

Demographic Parameters of Two Populations of *Trissolcus grandis* (Thomson) (Hymenoptera: Scelionidae) at Five Constant Temperatures

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ABSTRACT

Trissolcus grandis (Thomson) (Hymenoptera: Scelionidae) is the most important egg parasitoid of the common sunn pest, *Eurygaster integriceps* Puton (Hemiptera: Scutelleridae) in Iran. Demographic characteristics may be used for preliminary screening of parasitoid species or populations as well as for predicting their efficiency under different physical conditions in the field. In this study, the demography of two northwestern populations of *T. grandis* was studied under five constant temperatures including 20, 23, 26, 29, and 32±1°C, at 50±5% RH and 16:8 h (L: D) photoperiod. The two populations responded differently to the temperatures, thus, many life history parameters were significantly affected not only by temperature itself but also in interaction with population. The highest value of intrinsic rate of increase for the Marand population was 0.344±0.057 females/female/day that occurred at 26°C. The same rate for the Tabriz population increased regularly with temperature increase and the maximum value (0.368±0.063) was obtained at 29°C. Further increase in temperature led to a negligible change in the value of this parameter. As a whole, the Marand population seemed to be adapted to cooler conditions compared to the Tabriz population

Keywords: Egg parasitoid, *Eurygaster integriceps*, Intrinsic rate of increase, Life history.

INTRODUCTION

The sunn pest, *Eurygaster integriceps* Puton (Hemiptera: Scutelleridae), is the most important injurious insect pests of wheat and barley in Iran (Radjabi, 2000). The eggs of the bug are attacked by several Scelionidae including *Trissolcus grandis* (Thomson) (Hymenoptera: Scelionidae), the most abundant and widely distributed parasitoid of the sunn pest in Iran (Radjabi and Amir Nazari, 1989; Amir Maafi, 2000).

Egg parasitoids (e.g. *Trissolcus grandis*) have the potential to be highly effective biological-control agents. Efforts to augment natural populations of *Trissolcus* spp. in Iran during the 1940's failed because of technical problems and chemical treatments have been relied on ever since. In recent times, the egg

parasitoids, *Trissolcus* spp. were released in many parts of Turkey for biological control of SP (Tarla and Kornoşor, 2009). Conservation and enhancement are most likely to be the focus of biological control efforts in the future (Radjabi, 2007). Successful reliance upon biocontrol agents needs basic information on their ecological requirements, such as the demography of the parasitoid under different environmental conditions. Temperature is the most critical climatic factor affecting insect demography via its effects on metabolism and developmental rate (Liu *et al.*, 1995), which, in turn, affects population growth rate via an effect on the age of the first reproduction. It has been pointed out that population growth rate is more sensitive to the age at the first reproduction than to other population parameters such as fecundity (Lewontin, 1965;

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Price, 1997; Ebert, 1999). Andrewartha and Birch (1954) suggested that the intrinsic rate of increase (r_m) might be the best indicator of the physiological state of a species. Subsequently, r_m has been used as a criterion for determining the fundamental niche of a species, as a bioclimatic index, and for evaluating the potential of a pest to damaging a crop or a natural enemy to control a pest (Messenger, 1964; Dent, 1997).

Many studies were conducted on the effect of temperature on development, mortality, and reproductive ability of scelionid parasitoids (Yeargan, 1983; Orr *et al.*, 1985; Cave and Gaylor, 1988; James and Warren, 1991; Awadalla, 1996; Torres *et al.*, 1997, 2002; Cividanes *et al.*, 1998; Arakawa and Namura, 2002; Ruberson *et al.*, 1995; Canto-Silva *et al.*, 2005; Kivan and Kiliç, 2006a, b; Sadoyama, 2007; Bueno *et al.*, 2008). In a laboratory study, Amir Maafi (2000) measured demographic parameters for a wild population of *T. grandis* and the first generation progeny at two densities of host eggs. In an ecotoxicological study, Saber (2002) estimated these parameters for the same parasitoid exposed to two traditional insecticides, fenitrothion and deltamethrin, within host eggs of *E. integriceps* and *Graphosoma lineatum* L. (Hemiptera: Pentatomidae). Asgari (2004) calculated life history statistics for a related species, *Trissolcus semistriatus* (Nees) (Hymenoptera: Scelionidae), on the same hosts. Kivan and Kiliç (2006a) investigated the effect of temperature on demographic statistics of *T. semistriatus* at four constant temperatures. In this study, we investigated the effect of different temperature levels on demographic parameters of two separate populations of *T. grandis* from East Azerbaijan province, Iran.

