



Geographic variation in date palm pollen quality and its impacts on biological performance of *Amblyseius swirskii* (Acari: Phytoseiidae)

Mohammad-Amin Zarei¹ | Mostafa Khanamani^{1*} | Mahdi Ziaaddini² | Moslem Basij¹

1. Department of Plant Protection, Faculty of Agriculture, University of Jiroft, Kerman, Iran; E-mails: mohammadamin@gmail.com, m.khanamani@ujiroft.ac.ir, moslembasij2014@gmail.com

2. Department of Plant Protection, Faculty of Agriculture, Vali-e-Asr University of Rafsanjan, Kerman, Iran.; E-mail: ziaaddini@vru.ac.ir

* Correspondence

✉ m.khanamani@ujiroft.ac.ir

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ABSTRACT

Date palm pollen has received considerable attention among various pollen types due to its high nutritional value, availability, and positive effects on predator performance. However, the nutritional quality of date palm pollen can vary significantly depending on its geographical origin. Therefore, this study was conducted to evaluate the effect of geographical variation in date palm pollen quality on the biological performance of *Amblyseius swirskii* Athias-Henriot. Pollen samples were collected from the same date palm cultivar (Mazafati) at four locations in southern Iran: Bam and Jiroft (Kerman Province) and Rodan and Hajiabad (Hormozgan Province). The shortest pre-adult development was observed on Rodan pollen (6.38 days), and the longest times were observed on pollen from Jiroft (7.71 days) and Bam (7.69 days). Fecundity was significantly higher in individuals fed Rodan pollen (40.62 eggs/female) than those fed other pollens. The highest pre-adult mortality occurred in individuals reared on Bam pollen, followed by Jiroft pollen. The highest intrinsic (r) and finite (λ) rates of increase were obtained on Rodan pollen (0.181 and 1.199 day⁻¹, respectively), while the lowest values were recorded on Bam pollen (0.117 and 1.124 day⁻¹, respectively). Similarly, Rodan pollen exhibited the highest net (R_0) and gross (GRR) reproductive rates, while the lowest values were observed on Bam and Jiroft pollens. Rodan pollen had the shortest mean generation time (T) (16.45 days). Rodan pollen also had the highest protein content (43.18%), showing a significant difference compared to the other pollens. Our findings demonstrate that geographical origins of the date palm can directly affect its pollen quality and indirectly impact the biological performance of the predatory mite.

KEYWORDS

Biological control, life table, mass rearing, phytoseiid mites, pollen

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INTRODUCTION

Predatory mites are among the most effective biological control agents of sucking pests, especially phytophagous mites. They play a crucial role in integrated pest management (IPM) programs in agricultural and greenhouse systems (van Lenteren and Woets 1988; Khanamani and Dalir 2025). Successful application of these beneficial organisms, especially on a commercial scale, depends on sustainable, cost-effective, and reliable mass-rearing systems. The quality of food resources is one of the most critical limiting factors in the rearing process (McMurtry *et al.* 2013; Khanamani *et al.* 2017a, b; Hashemi *et al.* 2021; Khanamani 2025).

Phytoseiid mites have been widely used for both preventive and curative biological control



programs because of their fast development, high reproductive potential, broad prey range, ability to adapt to different environmental conditions, high consumption rate of prey individuals and effectiveness in reducing pest populations (McMurtry *et al.* 2013). *Amblyseius swirskii* Athias-Henriot is one of the most successfully commercialized species and plays a significant role in controlling key pests, such as thrips, whiteflies, and phytophagous mites (Calvo *et al.* 2015; Dalir *et al.* 2024, 2025). Due to the growing demand for predatory mites in sustainable agricultural systems, developing efficient, cost-effective mass-rearing methods for these natural enemies is crucial (van Houten *et al.* 2005; Kadkhodazadeh *et al.* 2021; Alpysbayeva *et al.* 2025).

Maintaining three trophic levels (plant-herbivore-predator) in natural rearing systems often leads to multiple constraints, including high production costs and labor requirements. Using alternative food sources, such as pollen can significantly reduce rearing expenses. In recent years, using plant pollens as an alternative or supplemental food source for rearing predatory mites has gained significant attention (Goleva and Zebitz 2013; Khanamani *et al.* 2017a; Riahi *et al.* 2017a, b; Nemati and Riahi 2020). Pollens are a rich source of nutrients, including proteins, essential amino acids, lipids, sterols, vitamins, and mineral elements (van Rijn and Tanigoshi 1999). This makes them an effective dietary supplement for predatory mites when prey is scarce or absent (Khanamani and Dalir 2025). Numerous studies have demonstrated that pollen's nutritional quality varies significantly among plant species and such variations can directly influence the developmental rate, survival, fecundity, and life table parameters of predatory mites (Samaras *et al.* 2021; Xia *et al.* 2024; Kouros and Rahmani 2025; Sedaghatzadeh and Rahmani 2025).

