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EFFECT OF TEMPERATURE ON THE REPRODUCTIVE PARAMETERS AND SURVIVAL OF *CENOPALPUS IRANI* DOSSE (TENUIPALPIDAE)

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ABSTRACT: *Cenopalpus irani* (Tenuipalpidae) is one of the main pests of apple trees in the Western regions of Iran. We studied the effect of six constant temperatures of 15, 20, 25, 30, 32 and 33.5°C on the reproductive parameters, life expectancy and the mortality rate of *C. irani* immature stages at 50 ± 5% relative humidity (RH) and a photoperiod of 16:8 (light : dark) h fed on apple leaves. The highest and lowest gross fecundity rate were observed at 30 ºC (34.60 eggs/female) and 15ºC (18.50 eggs/female), respectively. The maximum gross fertility rate was 32.87 (eggs/female) at 30ºC, whereas the minimum value was 9.94 eggs/female which obtained at 15ºC. As increasing temperature from 15°C to 30°C, the gross hatching rate increased and then decreased at 33.5°C. The highest and lowest life expectancy (e_x) were obtained at 83 and 27th days, at 15°C and 33.5°C, respectively. Also, the highest and lowest values of mortality percentage for immature stages of *C. irani* were recorded at 15ºC and 30ºC, respectively. As increasing temperature the reproductive value (V_x) increased from 15°C (5.95 females/female) to 30°C (9.27 females/female), then decreased at 33.5°C (5.61 females/female). The finding of this research can be used for establishing integrated pest management (IPM) strategies against *C. irani* in apple orchards.

KEY WORDS: Iranian false spider mite, reproductive parameters, life expectancy, reproductive value, Iran

INTRODUCTION

The false spider mite, *Cenopalpus irani* Dosse (Acari: Tenuipalpidae) is one of the main pests of apple trees in Western regions of Iran (Darbemamieh et al. 2009; Jafari et al. 2014). This phytophagous mite was reported from Fars, Hamedan, Kerman, Kermanshah, Kurdistan, Khuzestan, Lorestan and Tehran provinces of Iran (Dosse 1971; Kamali 1989; Darbemamieh et al. 2009; Khanjani et al. 2012; Khanjani et al. 2013; Jafari et al. 2014). This mite in addition to apple was also reported on pear, olive and pistachio (Mehrnejad and Ueckermann 2001; Khanjani et al. 2012). According to Rashki et al. (2004) the main host of this mite is apple and seen on pear rarely in Karaj province, Iran. According to Jafari et al. (2014) the population of this mite rapidly increases to a high density during the summer in Lorestan Province of Iran.

The reproduction parameters of insects are governed by interactions between intrinsic life history traits and extrinsic factors such as temperature, food, moisture, light intensity, chemicals, and pathogens (Danks 1994). Of the many abiotic factors that may influence the reproduction of insects and mites, temperature is usually the most important (Andrewartha 1952; Tauber et al. 1986). The development, survival, reproduction and life table parameters of phytophagous mites are influenced by temperature (Kennedy et al. 1996; Gotoh and Nagata 2001; Kasap 2004; Ullah et al. 2012). The high and low temperatures have negative effects on the reproduction parameters of mites (Honarparvar et al. 2014). Reproductive parameters have applications as analyzing population stability and structure, estimating extinction probabilities, predicting life history evolution, predicting outbreak in pest species, and examining the dynamics of colonizing or invading species (Vargas et al. 1997). The measurement of mortality, survival, fecundity, reproduction parameters and life expectancy of a pest is necessary to design and management of a successful control program against it. For this purpose, the analysis of the life history is an essential tool. The distribution of *C. irani* restricted to Iran and previous to our study only Rashki et al. (2004) studied the some biological characters of this mite at 32ºC, 52% RH and a photoperiod of 16L: 8D h, and also Bazgir et al. (2015) studied the effect of four ambient temperatures on life-table parameters of *C. irani* on apple leaves. But the effect of different temperatures on reproductive parameters, reproductive value and mortality percentage of this mite was unknown. Therefore, the aim of this study was to investigate the effect of six constant temperatures on reproductive parameters, life expectancy, reproductive value and mortality of the Iranian false spider mite under laboratory conditions. The finding of this research can be useful in pest control programs against *C. irani*.