MATERIALS AND METHODS

Source of Insects

Two populations of *T. grandis* were used in this study: one from Qaramalek, west of Tabriz (longitude 46°, 13' E, latitude 38°, 6'

N), and the other one from New Bonab county, 11 km west of Marand (longitude 45° 55' E, latitude 38° 26' N). Adult *E. integriceps* were collected from the same locations, reared under laboratory conditions (25±2°C, 40±10% RH, 16L: 8D h photoperiod), and their eggs harvested daily. The parasitoids were obtained using egg traps. Thirty four host eggs were pasted to the internal surface of a piece of folded, rectangular green cardboard (13×4 cm) like a trap. These traps were placed in wheat fields and removed one week later. Each egg mass was held separately within a 10 cm³ vial. Adult wasps were identified by reference to Kozlov and Kononova (1983) after they emerged from egg mass. After mating, *T. grandis* females were used to parasitize another series of eggs to produce the F₂ generation that was used in experiments.

Determination of Thermal Range

In order to determine the range of the temperature in the experiments, an apparatus modeled after that of Weseloh (1971) was used to create a gradient of temperature from 15 to 50°C. The apparatus was a 7×26 cm rectangular arena made of galvanized iron divided into eight equal parts, each equipped with a thermometer, numbered from 1 to 8 from cold to hot. One end of the arena was held in contact with a tank of boiling water and the other end was held in contact with an ice tank. Thirty female wasps were then released into the arena in three series, ten from the hot end, ten from the cold end, and ten from the center of the arena. The number of wasps in each part of the arena, as well as the temperature of each part, was recorded three times: 5, 15, and 30 minutes after release, respectively. The experiment was performed three times using individuals of the Marand population and five constant temperatures with equal intervals were selected spanning the preferred temperature (26°C).

Parasitoid Development

Twenty newly parasitized host eggs of each population (< 24 hour-old) were placed in each of five growth chambers held at constant temperatures of 20, 23, 26, 29, and 32±1°C, respectively, at 50±5% RH and 16L: 8D h photoperiod with honey droplets provided as food. After emergence, fresh host eggs were offered to each mated and fed female; 2-3 egg masses on the first four days, and 1 egg mass on the remaining days of their life.

Experimental Design and Data Analysis

Gross reproductive rate (GRR), net reproductive rate (R_0), intrinsic rate of population increase (r_m), finite rate of population increase (λ), cohort generation time (T), and doubling time (DT) were estimated for each population (Carey, 1993). Life expectancies and mortality rates were calculated and survivorship curves were drawn.

A completely randomized design (CRD) ANOVA was conducted using the GLM procedure of SAS (SAS institute, 1999) with 'temperature' and 'population' as independent variables. Duncan's multiple range test (at 95 and 99% confidence levels) was used to separate means among temperature treatments. Also, a one-way ANOVA with Duncan's multiple range test at the same levels was used to separate means among each population. Parameter estimation was carried out according to Carey (1993). Variance of the parameters was estimated using Jackknife pseudovalues according to Meyer *et al.* (1986). Entropy was used as a criterion for determining direction of curvature of survivorship curves (Carey, 1993):

$$H = \frac{\sum_{x=0}^{\omega} e_x d_x}{e_0} \quad (1)$$

Where, H = Entropy value, x denotes age, ω the final age of cohort, e life expectancy and d age-specific mortality. An entropy

value of 0.5 implies a linear decrease of survival, whereas a lesser value implies a convex curve, and a greater value, a concave curve.

