host-deprivation regimes of *Eurygaster integriceps*. C = control, C/2 = every other day, C/3 = every third day, C/7 = once a week, -7C = full access following a week of deprivation.

Fecundity

Total fecundity was significantly affected by host-deprivation regime ($F = 13.41$; $df = 4, 70$; $P < 0.0001$). Mean fecundity ($\pm$ SE) was 114.5 ± 6.79 , 75.9 ± 7.88 , 60.9 ± 5.06 , 42.9 ± 4.11 , and 100.0 ± 12.66 eggs for treatments C, C/2,

C/3, C/7, and -7C, respectively. The difference between the control and all other treatments, except -7C, was significant.

In control females, daily fecundity peaked between days 3 and 8, then declined gradually and reached zero on day 23. Approximately

44% and 84% of total fecundity occurred during the first and second weeks of adult life, respectively, with 50% achieved within eight days (Fig. 2).

In the C/2 treatment, females exhibited higher fecundity than the control on their first access day, achieving approximately two-thirds of the control total fecundity. Oviposition ceased on day 24 (Fig. 2).

In C/3, females laid twice as many eggs as the control on the first access day (day 3 of adulthood), compensating for 90% of the potential fecundity missed during deprivation. However, fecundity declined sharply afterward, with total output reaching 54% of control levels. The last oviposition occurred on day 27 (Fig. 2).

In the C/7 treatment, females parasitized 17 eggs on their first access day, the highest daily fecundity observed across treatments. This corresponded to the cumulative four-day fecundity of control females (40% of control total). Total fecundity reached only 38% of control levels, with oviposition continuing until day 28.

In the -7C treatment, fecundity peaked on the first day of host access (day 7 of adulthood) and exceeded that of same-aged control females over the following 10 days. These parasitoids achieved 92% of the control total fecundity, though oviposition ended slightly earlier (Fig. 2).

Stable population growth parameters

All stable population growth parameters were significantly affected by the host-deprivation regime (Table 1). Gross and net reproductive rates (GRR and R_0) differed little among treatments because survivorship curves were convex. Both rates were significantly lower than control in all treatments except -7C. The intrinsic rate of increase (r) was highest in the control and decreased with longer deprivation intervals. Generation time (T) varied significantly among treatments, differing by up to five days between the shortest (control) and longest (C/7) regimes.