MATERIALS AND METHODS

Preparing the colony of *Cenopalpus irani*

Apple leaves infested by *C. irani* were collected from apple orchards in Chaghalvandi region in the vicinity of Khorramabad, Lorestan

Province, Western Iran, during summer 2013 and transferred to the laboratory. For provide the colonies of *C. irani*, apple leaves were maintained at 27±1°C, 50±5% RH and a photoperiod of 16:8 (L: D) h. The reared mites of *C. irani* on apple leaves under laboratory conditions after two generation were used for experiments.

Experimental units

Experiments were carried out using arenas consisted of a piece of apple leaf (4 cm in diameter), that placed upside down on water saturated foam mat covered with wet filter paper, inside plastic Petri dishes (6 cm in diameter) with a hole in its center (0.5 cm in diameter). To keep the leaves fresh and prevent the escape of mites, these arenas were placed in the larger Petri dishes (9 cm) filled with water. The lid of each Petri dish was covered by fine mesh for ventilation. The mites were transferred to new arenas every three or four days.

Effect of temperature on mortality of *C.irani*

The mortality percentage of immature stages of *C. irani* was measured at six constant temperatures of 15, 20, 25, 30, 32 and 33.5°C with 50± 5% RH and a photoperiod of 16:8 (L: D) h on detached apple leaves. For this purpose, a cohort consisted of 80 same-aged eggs were used. The new mated females were transferred to 80 experimental units and after 12 hours the females and surplus eggs were removed and only one egg remained in each unit. To determine the mortality of the immature stages inspections were carried out each 12 h under a stereomicroscope until the mites reached adulthood. Mortality is a proportion of original number of individuals dying during each stage or class. For calculate the mortality percentage, the total number of death of during each stage should be divided by the total alive population of the previous stage, then times that by 100.

Reproductive parameters

In each temperature tested newly emerged females that developed in the previous experiments were coupled with males obtained in the same experiment or taken from the colony at the same temperature. The dead or lost males were replaced by new ones that picked up from the stock colony. The experimental units were daily monitored and any changes recorded until the death of the last female. This monitoring allowed us to determine the reproductive parameters and reproductive value. The following reproduction parameters calculated for *C. irani* according to following equations (Carey 1993, 2001):

$$\text{Gross fecundity rate} = \sum_{x=0}^{\beta} M_x$$

$$\text{Gross fertility rate} = \sum_{x=\alpha}^{\beta} h_x M_x$$

$$\text{Gross hatch rate} = \frac{\sum_{x=\alpha}^{\beta} h_x M_x}{\sum_{x=\alpha}^{\beta} M_x}$$

$$\text{Net fecundity rate} = \sum_{x=\alpha}^{\beta} L_x M_x$$

$$\text{Net fertility rate} = \sum_{x=\alpha}^{\beta} L_x h_x M_x$$

$$\text{Daily eggs per female} = \frac{\sum_{x=\alpha}^{\beta} M_x}{(\varepsilon-\omega)}$$

$$\text{Daily fertile eggs per female} = \frac{\sum_{x=\alpha}^{\beta} M_x h_x}{(\varepsilon-\omega)}$$

where, L_x is the days lived in interval x and x+1, M_x is the average number of eggs produced by a female at age x and h_x is the hatching rate; α is the age of female at the first oviposition and β is the age of female at the last oviposition and ε-ω is the female longevity.

Reproductive value (V_x)

Reproductive value is defined as the contribution an individual age x will make to the future generation number relative to the contribution in population number one newborn individual will make over the remaining life of the female. It is basically a sum of ratios. The sum is a relative index of the importance of a female's contribution to future generations. Reproductive value (V_x) is given by the equation (Caswell 1989):

$$Vx = \frac{\sum_{y=x}(e^{r_m \cdot y} \cdot l_y m_y)}{l_x \cdot e^{r_m \cdot x}}$$

where r_m is the intrinsic rate of increase, and l_y denote survival to age y and m_y reproduction at age y.

Life expectancy (e_x) and life table entropy (*H*)

The life expectancy (e_x) is the expectation of life at age x, that an individual in age x is expected to live in different temperatures. Life expectancy for all stages of mite was calculated by the following equation (Carey 1993):

$$e_x = \frac{T_x}{l_x}$$

The distribution of deaths in a cohort varies greatly between the two patterns. A measure of this heterogeneity is referred to as life table entropy (*H*). If $H = 0$, then all deaths occur at exactly

Table 1.
Reproduction parameters (Mean ± SE) of *Cenopalpus irani* females fed on apple leaves at six constant temperatures, 50 ± 5% RH and 16L : 8D.