RESULTS

Preferred Temperature Range

The thermal gradient from the cold end to the hot end of the apparatus was exponential rather than linear. Moreover, observed points were more scattered in the hot end of the apparatus (Figure 1), possibly reflecting the higher variation of temperature at this end. The release point affected the spatial distribution of wasps in the apparatus (Figure 2), with wasps tending to remain near the release point. However, the density of the wasps remaining at either end of the arena was negligible in all cases. When the wasps were released from the cold end, no individual was observed in either section 7 or 8; only 6% were recorded in section 1, and density was highest in sections 3 and 4. When wasps were released at the hot end, section 8 remained empty, while more than half of the wasps crowded into sections 5 and 6. Finally, when released at the midpoint of the apparatus, more than 80% of the wasps distributed themselves approximately equally among the four median sections of the apparatus. The preferred thermal range was determined from the overall results: 85% of the wasp observations occurred in sections 2-6, where the temperature ranged from 20.32 to 32.08°C. On this basis, 20, 23, 26, 29, and 32°C were selected as the experimental temperatures.

Survivorship Curves, Mortality Rates, and Life Expectancies

Survivorship curves and age-specific reproductive rates are depicted in Figure 3. In all cases, the curves were convex with the majority of mortality occurring late in life

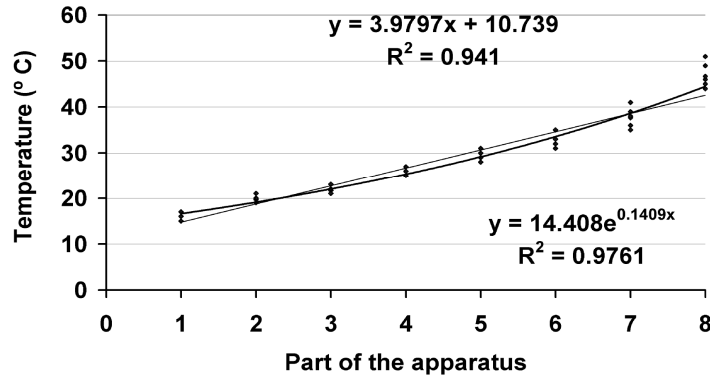


Figure 1. Temperature gradient in different parts of an apparatus modeled after that of Weseloh (1971). Points show the observed data while the lines show linear and exponential predictions of the same data

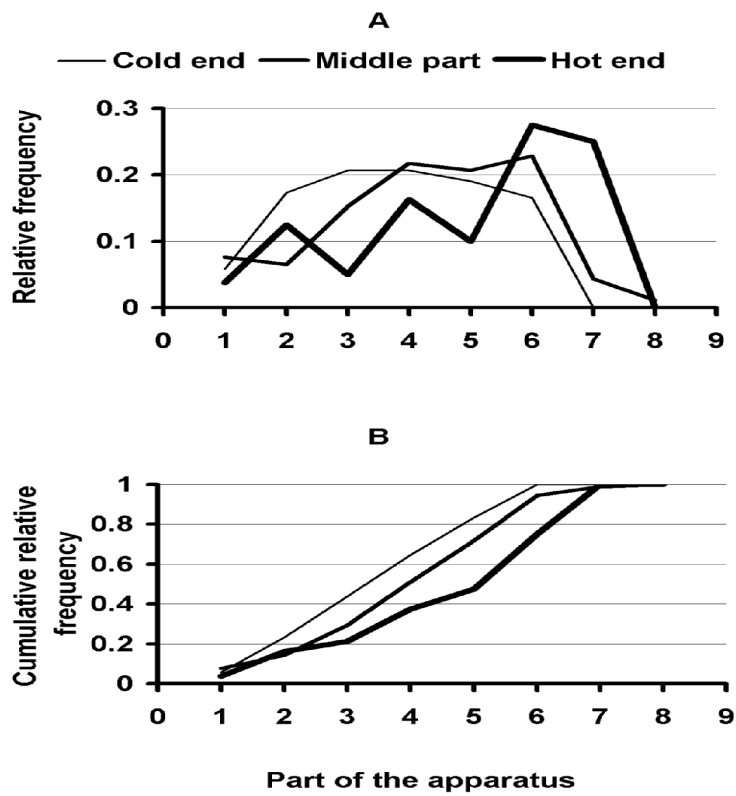


Figure 2. Distribution of *Trissolcus grandis* wasps in the eight parts of an apparatus explained in the text, released from three points of the apparatus. A: Relative frequency, B: Cumulative relative frequency.