Recent studies have reported that pollen grains from various plant species, including almond (Khanamani *et al.* 2017a; Riahi *et al.* 2017a), pistachio (Hashemi *et al.* 2021; Kadkhodazadeh *et al.* 2021), saffron (Goleva and Zebitz 2013; Khanamani and Dalir 2025), pomegranate (Gorji *et al.* 2025), and date palm (Al-Shammery 2011; Hashemi *et al.* 2021; Kadkhodazadeh *et al.* 2021), are suitable food sources for rearing different species of predatory mites. Depending on their chemical composition, these pollens have shown beneficial effects on the biological performance of the studied predatory mites. However, limitations such as seasonal or annual flowering, restricted availability, high cost, and storage difficulties pose challenges to the large-scale commercial use of some of these pollen sources (Duarte *et al.* 2021).

Date palm pollen (*Phoenix dactylifera* L.: Arecaceae) is a highly suitable and practical resource for mass rearing of predatory mites. It is abundant, widely available, storable long-term, and has an acceptable nutritional composition. So far, life history and biological performance of several phytoseiid mite species feeding on date palm pollen have been studied, for example, *A. swirskii* (Abou-Elella *et al.* 2013; Riahi *et al.* 2017; Kadkhodazadeh *et al.* 2021), *Typhlodromus* (*Anthoseius*) *bagdasarjani* Wainstein & Arutunjan (Abou-Elella *et al.* 2013; Riahi *et al.* 2016), *Euseius scutalis* (Athias-Henriot) (Al-Shammery 2011; Abou-Elella *et al.* 2013, 2014; Fouly *et al.* 2013), *E. finlandicus* (Oudemans) (Abou-Elella *et al.* 2014), *Proprioseiopsis acetui* (Chant) (Fouly 1997), and *Neoseiulus californicus* McGregor (Khanamani *et al.* 2017a; Hashemi *et al.* 2021). However, the nutritional quality of date palm pollen from certain regions has been reported to be relatively low (Riahi *et al.* 2017a). Predators reared on such pollen exhibit poor biological performance. These findings suggest that pollen quality is not solely determined by the species of plant but is also significantly influenced by climatic and geographical conditions in the production area. These conditions include temperature, humidity, soil characteristics, and environmental stresses, all of which can affect the pollen's chemical compositions and nutritional value (Roulston *et al.* 2000; Human and Nicolson 2006).

The effect of the geographical origin of date palm pollen on its suitability for rearing predatory mites, particularly under Iran's diverse climatic conditions, has received limited attention thus far. The present study assessed the impact of date palm pollen collected from four regions in Iran—two in Kerman Province (Bam and Jiroft) and two in Hormozgan Province (Rodan and Hajiabad)—on the biological performance and life table parameters of the predatory mite *A. swirskii*. The provinces of Kerman and Hormozgan, major date-producing regions in Iran, provide abundant and accessible pollen resources. Evaluating the nutritional value of these pollens and their suitability for feeding *A. swirskii* could reduce mass-rearing costs, facilitate storage processes, and enhance the efficiency of biological control programs in greenhouse systems.

MATERIAL AND METHODS

Pollen collection

Date palm pollen was collected during the flowering season from four geographical regions: two regions in Kerman Province (Bam and Jiroft) and two regions in Hormozgan Province (Rodan and Hajiabad). All sampled trees were from the same cultivar, 'Mazafati', which is one of the most important and widely cultivated date palm cultivars in southern Iran. Pollen was collected from male inflorescences by gentle shaking. The sampled trees had not received any pesticide or acaricide treatment during the study period, particularly during the flowering and pollen collection stages. The collected pollen samples were dried in an oven at 37 °C for 48 hours. After sieving, the pollen from each location was transferred separately into plastic microtubes. The samples were kept at -20 °C for long-term storage and refrigerated at 4 °C for up to two weeks during the experiments.

Plant cultivation and mites rearing

To establish a laboratory colony of the two-spotted spider mite (natural prey), *Phaseolus vulgaris* L. var. Khomein (bean plant) was used. Initially, fifteen bean pots, each containing five seeds, were cultivated in the greenhouse with natural conditions at Jiroft University. The initial population of two-spotted spider mites was collected from mulberry leaves at the Jiroft university campus in August 2024 and transferred to the greenhouse. There, the mites were released onto bean plants in specialized insect-rearing cages (a fine-mesh rearing cage that ensures mite containment on bean foliage while allowing observation and airflow) under natural greenhouse conditions. To maintain the continuity of the two-level plant-pest system, five new bean pots were planted weekly. Every few days, two pots containing healthy leaves were added to the mite-rearing cage. One day after the mites were transferred to the new pots, the old, dried pots were removed. Identification of the two-spotted spider mite was conducted after slide preparation using relevant taxonomic keys.