Parameters	Temperature (°C)					
	15	20	25	30	32	33.5
Gross fecundity rate	18.50 ± 0.79d	25.78 ± 0.99c	31.00 ± 1.01b	34.60 ± 1.21a	29.50 ± 1b	20.38 ± 0.65d
Gross fertility rate	9.94 ± 0.43d	18.69 ± 0.72c	26.74 ± 0.87b	32.87 ± 1.15a	26.18 ± 0.89b	12.74 ± 0.40d
Net fecundity rate	5.00 ± 0.21d	10.77 ± 0.42c	17.98 ± 0.59b	27.55 ± 0.96a	18.14 ± 0.62b	9.51 ± 0.30c
Net fertility rate	2.69 ± 0.12d	7.81 ± 0.30c	15.51 ± 0.51b	26.17 ± 0.91a	16.10 ± 0.55b	5.95 ± 0.19c
Gross hatch rate	0.54	0.73	0.86	0.95	0.89	0.62
Daily eggs per female	0.17 ± 0.005e	0.41 ± 0.01d	0.69 ± 0.02c	0.99 ± 0.02a	0.90 ± 0.02b	0.68 ± 0.02c
Daily fertile eggs per female	0.09 ± 0.003f	0.29 ± 0.01e	0.60 ± 0.01c	0.94 ± 0.02a	0.80 ± 0.02b	0.43 ± 0.01d

Note: Means followed by different letters within the same row are significantly different (P < 0.05, Duncan's test).

the same age, and if $H = 1$, then the survival schedule is exponentially declining. The intermediate value, $H = 0.5$, indicates a linear survival schedule (Carey 1993). The value of entropy parameter was computed according the following equation:

$$H = \frac{\sum_{x=0}^{\omega} e_x \, d_x}{e_0}$$

where e_x is the life expectancy and d_x is the frequency of deaths.

Data analysis

The Jackknife technique was used to calculate the variance of the reproductive parameters (Meyer et al. 1986; Maia et al. 2000). The influence of temperatures on reproductive parameters of *C. irani* was analyzed using one-way analysis of variance (ANOVA). When a significant difference was detected, the means of reproductive parameters were compared using Duncan's multiple-range test ($P < 0.05$). The ANOVA and mean comparison were carried out using the SAS software (Proc GLM, SAS Institute 2003).

RESULTS

Reproductive parameters

The reproductive parameters of *Cenopalpus irani* females fed on apple leaves at six constant temperatures are shown in Table 1. As shown temperature had a significant influence on gross fecundity rate ($F = 25.49$; $df = 5, 147$; $P < 0.0001$), gross fertility rate ($F = 65.09$; $df = 5, 147$; $P < 0.0001$), net fecundity rate ($F = 98.17$; $df = 5, 147$; $P < 0.0001$), net fertility rate ($F = 136.73$; $df = 5, 147$; $P < 0.0001$), daily eggs per female ($F = 131.71$; $df = 5, 147$; $P < 0.0001$) and daily fertile eggs per female ($F = 199.38$; $df = 5, 147$; $P < 0.0001$) of *C. irani*. The highest gross fecundity rate was 34.60 (eggs/female) at 30°C and lowest was 18.50 (eggs/female) at 15°C. The gross hatching rate increased as increasing temperature from 15°C (0.54) to 30°C (0.95), then decreased at 32°C (0.89) and 33.5°C (0.62) (Table 1).

As temperature increased from 15°C to 30°C, the daily eggs per female increased from 0.17 to 0.99 (eggs/female/day), then decreased at 33.5°C and reached 0.68 (eggs/female/day). In addition, the maximum daily fertile eggs per female was 0.94 (egg/female/day) at 30°C and minimum value was 0.09 (egg/female/day) that observed at 15°C.