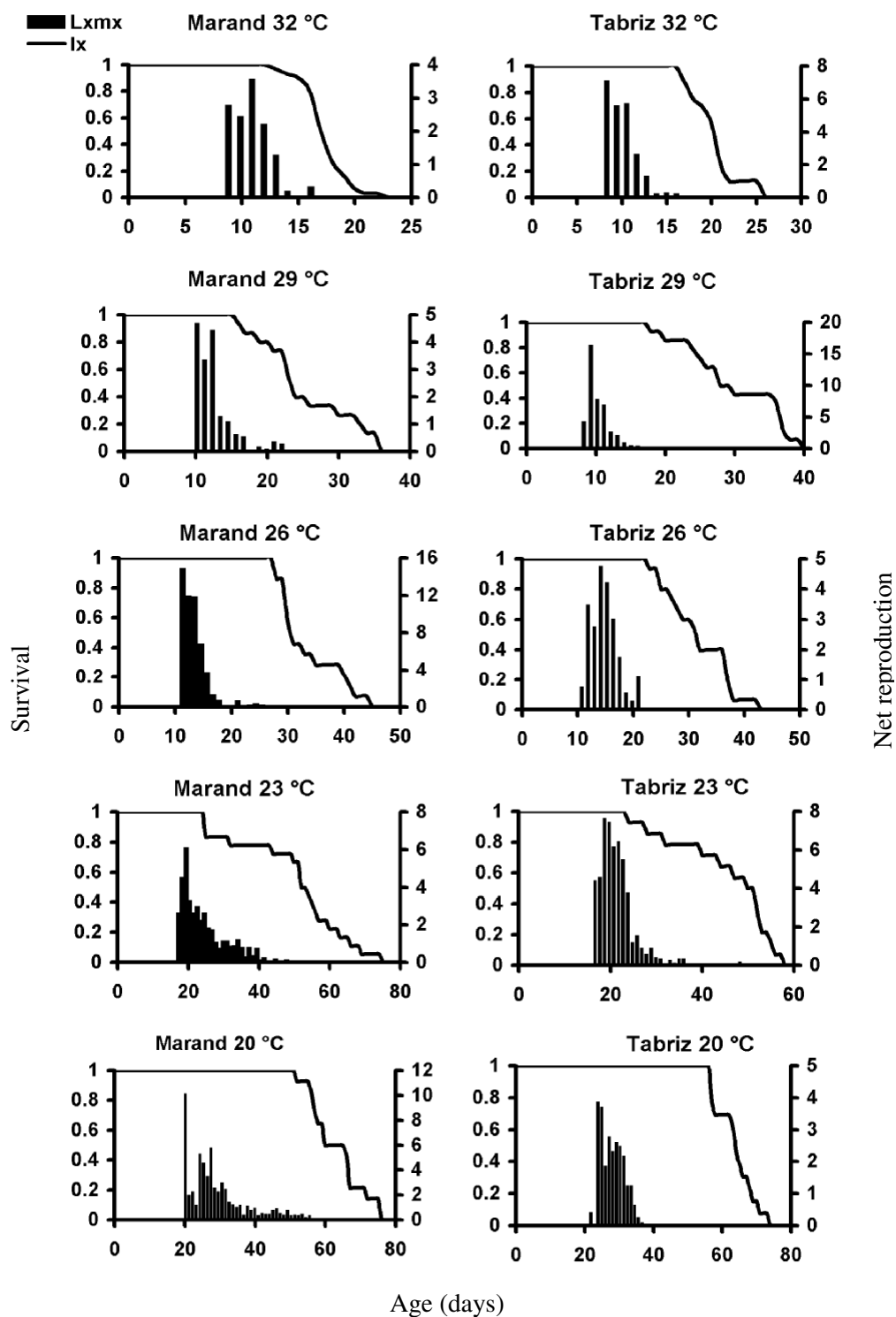


Figure 3. Survivorship curves and age-specific reproduction of the two populations of *Trissolcus grandis* at five constant temperatures.