The initial population of *A. swirskii* was obtained from the Abad Gostaran Hegmatan Milad Company. The mites were established under controlled conditions on an artificial rearing arena that was called "rearing island". This setup consisted of a plastic container (10 × 18 × 25 cm) containing a water-saturated sponge and a green plastic sheet placed on top of the sponge. The container was filled with water. To prevent the mites from escaping, the edges of the plastic sheet were covered with tissue paper, half of which was submerged in water. This design prevented the predators from escaping while providing the necessary humidity for their survival. After preparing the rearing substrate, the predatory mites were released onto the plastic sheet. Every other day, bean leaves infested with two-spotted spider mites were placed on the sheet for feeding. In some cases, spider mites were brushed directly onto the plastic sheet surface from the underside of bean leaves using a fine brush to ensure access for the predators. Before performing life table experiments, *A. swirskii* individuals were reared for one generation on each pollen treatments separately to acclimate them to the test diets.

Experimental unit

The experimental units were based on an artificial substrate, a green plastic sheet that replaced natural leaves. They were similar to the predatory mite colony rearing "island," but on a smaller scale. Each unit consisted of a 9 × 7 × 4 cm plastic container with a 6 × 4 × 2 cm sponge piece inside and a 3.5 × 3.5 × 0.1 cm green plastic sheet on top of the sponge. After placing the plastic sheet on the sponge, the edges were wrapped with tissue paper, and the ends were submerged in water. This arrangement prevented mite escape. To provide shelter and oviposition sites for the predatory mites, a small amount of cotton fibers was affixed to the center of the artificial substrate.

Estimating life table parameters

Life table studies were conducted to evaluate the effects of geographical variation in date palm pollen quality on the biological performance of the predatory mite *A. swirskii*. Pollen treatments included four locations in southern Iran: Bam and Jiroft (Kerman Province) and Rodan and Hajiabad (Hormozgan Province). In addition, *T. urticae* was examined as a control treatment. All experiments were carried out at laboratory conditions at 25 ± 1 °C, 60 ± 5% RH and a photoperiod of 16:8 (L:D) h. At the beginning

of experiments, to obtain the same-aged eggs of *A. swirskii*, 50 pairs of both sexes of the predator were transferred from the conditioned colonies onto a leaf disc for each dietary treatment. After 12 h, the deposited eggs were transferred individually to the experimental units up to 60 replicates per treatment. After the emergence of larval predators, the respective test pollen (0.05 mg/experimental unit) was offered as food. In addition, for natural prey treatment, 15 and 40 prey nymphs were added daily to the experimental units during immature and adult stages, respectively (Khanamani *et al.* 2017b).

The experimental units were daily checked under a stereomicroscope, and duration of different life stages as well as their mortality were monitored. After adult emergence, females were coupled with males obtained in the same treatment or taken from the colony on the same dietary treatment. Daily observations continued to record adult longevity and female oviposition until the death of the last individual. To avoid pollen contamination with fungi, fresh pollen was offered in 5-day intervals.

Assessment of protein content

Due to the critical importance of pollen protein as an indicator of nutritional quality (Khanamani *et al.* 2017a) and its relationship with predatory mite performance, the protein content of date palm pollens from different regions was evaluated. The total protein content of pollen (w/w%) was determined using the Kjeldahl method. First, the total nitrogen content (%N) in one gram of dried pollen was measured (Szczesna 2006; Khanamani *et al.* 2017a). Then, the total protein content was calculated by multiplying the nitrogen percentage by a conversion factor of 6.25. This factor is based on the percentage of nitrogen (%N) in 100 g of protein.

Statistical analysis

The biological data of the predatory mite *A. swirskii* on different dietary treatments (date palm pollens from various regions and natural prey as the control treatment) were analyzed using the two-sex life table approach (Chi and Liu 1985), as described by Chi (1988). The TWOSEX-MSChart program (Chi 2024) was used for data analysis. The variances and standard errors of the life table parameters were estimated using the bootstrap procedure with 100,000 iterations. The bootstrapped parameters included the duration of different life stages, immature mortality, fecundity, and the reproductive periods (pre-oviposition periods [APOP, adult pre-ovipositional period; TPOP, total pre-ovipositional period (from egg to first oviposition)], and oviposition days). They also included the population growth parameters including intrinsic rate of increase (r), finite rate of increase (λ), gross reproductive rate (GRR), net reproductive rate (R_0), and mean generation time (T). Comparisons among dietary treatments were conducted using the paired bootstrap test based on confidence intervals, which is also implemented in the TWOSEX-MSChart (Chi 2024).

To compare the protein content of date palm pollens from different regions, data were subjected to one-way analysis of variance (ANOVA), followed by Tukey's post-hoc test at a 5% significance level, using SPSS 22 software.

RESULTS

Duration of different developmental stages

Table 1 presents the durations of the different developmental stages of the predatory mite *A. swirskii* fed on two-spotted spider mite and date palm pollen from four different regions. These results suggest that the duration of each stage is strongly influenced by diet, reflecting the effect of geographical origin on the nutritional quality of date palm pollen. The value of incubation period was higher on Bam pollen and lower on Rodan pollen. The larval stage, which does not feed, showed no variation across treatments. The protonymph and deutonymph stages were longest on Jiroft and Bam pollen and shortest on Rodan pollen. Overall, the total immature period differed significantly among tested pollens. The longest pre-adult durations were observed on Jiroft and Bam pollen grains, and the shortest duration was observed on Rodan pollen.