Reproductive value (V_x)

The reproductive values (V_x) of *C. irani* females were greatly influenced by temperature (Fig. 1). As increasing temperature from 15°C to 30°C, the reproductive value (V_x) increased, and then slightly decreased at 30°C to 33.5°C. The reproductive value (V_x) reached a peak on the 93th day at 15°C (5.95 females/female), on the 53th day at 20°C (7.55 females/female), on the 42th day at 25°C (8.61 females/female), on the 28th day at 30°C (9.27 females/female) on the 23th day at 32°C (8.01 females/female) and on the 22th day at 33.5°C (5.61 females/female).

Mortality percentage

Table 2 shows the mortality percentage of *C. irani* immature stages at six constant temperatures. The results show that the mortality percentage in immature stages was the highest at egg stage. The highest and lowest values of egg mortality percentage were observed at 15°C (46.25%) and 30°C (5%), respectively. The maximum mortality percentage for egg, larva, protonymph and

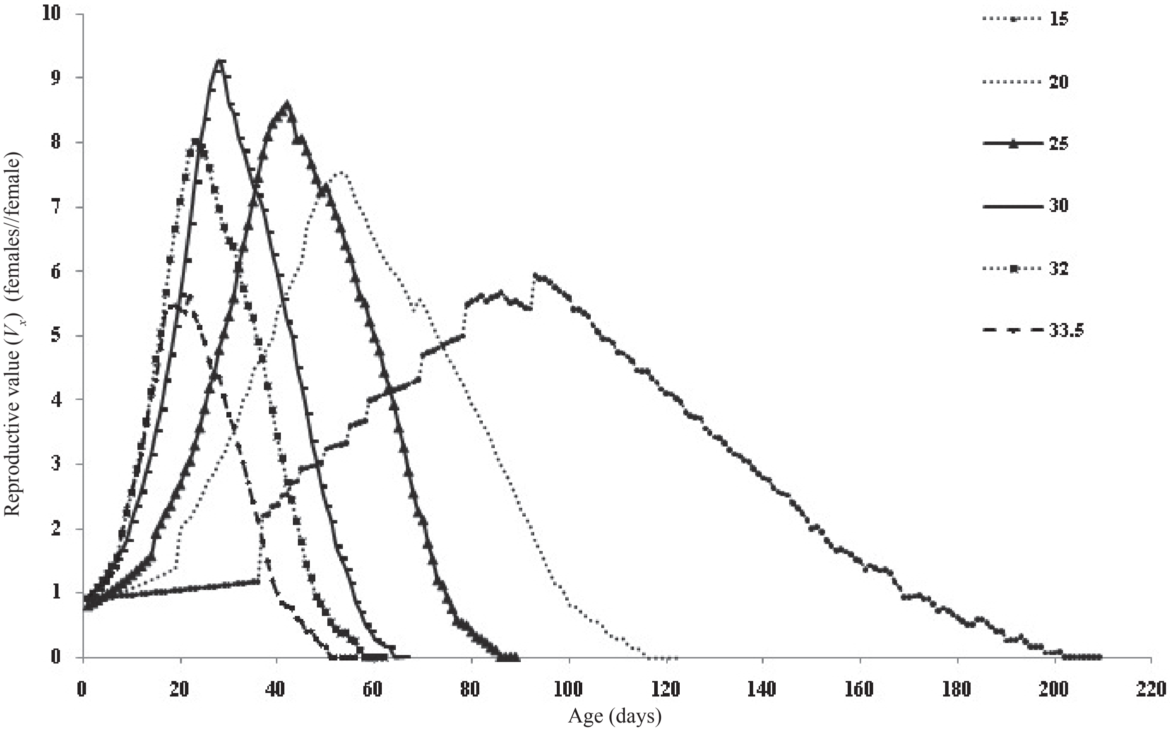

Fig. 1. Reproductive value (V_x) of *Cenopalpus irani* females fed on apple leaves at six constant temperatures, 50 ± 5% RH and 16L : 8D.

Table 2.
Mortality percentage (%) of immature stages of *Cenopalpus irani* females fed on apple leaves at six constant temperatures, 50 ± 5% RH and 16L : 8D.