(type I curves bearing entropy values below 0.5). Entropy values were 0.074, 0.165, 0.157, 0.227, and 0.120 at, respectively, 20 to 32°C for the Tabriz population, and 0.099, 0.225, 0.145, 0.250, and 0.114 at those temperatures for the Marand population. Maximum life expectancy (at birth, $x=0$) was 63.6, 45.5, 31.6, 29.8, and 20.1 days at the five temperatures, respectively, for the Tabriz population and 63.1, 50.2, 33.4, 25.2, and 17.2 days for the Marand population.

Effect of Temperature on Stable Population Growth Parameters

Effect of temperature and interactions between temperature and population were significant on GRR , but the effect of population was non-significant ($F=3.84$; $df=4, 153$; $P=0.0053$ for temperature, $F=0.31$; $df=1, 153$; $P=0.58$ for population, and $F=3.85$; $df=4, 153$; $P=0.0052$ for interaction). The pattern of changes was different in the two populations. Values of R_0 more closely followed the GRR (Table 1). The reason was the delayed mortality that mostly occurred at the end of the life time after reproduction. Therefore, the effect of different factors on R_0 was similar to previous parameter. Thus, the effect of population was non-significant, whereas the effect of temperature as well as interaction between the two factors were significant ($F=3.62$; $df=4, 153$; $P=0.0075$ for temperature, $F=0.25$; $df=1, 153$; $P=0.616$ for population, and $F=4.02$; $df=4, 153$; $P=0.0040$ for interaction).

Mean generation time significantly decreased by temperature ($F=411.79$; $df=4, 153$; $P<0.0001$; Table 1). Difference between the populations was non-significant ($F=0.83$; $df=1, 153$; $P=0.364$) and the change patterns were similar in both of them, but interaction between the two factors was significant at 0.05 level ($F=2.95$; $df=4, 153$; $P=0.022$). Doubling time was affected only by the temperature ($F=15.06$; $df=4, 153$; $P<0.0001$). This parameter ranged from 1.88 ± 0.09 to

5.37 ± 0.60 in different treatments. Both of these extremes were recorded for the Tabriz population (Table 1).

The intrinsic rate of natural increase was significantly affected by temperature ($F=12.01$; $df=4, 153$; $P<0.0001$) and the 'temperature×population' interaction was also significant ($F=3.47$; $df=4, 153$; $P=0.0095$). The Marand population had the maximum r_m (0.334 ± 0.015 d^{-1}) at 26°C, growth rate declining significantly under colder conditions and non-significantly under warmer ones (Table 1). In the Tabriz population, r_m increased from 0.128 ± 0.013 d^{-1} at 20°C to 0.368 ± 0.017 d^{-1} at 29°C and remaining unchanged from that value at 32°C. The parameter λ ranged from 1.136 ± 0.015 to 1.444 ± 0.024 in different treatments and followed a similar temperature trend as r_m (Table 1).

DISCUSSION

No distinctive trend was observed in net replacement rate of *T. grandis* with temperature. The highest value of R_0 occurred at different temperatures in the two populations. This was also true in the case of intrinsic rate of increase. This parameter denotes fitness of a population under a physical condition. Therefore, it may be claimed that the best temperature to rear this parasitoid was 26°C for the Marand population and between 29 and 32°C for the Tabriz population. Moreover, the preferable temperature of the Marand wasps was found to be 26°C with the highest crowding in this part of the arena. This may show that the parasitoid substantially tends to remain in locations that may lead to its higher performance. The Marand population was more efficient than the Tabriz population under the coldest condition. This may refer to the colder origin of this population. Intrinsic rate of increase estimated for the two cohorts of *T. grandis* at 25°C in the three sets of experiments (Amir Maafi, 2000) was well in the range of the Marand population at 26°C. Amir Maafi (2000)

Table 1. Summary statistics (mean^a±SE) of life history parameters^b of the two populations of *Trissolcus grandis* at five constant temperatures.