Male and female adult longevity of *A. swirskii* varied significantly among pollen treatments (Table 1). The value of male longevity was higher on Rodan pollen and lower on Jiroft pollen. The value of

female longevity was higher on natural prey and lower on Jiroft pollen. Total lifespan (from egg to death) also varied significantly among diets. Predator reared on Rodan pollen and natural prey had the longest total lifespan, while those fed Bam and Jiroft pollen grains had the shortest lifespan period.

Table 1. Duration of different life stages (days) ($\pm$ SE) of *Amblyseius swirskii* reared on natural prey (two-spotted spider mite) and date palm pollen from four different geographical locations.

Parameters	Prey	Date palm pollen grains			
	<i>T. urticae</i>	Bam	Jiroft	Rodan	Hajiabad
Egg	2.05 $\pm$ 0.03ab	2.25 $\pm$ 0.11a	2.10 $\pm$ 0.08a	1.92 $\pm$ 0.05b	2.15 $\pm$ 0.10a
Larva	1.00 $\pm$ 0.00a	1.00 $\pm$ 0.00a	1.00 $\pm$ 0.00a	1.00 $\pm$ 0.00a	1.00 $\pm$ 0.00a
Protonymph	2.06 $\pm$ 0.08b	2.15 $\pm$ 0.12ab	2.31 $\pm$ 0.11a	1.77 $\pm$ 0.12c	2.23 $\pm$ 0.14ab
Deutonymph	1.97 $\pm$ 0.09b	2.27 $\pm$ 0.13a	2.29 $\pm$ 0.09a	1.69 $\pm$ 0.11c	1.92 $\pm$ 0.15b
Preadult	7.08 $\pm$ 0.09ab	7.69 $\pm$ 0.16a	7.71 $\pm$ 0.17a	6.38 $\pm$ 0.14b	7.31 $\pm$ 0.13a
Adult longevity (M*)	26.41 $\pm$ 4.14ab	24.98 $\pm$ 2.91b	24.29 $\pm$ 2.28b	32.77 $\pm$ 1.06a	28.85 $\pm$ 0.17ab
Adult longevity (F*)	35.14 $\pm$ 1.27a	22.92 $\pm$ 1.75b	21.57 $\pm$ 1.16b	30.08 $\pm$ 0.95ab	25.31 $\pm$ 0.79b
Total life span	38.41 $\pm$ 1.09a	30.54 $\pm$ 1.37c	30.64 $\pm$ 1.50c	37.81 $\pm$ 1.50ab	34.38 $\pm$ 1.15b
APOP*	2.23 $\pm$ 0.09b	3.54 $\pm$ 0.24a	3.57 $\pm$ 0.17a	2.54 $\pm$ 0.19b	3.23 $\pm$ 0.15a
TPOP*	9.36 $\pm$ 0.12b	11.31 $\pm$ 0.33a	11.07 $\pm$ 0.22a	8.77 $\pm$ 0.28b	10.46 $\pm$ 0.25a
Oviposition days	21.45 $\pm$ 0.75a	14.62 $\pm$ 0.74c	13.79 $\pm$ 0.68c	21.69 $\pm$ 0.98a	18.31 $\pm$ 0.85b

* M, Male; F, Female; APOP, adult pre-ovipositional period; TPOP, total pre-ovipositional period (from egg to first oviposition). The means followed by different letters in the same row are significantly different ($P < 0.05$, Paired bootstrap test).

Reproductive periods and fecundity

The reproductive parameters of *A. swirskii*, including the adult pre-oviposition period (APOP) and the total pre-oviposition period (TPOP) (from egg to the first oviposition), as well as total fecundity, are presented in Table 1 and Figure 1 for different dietary treatments. The highest APOP occurred in individuals reared on Jiroft and Bam pollens, while the lowest APOP occurred with natural prey and Rodan pollen. Similarly, the longest and shortest TPOPs were recorded on Bam pollen (followed by Jiroft pollen), and Rodan pollen, respectively. The oviposition days (the number of days that female laid eggs) was longest on Rodan pollen and natural prey and shortest on Jiroft and Bam pollen. Fecundity was highest in mites fed Rodan pollen, followed by those reared on natural prey. The lowest fecundity was observed in mites fed Bam and Jiroft pollen grains.