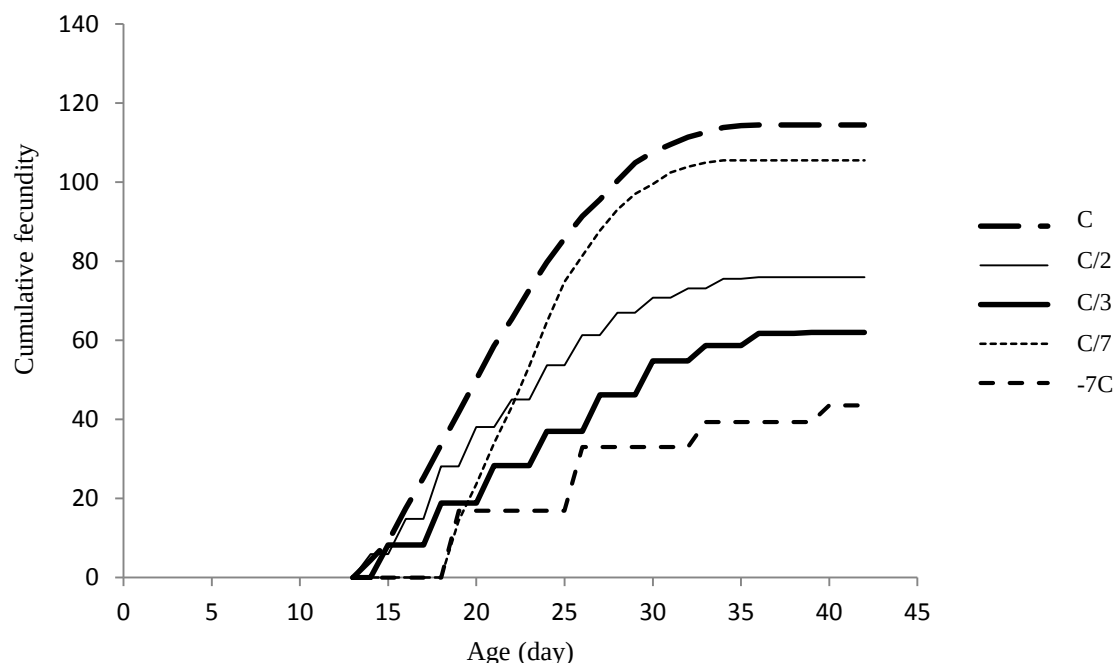


Figure 2 Cumulative number of eggs laid by *Ooencyrtus fecundus* at different host-deprivation regimes of *Eurygaster integriceps*. C = control, C/2 = every other day, C/3 = every third day, C/7 = once a week, -7C = full access following a week of deprivation.

Table 1 Stable population growth parameters (mean $\pm$ SE) of *Ooencyrtus fecundus* in different host-deprivation regimes of *Eurygaster integriceps* compared to control.

Parameter	Access to host ¹				
	C	C/2	C/3	C/7	-7C
GRR (daughter/ female.generation)	63.83 $\pm$ 3.85a	41.69 $\pm$ 4.23b	33.44 $\pm$ 2.72b	24.11 $\pm$ 2.21c	57.79 $\pm$ 6.47a
R ₀ (daughter/ female.generation)	63.83 $\pm$ 3.85a	41.66 $\pm$ 4.23b	33.41 $\pm$ 2.72b	23.66 $\pm$ 2.19c	54.88 $\pm$ 6.65a
T (d)	21.18 $\pm$ 0.30c	21.29 $\pm$ 0.47c	23.06 $\pm$ 0.55b	25.65 $\pm$ 0.38a	26.37 $\pm$ 0.29a
DT (d)	3.53 $\pm$ 0.05d	3.97 $\pm$ 0.13c	4.56 $\pm$ 0.17b	5.63 $\pm$ 0.19a	4.580 $\pm$ 0.13b
r (d ⁻¹)	0.196 $\pm$ 0.0030a	0.175 $\pm$ 0.0056b	0.152 $\pm$ 0.0056c	0.123 $\pm$ 0.0042d	0.152 $\pm$ 0.0042c
λ (d ⁻¹)	1.217 $\pm$ 0.0037a	1.191 $\pm$ 0.0066b	1.164 $\pm$ 0.0065c	1.131 $\pm$ 0.0047d	1.164 $\pm$ 0.0049c
b (d ⁻¹)	0.217 $\pm$ 0.0037a	0.191 $\pm$ 0.0066b	0.165 $\pm$ 0.0065c	0.132 $\pm$ 0.0046d	0.164 $\pm$ 0.0048c
d (d ⁻¹)	5.11 $\pm$ 1.20E ⁻⁵ b	9.59 $\pm$ 3.52E ⁻⁵ b	20.94 $\pm$ 4.7E ⁻⁵ a	43.53 $\pm$ 10.99E ⁻⁵ a	50.38 $\pm$ 30.04E ⁻⁵ a

¹ Different letters in a row indicate significant differences (Bootstrap pairwise comparison, $\alpha = 0.05$). Abbreviations: C = control, C/2 = every other day, C/3 = every third day, C/7 = once a week, -7C = full access following a week of deprivation.

Discussion

This study examined how *O. fecundus* responds to various host-deprivation scenarios. Three conditions were investigated: (i) continuous host access, (ii) prolonged deprivation followed by unlimited access, and (iii) intermittent deprivation at regular intervals. Because *E. integriceps* lays eggs in clusters, *O. fecundus* can parasitize multiple eggs within a patch, potentially compensating for earlier missed opportunities. The experiments were thus designed to allow females to compensate when hosts became fully available.