Temperature	GRR		R ₀		r _m		λ		T		DT		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Tabriz	20	25.41 B	8.34	25.41 B	8.34	0.128 C	0.013	1.136 C	0.015	25.81 A	0.17	5.37 A	0.60
	23	53.25 A	10.77	52.17 A	10.79	0.198 B	0.009	1.219BC	0.011	20.07 B	0.43	3.49 B	0.17
	26	22.47 B	9.99	22.47 B	9.99	0.256 B	0.040	1.290 B	0.051	12.57 C	0.57	2.63BC	0.48
	29	41.04AB	7.55	41.04AB	7.55	0.368 A	0.017	1.444 A	0.024	10.15 D	0.20	1.88 C	0.09
	32	22.79 B	4.83	22.79 B	4.83	0.363 A	0.026	1.438 A	0.037	8.66 E	0.30	1.90 C	0.14
Marand	20	58.67 A	12.97	58.58 A	12.93	0.166 B	0.012	1.180 B	0.014	24.63 A	0.99	4.16 A	0.31
	23	42.12AB	12.54	39.32AB	11.91	0.177 B	0.013	1.193 B	0.016	21.04 B	0.69	3.90 A	0.30
	26	50.85 A	9.87	50.85 A	9.87	0.334 A	0.015	1.396 A	0.021	11.82 C	0.16	2.07 B	0.10
	29	16.47BC	8.30	16.66 B	8.19	0.267AB	0.052	1.305AB	0.066	11.03CD	0.31	2.46 B	0.61
	32	12.77 C	4.12	12.68 B	4.10	0.256AB	0.036	1.291AB	0.045	10.12 D	0.27	2.65 B	0.41

^a Means followed by the same letter in the same column of each population are not significantly different according to Duncan's multiple range test ($P \leq 0.05$), ^b For parameter abbreviations see the text.



estimated r_m to be 0.321 females/female/day for a wild population from Karaj, and 0.339 and 0.366 d^{-1} for a laboratory cohort obtained from the same population reared on densities one and four host egg clutches/day. In contrast to r_m , his estimates of R_0 were considerably higher than both populations in all temperatures of the present study. Values of R_0 in the above mentioned experiments were 68.75, 157.75, and 136.35 females/female/generation, respectively. Such differences may be intrinsically present among populations with different origins, but what requires attention is similar r_m of the two studies despite such considerable differences in the net fecundity rates. The reason was the longer generation time in Amir Maafi's (2000) study. The value of this parameter was 13.20, 14.90, and 13.43 days in different treatments of his study. Obviously, the higher fecundity rate of those cohorts had been distributed in a wider horizon of time; as a result, the mean age of reproduction was driven to upper ages. Such a phenomenon suggests a trade off between higher net fecundities (at logarithmic scale) and longer generation times, so identical that r_m remained unchanged in spite of such a large replacement rate. This is because r_m is more sensitive to the age of reproduction than to the number of offspring. Although r_m suggests that the populations in the two studies are of the same value in the pest control, but we believe that Karaj population is more efficient, particularly in higher densities of host, because fecundity is not warranted to realize in the nature as soon as in the laboratory conditions. In this way, generation time will lengthen and lose its impact on population growth rate. Under such a condition, an equal increase in generation time of the two populations will lead to a higher decline in growth rate of that population with lower fecundity. Saber (2002) calculated the intrinsic rate of population increase of *T. grandis* at a single temperature of 26°C. His estimates were between those of the two populations of our study (0.298 females/female/day) at the same temperature. The same parameters

were estimated by Asgari (2004) and Kivan and Kiliç (2006a) for a related species *T. semistriatus*. Asgari (2004) estimated r_m , λ , T , DT , GRR and R_0 to be 0.249 d^{-1} , 1.283, 18.0 d, 2.78 d, 89.04, and 88.90 on *G. lineatum* and 0.266 d^{-1} , 1.305, 18.26 d, 2.6 d, 129.99, and 129.86 on *E. integriceps* at 25.5±0.5 C, respectively. In contrast to a higher record for T , GRR , and R_0 , the results dealing with r_m , λ , and DT are in agreement with the Tabriz population at 26°C. The differences may be due to intrinsic difference in species and their origins. Kivan and Kiliç (2006a) studied demography of *T. semistriatus* at four constant temperatures in the range of 17– 32°C. In their experiment, r_m increased linearly from 0.086 to 0.389 females/female/ day with temperature. These values are well in the range of *T. grandis* in the present study. The other parameters including λ , T , DT and R_0 were also in relative agreement with the results obtained here. Upper limit of T and DT in their study both exceeded our results (42.5 and 8.1 days, respectively), probably due to a colder condition included in their experiment. Lower limits, however, are both in the range of our data. Net replacement rate also ranged accordingly from 34.8 to 64.1 females/female/generation without any distinctive correlation with temperature, like our study.