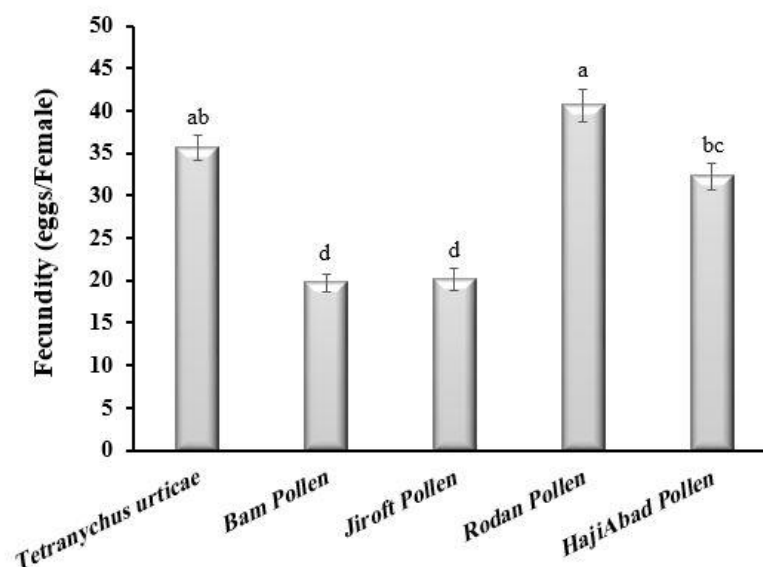


Figure 1. Mean ($\pm$ SE) fecundity (eggs/female/generation) of *Amblyseius swirskii* reared on natural prey and date palm pollen from four different geographical locations (Paired bootstrap test, $P < 0.05$).

Mortality of different developmental stages

Table 2 presents the percentage mortality of various developmental stages of *A. swirskii* fed on two-spotted spider mites (control) and date palm pollens from four regions of Kerman and Hormozgan Provinces. According to the results, the highest pre-adult mortality occurred in individuals reared on Bam pollen (followed by Jiroft pollen). No mortality was observed during the immature stages of mites fed Rodan and Hajiabad pollens.

Table 2. Stages mortality (%) of *Amblyseius swirskii* reared on natural prey and date palm pollen from four different geographical locations.

Life stages	Different treatments				
	<i>T. urticae</i>	Bam	Jiroft	Rodan	Hajiabad
Egg	0.000±0.000a*	0.000±0.000a	0.000±0.000a	0.000±0.000a	0.000±0.000a
Larva	0.000±0.000a	0.000±0.000a	0.000±0.000a	0.000±0.000a	0.000±0.000a
Protonymph	0.025±0.004b	0.036±0.003a	0.000±0.000c	0.000±0.000c	0.000±0.000c
Deutonymph	0.000±0.000b	0.036±0.009a	0.034±0.007a	0.000±0.000b	0.000±0.000b
Preadult	0.025±0.004c	0.071±0.008a	0.034±0.007b	0.000±0.000d	0.000±0.000d
Female	0.550±0.009b	0.710±0.007a	0.630±0.008ab	0.730±0.009a	0.600±0.008b
Male	0.425±0.008a	0.219±0.009c	0.336±0.008bc	0.270±0.007c	0.400±0.007ab

* The means followed by different letters in the same row are significantly different ($P < 0.05$, Paired bootstrap test).

Survivorship and fecundity curves

Figure 2 presents the age-stage-specific survival rate (s_{xj}) of *A. swirskii* at different treatments tested. The s_{xj} represents the proportion of individuals surviving to age x and stage j , and it provides a detailed description of survival and transition between stages. Obvious overlapping between stages, which is shown in this figure, is attributable to the different developmental rate among individual. Figure 3 shows the age-specific survivorship (l_x), which indicates the proportion of individuals surviving to age x . The l_x curve is a simplified version of the s_{xj} curves and does not capture stage-specific developmental overlaps. According to these curves, the highest pre-adult mortality occurred in mites reared on Bam pollen, followed by Jiroft pollen. No pre-adult mortality was observed on other pollen grains.

In addition, Figure 3 also presents the fecundity curves of *A. swirskii* fed on different tested diets. The values of m_x curves are less than the f_{xj} curves, except in cases where there are no males in the population, in which case their values are equal. Based on these curves, the highest peak in egg production occurred with Rodan pollen, while the lowest peaks occurred with Bam and Jiroft pollens. Additionally, individuals fed Rodan pollen began laying eggs earlier than those fed other pollen grains.

Age-stage life expectancy (e_{xj})

Figure 4 shows the effects of different date palm pollen, as well as two-spotted spider mites (control), on the age-stage life expectancy (e_{xj}) of *A. swirskii*. According to these curves, the life expectancy of newly hatched individuals was 37.80, 34.38, 28.82, 29.79, and 37.55 days, for Rodan, Hajiabad, Bam, Jiroft pollens, and natural prey, respectively. The highest life expectancy was observed with Rodan pollen, while the lowest value was with Bam pollen. Additionally, the minimum and maximum values of life expectancy at the time of adult emergence were recorded for mites reared on Bam and Rodan pollens, respectively.

Age-stage reproductive value (v_{xj})

Figure 5 shows the effects of different treatments on the age-stage reproductive value (v_{xj}) of *A. swirskii*. Age-stage-specific reproductive value (v_{xj}) represents the individual's contribution to the future population at age x and stage j . The reproductive value of a newly laid egg (v_{01}) is equal to the finite rate of increase (λ) for all treatments. According to these curves, the highest reproductive value was observed in adult females in all treatments, while males have no reproductive value because they do not directly produce offspring. Reproductive value of female adults initially increased in all treatments; then, it gradually declined as fecundity and survival decreased. Overall, the highest reproductive value of adult females occurred at the peak of oviposition.