In natural settings, *E. integriceps* eggs are patchily distributed, and *O. fecundus* must locate these discrete patches. Each cluster typically contains 14 eggs, whereas the maximum daily fecundity of a female *O. fecundus* is around 20 eggs (Iranipour *et al.*, 2020). A female encountering a single cluster could therefore realize approximately 70% of her daily oviposition potential, and access to additional clusters would allow full compensation for previous deprivation. Field surveys have reported host-egg densities ranging from 10 eggs m⁻² (Iranipour *et al.*, 2011) to 182 eggs m⁻² (Iranipour and Kharrazi Pakdel, 2012), corresponding to fewer than one to roughly 13 clusters per square meter. Given that cumulative fecundity can reach 182

eggs over 20 days (Ahmadpour *et al.*, 2013), a single *O. fecundus* female encountering such a patch after a deprivation period could compensate for missed oviposition opportunities. Although extended deprivation was not tested here, the -7C treatment demonstrated that the parasitoid could recover up to 92% of control fecundity within two weeks of renewed access.

Similar patterns have been observed in other parasitoid–host systems. For example, *Gryon gonikopalense* Sharma successfully parasitized *Bagrada hilaris* (Burmeister) (Hemiptera: Pentatomidae) eggs after 60 days of host deprivation, though fecundity declined by 84% (Martel and Sforza, 2021). The response of *Mastrus ridibundus* (Gravenhorst) (Hymenoptera: Ichneumonidae), a parasitoid introduced for codling moth control, also resembles that of *O. fecundus*; host-deprived females immediately resumed oviposition but produced fewer eggs overall (Hougardy *et al.*, 2005).

In the current study, the C/2, C/3, and C/7 regimes simulated natural conditions where hosts are scarce and parasitoids must wander among patches of variable quality. Increasing deprivation length had increasingly negative impacts on reproductive and population-growth parameters, with the most severe effects in the C/7 treatment. These findings are consistent with previous results for *T. grandis*

(Tarla, 2011; Bazavar et al., 2015). *Ooencyrtus fecundus* compensated more effectively when deprivation occurred early in adulthood than when deprivation was intermittent. Although we did not examine females for egg load after deprivation to assess possible egg resorption, previous studies have shown that in host-deprived parasitoids, eggs can be reabsorbed (e.g., Rosenheim et al., 2000; Guo et al., 2011).

Comparable trends have been reported for other parasitoids. *Trichogramma brassicae* Bezdenko females exhibited marked declines in fecundity and female-biased sex ratio following prolonged host deprivation (Karimi-Malati et al., 2006). *Trissolcus grandis* showed similar reductions in reproductive output (Tarla, 2011; Bazavar et al., 2015), as did *Trichogramma cordubensis* Vargas and Cabello (Garcia et al., 2001). Fleury and Bouletreau (1993) found that *T. brassicae* could not increase its parasitism rate even when hosts later became abundant, indicating irreversible physiological constraints. In contrast, *O. fecundus* maintained oviposition activity until senescence when deprived early in life, suggesting a greater capacity for late-life compensation.

While both *O. fecundus* and *T. grandis* exhibited compensatory increases in daily fecundity after deprivation, *T. grandis* generally achieved higher proportional recovery, except when *O. fecundus* experienced early-season deprivation. In that case, *O. fecundus* achieved 92% of potential fecundity, compared with 78% for *T. grandis* (Bazavar et al., 2015), possibly due to the delayed reproductive senescence of *O. fecundus* females.

Host deprivation also affects progeny sex ratio in some species. For example, *Trichogramma minutum* Riley produced more female offspring after deprivation (Li et al., 1993), whereas *T. kaykai* Pinto and Stouthamer showed the opposite trend (Hohmann et al., 2001). Although this study did not collect sex-ratio data, the observed longevity patterns suggest that deprived females lived slightly longer, likely because reduced reproductive effort conserves metabolic resources.