Considerable differences among different experiments make a comprehensive conclusion difficult, but it seems that the origin of parasitoid may produce considerable inter-population variations. These variations apparently follow the host situation most probably via physiological state of the host. Reports show that sun-pest attacks are more serious in central parts of Iran plateau than borderlands or Iran neighbors e.g. Turkey (Radjabi, 2000; 2007). On the other hand, the parasitic wasps originating from central parts of Iran plateau (*T. grandis* in Amir Maafi (2000) and Saber's (2002) studies as well as *T. semistriatus* in Asgari's (2004) study) are more fecund than those wasps originating from borderlands of Iran (*T. grandis* of

Marand and Tabriz) and probably neighbor countries such as Turkey (*T. semistriatus* in Kivan and Kiliç (2006a) study). Low parasitism rates of *Trissolcus* spp. in Haghshenas (2004) and Nozad and Iranipour (2009) studies may also provide supporting evidences. While there is no information on comparative body sizes of different populations of *Trissolcus* spp. and their relationship with reproduction, it may be a possible explanation for differences observed.

It may be stated that augmentation efforts of this parasitoid (and most probably other natural enemies) may lead to a better result in different conditions for different populations. Moreover, populations with colder origins may indicate better performance in colder conditions and vice versa. Therefore, they should be released when and where the weather condition is favorable. As a whole, paying attention to rearing condition as well as the site-specific performance of natural enemies are very important tasks of insectaries in the future.

ACKNOWLEDGEMENTS

This study was financially supported by the University of Tabriz.

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دموگرافی دو جمعیت زنبور *Trissolcus grandis* (Hymenoptera: Scelionidae) در پنج دمای ثابت آزمایشگاهی

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چکیده

زنبور *Trissolcus grandis* (Thomson) مهم‌ترین پارازیتوئید تخم سن معمولی گندم *Eurygaster integriceps* Puton در ایران می‌باشد. ویژگی‌های دموگرافیک می‌توانند برای غربال مقدماتی گونه‌ها یا جمعیت‌های پارازیتوئید و پیش‌بینی کارایی آن‌ها در شرایط فیزیکی مختلف در مزرعه به کار روند. در این بررسی، دموگرافی دو جمعیت شمال‌غرب در پنج دمای ثابت ۲۰، ۲۳، ۲۶، ۲۹ و ۳۲±۱ درجه‌ی سلسیوس، رطوبت نسبی ۵۰±۵ درصد و دوره‌ی نوری ۱۶ ساعت روشنایی در شبانه‌روز بررسی شد. دو جمعیت واکنش متفاوتی به دما نشان دادند، بدین ترتیب، بیشتر پارامترهای تاریخچه‌ی زیستی نه تنها از خود دما، بلکه از برهمکنش آن با جمعیت نیز به‌طور معنی‌داری متأثر گردید. بالاترین مقدار نرخ ذاتی افزایش برای جمعیت مرند ۰/۵۷۰±۰/۳۴۴ ماده بر ماده بر روز بود که در ۲۶ درجه حادث شد. مقدار این پارامتر در بالاتر و پایین‌تر از این دما هرچند به‌طور نامساوی کاهش یافت. همین کمیت برای جمعیت تبریز به‌طور منظم از ۲۰ تا ۲۹ درجه افزایش یافت تا به بیشینه‌ی ۰/۰۶۳±۰/۳۶۸ رسید. افزایش بیشتر دما تغییر مختصری در مقدار این پارامتر ایجاد کرد. درکل به‌نظر می‌رسد جمعیت مرند نسبت به جمعیت تبریز به شرایط خنک‌تر سازگاری بیشتری دارد.