Stage	Temperature °C					
	15	20	25	30	32	33.5
Egg	46.25	27.50	13.75	5.00	11.25	21.25
Larva	18.60	17.24	7.25	3.95	14.08	15.87
Protochrysalis	5.71	6.25	3.13	1.37	3.28	3.85
Protonymph	15.15	13.33	11.29	4.17	8.47	10.00
Deutochrysalis	3.57	2.56	1.82	0	3.70	4.44
Deutonymph	7.41	5.26	1.85	0	0	2.33
Teleiochrysalis	4.00	2.78	0	1.45	0	4.76
Immature stages	70.00	56.25	33.75	15.00	35.00	48.75

deutonymph was attained at 15°C. As increasing temperature from 15°C to 30°C, the mortality percentage for immature stages decreased from 70% to 15%, then increased at 33.5°C and reached 48.75%.

Life expectancy

The life expectancy curves (e_x) of *C. irani* reared on apple leaves at six tested temperatures are shown in Fig. 2. The life expectancy (e_x) of *C. irani* decreased as temperature increased from 15°C to 33.5°C. The life expectancy (e_x) of *C. irani* from the first day of life at 15, 20, 25, 30, 32 and 33.5°C was about 83, 60, 56, 49, 36 and 27 days, respectively.

Life table entropy

The life table entropy of *C. irani* at 15, 20, 25, 30, 32 and 33.5˚C, were 0.608, 0.536, 0.362, 0.207, 0.405 and 0.547, respectively. The estimated *H* parameter showed that the survival schedules of *C. irani* at 15, 20 and 33.5°C are type III survivorship curves ($H > 0.5$), but at 25, 30 and 32°C is type I ($H < 0.5$).

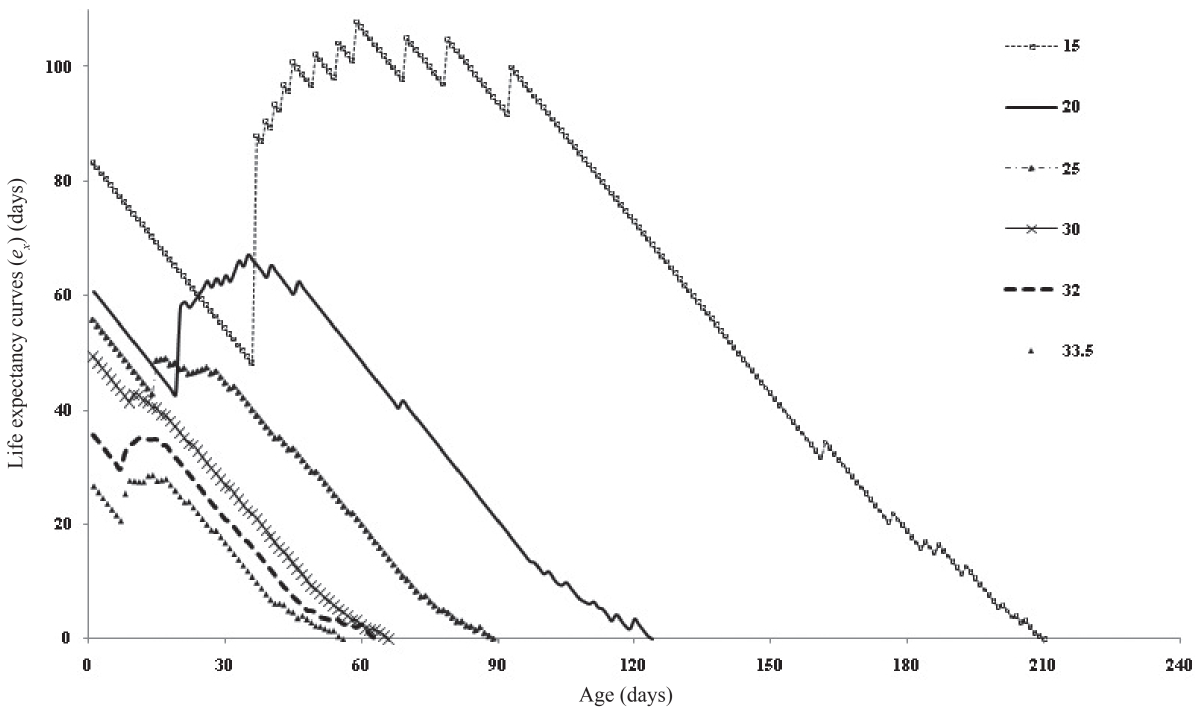

Fig. 2. Life expectancy curves (e_x) of *Cenopalpus irani* females reared on apple leaves at six constant temperatures, 50 ± 5% RH and 16L : 8D.