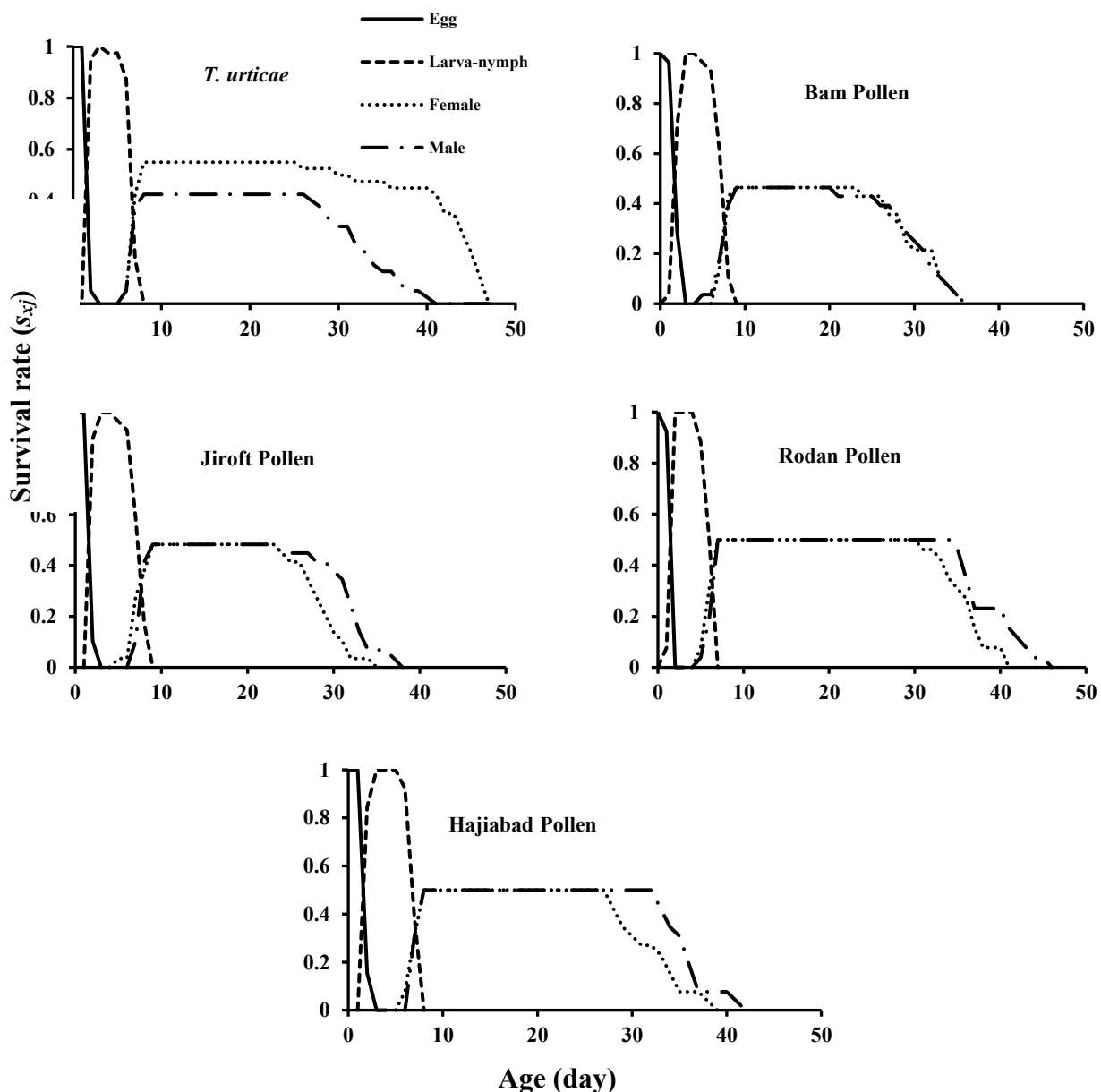


Figure 2. Age-stage survival rate (s_{xj}) of *Amblyseius swirskii* reared on natural prey and date palm pollen from four different geographical locations.

Population growth parameters

The population growth parameters of *A. swirskii* fed on two-spotted spider mites and different tested date palm pollen grains are presented in Table 3. The results indicate that the highest intrinsic (r) and finite (λ) rates of increase were observed in individuals fed Rodan pollen, while the lowest values were recorded on Bam pollen. The highest net reproductive rate (R_0) and gross reproductive rate (GRR) were recorded for Rodan pollen and natural prey, while the lowest values were recorded for Bam and Jiroft pollens. The shortest mean generation time (T) was recorded for mites reared on Rodan pollen. The values of this parameter did not differ significantly among the other dietary treatments.

Table 3. The mean ($\pm$ SE) two-sex life table parameters of *Amblyseius swirskii* reared on natural prey (two-spotted spider mite) and date palm pollen from four different geographical locations.