Conclusion

From a biological control perspective, early-season delays in host availability do not pose a major challenge to managing the common sunn pest, as *O. fecundus* can compensate for missed oviposition opportunities once hosts become available. However, intermittent or discontinuous access to host eggs, which commonly occurs when host density is low, may harm parasitoid performance.

To enhance parasitoid persistence and efficiency, several ecological measures can be adopted. Maintaining non-target hosts on banker plants and avoiding excessive weed control in hedgerows can provide alternative resources during host-scarce periods. Certain cruciferous weeds frequently found around cereal fields may serve as refuges for alternative hosts of egg parasitoids. Similarly, lucerne fields can act as reservoirs for parasitoid populations. Locating cereal crops adjacent to lucerne fields may therefore increase parasitism rates in cereals (Iranipour, 1996). Further research is recommended to evaluate the potential of these habitat modifications as components of conservation biological control strategies to improve parasitoid performance against *E. integriceps*.

Acknowledgments

All authors would like to thank the University of Tabriz for funding this research. The authors also thank Dr. Parisa Bena Molaei, Dr. Zahra Nozad-Bonab, Sajjad Ahmadpour, and the deceased Miss Maryam Akramifar for their kind assistance.

Conflicting interests

The authors declare no competing interests.

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پاسخ *Ooencyrtus fecundus* (Hym., Encyrtidae) به محرومیت از تخم‌های سن گندم *Eurygaster integriceps* (Hem., Scutelleridae)

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دریافت: ۱۴ مهر ۱۴۰۳؛ پذیرش: ۲ تیر ۱۴۰۵

چکیده: سن معمولی گندم، *Eurygaster integriceps* Puton (Hemiptera: Scutelleridae)، یکی از آفات مهم گندم و جو در ایران است. زنبورهای پارازیتوئید تخم Scelionidae و Encyrtidae امیدبخش‌ترین دشمنان طبیعی این آفت به‌شمار می‌روند. با این‌حال، این پارازیتوئیدها اغلب در اوایل فصل با نبود میزبان مواجه می‌شوند. در این مطالعه، اثر دوره‌های مختلف محرومیت از میزبان بر *Ooencyrtus fecundus* Ferrière and Voegelé (Hymenoptera: Encyrtidae)، که یکی از پارازیتوئیدهای تخم گسترده *E. integriceps* است، بررسی شد. آزمایش‌ها در شرایط محیطی ثابت (دمای 25 ± 1 درجه سلسیوس، رطوبت نسبی 50 ± 10 درصد و دوره نوری ۱۶ ساعت روشنایی: ۸ ساعت تاریکی) و با پنج رژیم دسترسی به میزبان انجام شدند: دسترسی پیوسته (شاهد)، دسترسی یک روز در میان، هر سه روز یکبار، یکبار در هفته و دسترسی کامل پس از یک دوره هفت‌روزه محرومیت. میزان پارازیتسم با افزایش فاصله زمانی محرومیت کاهش یافت و شدیدترین اثرات منفی در تیمار دسترسی یکبار در هفته مشاهده شد. در تمام تیمارها، طی روزهای دسترسی به میزبان، جبران نسبی رخ داد. ماده‌ها هنگامی که پس از یک دوره محرومیت طولانی، دسترسی نامحدود به میزبان داشتند، بازبایی قابل‌توجهی نشان دادند. بنابراین، تأخیر در دسترسی به میزبان در اوایل فصل بعید است کنترل زیستی سن گندم را تهدید کند، زیرا *O. fecundus* می‌تواند فرصت‌های از دست رفته را در دسترسی‌های بعدی جبران کند. با این‌حال، دسترسی متناوب به میزبان ممکن است عملکرد پارازیتوئید را به‌طور منفی تحت تأثیر قرار دهد.

واژگان کلیدی: جبران، پارازیتسم، افزون‌سازی، محدودیت‌های محیطی، Hymenoptera، Encyrtidae