DISCUSSION

This study is the first to evaluate the effect of different temperatures on reproductive parameters of *C. irani.* The reproduction parameters of a pest are one of the essential components in developing an integrated pest management strategy (Naseri et al. 2011). Reproductive table information can provide a comprehensive description of the survival, fecundity and fertility of the pest populations. Temperature exerted strong effects on reproductive parameters of arthropods (Vargas et al. 2000). This study clearly shows that temperature had a great influence on the reproductive parameters of Iranian false spider mite. As shown in our findings the reproductive parameters of *C. irani* increased with increasing temperatures from 15 to 30°C, then decreased at 32 and 33.5ºC. Our results revealed that the optimum temperature for net and gross fecundity and fertility rates of *C. irani* is around 30˚C and with away from at 30˚C, temperature had negative effects on the reproduction parameters of *C. irani* (Table 1). Similar results were reported for *Bryobia rubrioculus Scheuten* reared on sweet-cherry (Honarparvar et al. 2014) and *Tetranychus urticae* Koch reared on bean different cultivars at 25°C (Ahmadi et al. 2004).

The mortality percentage of *C. irani* immature stages decreased as temperatures increased from 15°C to 30°C and then increased at 33.5°C. A similar course for *Tetranychus evansi* Baker and Pritchard was reported by Bonato (1999). According to Sohrabi and Shishehbor (2008), mortality percentage of *Tetranychus turkestani* Ugarov and Nikolski immature stages at 25ºC on cowpea, green gram and pinto bean was 21.6%, 28.5% and 42.1%, respectively, while at 30ºC was 18.6%, 11.6% and 38.3%, that showed with increasing temperature from 25 to 30°C the mortality percentage of immature stages decreased. The mortality percentage of immature stages of *Brevipalpus phoenicis* (Geijskes) (Tenuipalpidae) was 10.40% at 26°C (Kennedy et al. 1996) that obviously is lower than those obtained in our study at 25°C (33.75%).

Our research clarified that the life expectancy of *C. irani* decreased with increasing temperature from 15 to 33.5°C. Similar results was reported for *B. rubrioculus*, that its life expectancy (e_x) decreased as the temperature increased from 15°C to 32.5°C (Honarparvar et al. 2014). The life expectancy of one-day-old adults of the *T. urticae* on seven eggplant cultivars (Isfahan, Dezful, Shend-Abad, Neishabour, Bandar-Abbas, Jahrom and Borazjan) at 25°C was estimated to be 7.550, 8.380, 5.820, 4.850, 5.440, 5.330 and 3.950 days, respectively (Khanaman et al. 2012). Also the life expectancy of one-day-old adults of *T. urticae* at 25°C on four cucumber genotypes was estimated to be 26.62, 24.21, 25.28 and 19.94 days (Ghazazani et al. 2013), which are lower than our finding at 25°C (39.11 days). The estimated life expectancy for *Brevipalpus phoenicis* on tea leaves was 34.95 days (with a RH of 65–75% , light phase of 16 h, 26±2°C) (Kennedy et al. 1996), which is lower to our finding at 25°C (56 days).

The entropy value as a quantitative characterization of survival patterns presents the influence of changes in mortality rates on life expectancy (Zahiri et al. 2010). Life table entropy (*H*) for *C. irani* females decreased with increasing temperatures from 15°C to 30°C and then increased at 33.5°C. The reported values of life table entropy (*H*) for *B. phoenicis* (0.234 at 26°C) and *T. urticae* (0.491 at 25°C on eggplant) (Khanaman et al. 2012) are near to our results at 25°C. According to Daneshnia et al. (2013), the reproductive value of *Eotetranychus hirsti* Pritchard and Baker females at 30°C was 17th day that gave a peak of 23 females per female that is higher than our finding in 28th day (9.27 females per female) at the same temperature.

The data presented here provide fundamental information on the effect of temperature on reproductive parameters of *C. irani*. Our findings revealed that 30ºC is the most suitable temperature for population growth of *C. irani* on the apple leaves. This study will be important in the management of *C. irani* as a potential pest in apple orchards of Iran, by providing a better understanding of its reproductive parameters and life expectancy under different temperature regimes.

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