Parameters	Prey	Date palm pollens			
	<i>T. urticae</i>	Bam	Jiroft	Rodan	Hajiabad
GRR^* (offspring)	21.11 $\pm$ 2.96a	11.17 $\pm$ 2.28b	10.96 $\pm$ 2.33b	20.61 $\pm$ 4.19a	17.40 $\pm$ 3.76a
R_0 (offspring)	19.60 $\pm$ 2.91a	9.14 $\pm$ 1.90b	9.74 $\pm$ 1.94b	20.30 $\pm$ 4.05a	16.15 $\pm$ 3.22a

Table 3. Continued.

Parameters	Prey	Date palm pollens			
	<i>T. urticae</i>	Bam	Jiroft	Rodan	Hajiabad
r (day ⁻¹)	0.165±0.009b	0.117±0.013c	0.123±0.012c	0.181±0.015a	0.154±0.013b
λ (day ⁻¹)	1.180±0.011b	1.124±0.014c	1.131±0.013c	1.199±0.018a	1.166±0.015b
T (day)	17.89±0.27a	18.69±0.59a	18.22±0.47a	16.45±0.37b	17.93±0.44a

* Gross reproductive rate (GRR); Net reproductive rate (R_0); Intrinsic rates of increase (r); Finite rates of increase (λ); Mean generation time (T). The means followed by different letters in the same row are significantly different ($P < 0.05$, Paired bootstrap test). Data were calculated using the bootstrap procedure with 100,000 samples.

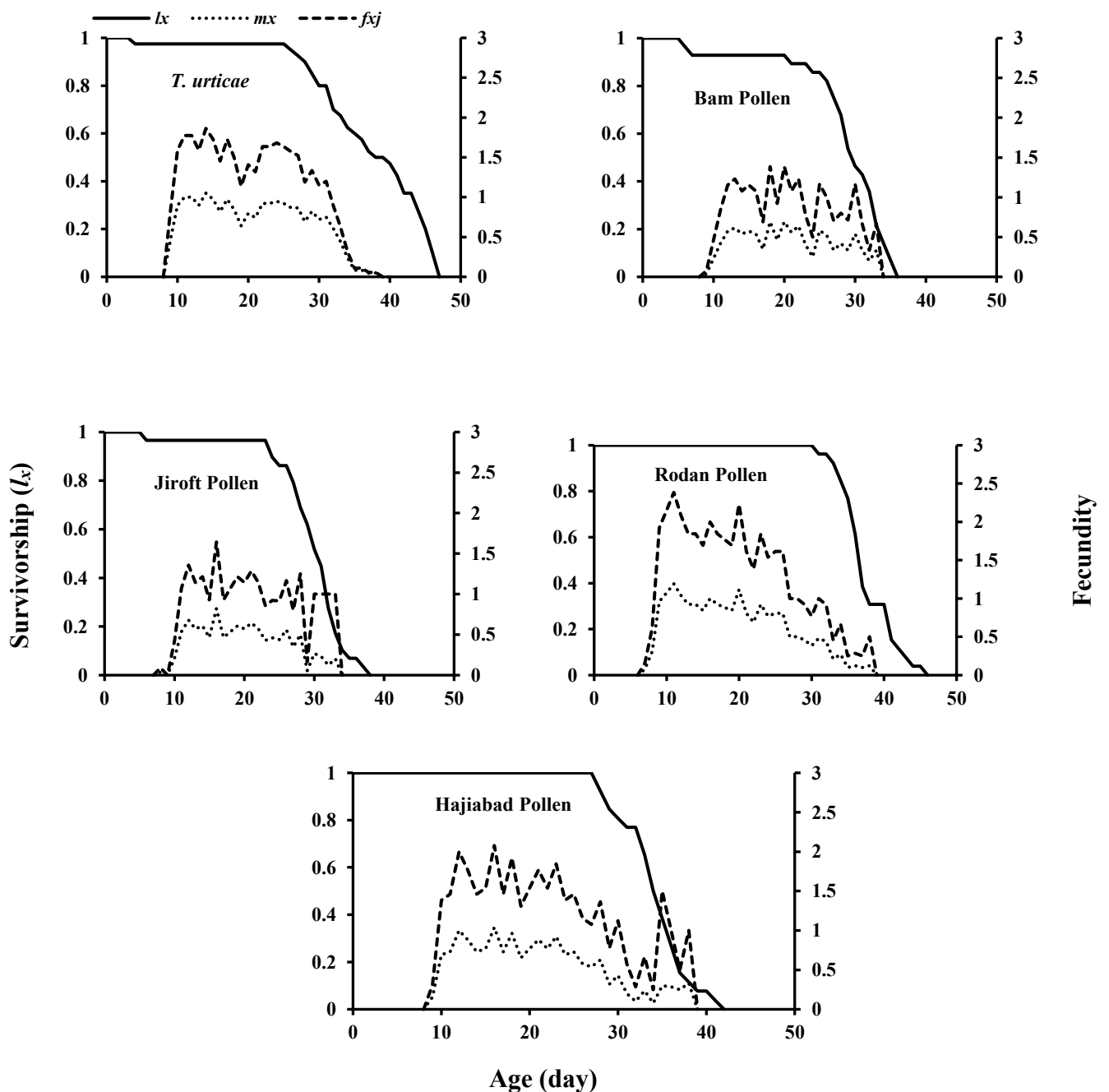


Figure 3. Age-specific survivorship (l_x), age-specific fecundity (m_x) and age-stage specific fecundity (f_{xj}) of *Amblyseius swirskii* reared on natural prey and date palm pollen from four different geographical locations.

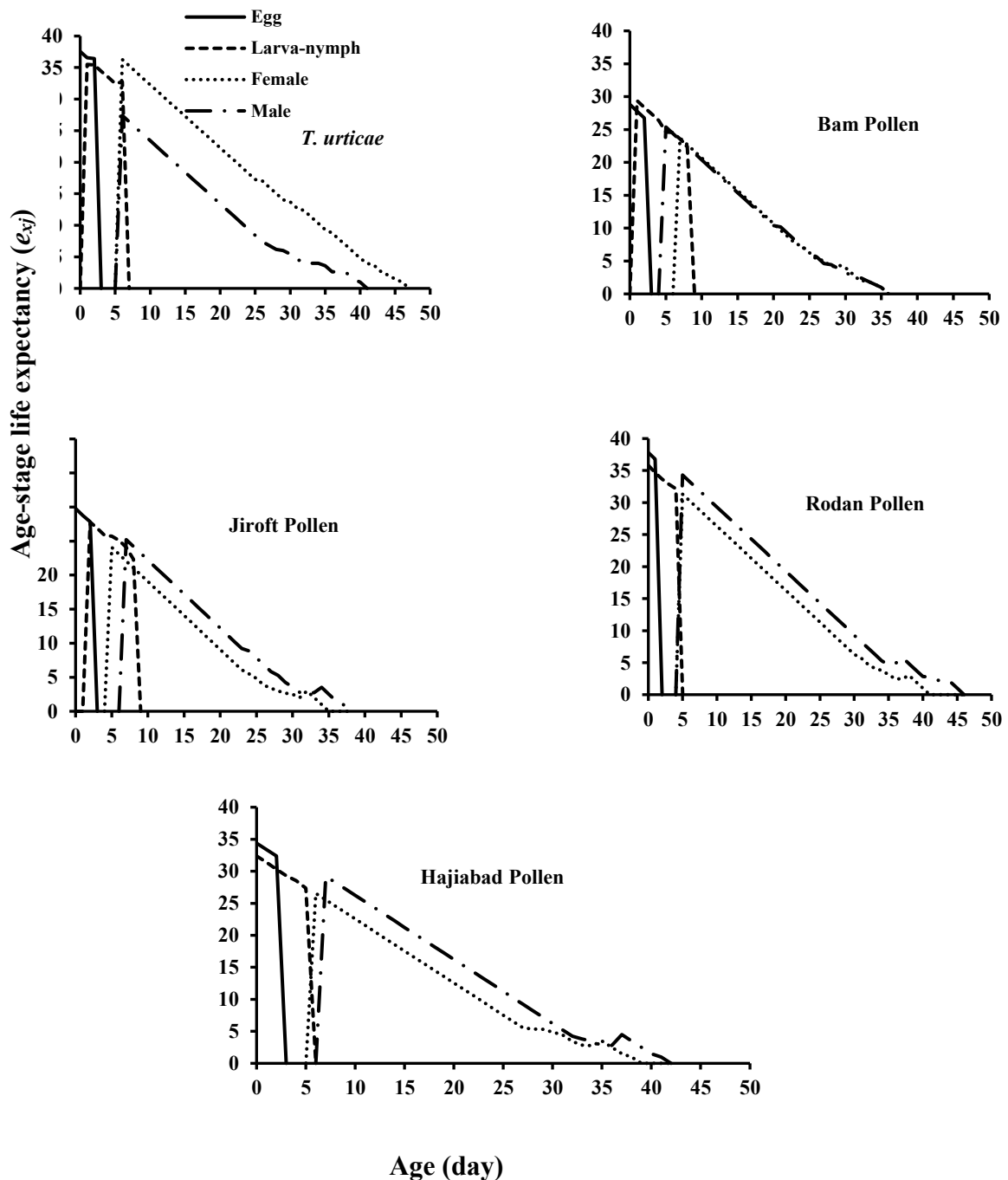


Figure 4. Age-stage life expectancy (e_{xj}) of *Amblyseius swirskii* reared on natural prey and date palm pollen from four different geographical locations.

Protein content of date palm pollens from different regions

Figure 6 presents the protein content (% w/w) of date palm pollens from Bam, Jiroft, Rodan and Hajiabad regions. According to the results, the highest protein content was found in Rodan pollen (43.18%), which was significantly higher than the other pollens. The next highest protein content was found in Hajiabad pollen (35.09%), though it did not differ significantly from the pollens of Jiroft (33.49%) and Bam (33.15%).

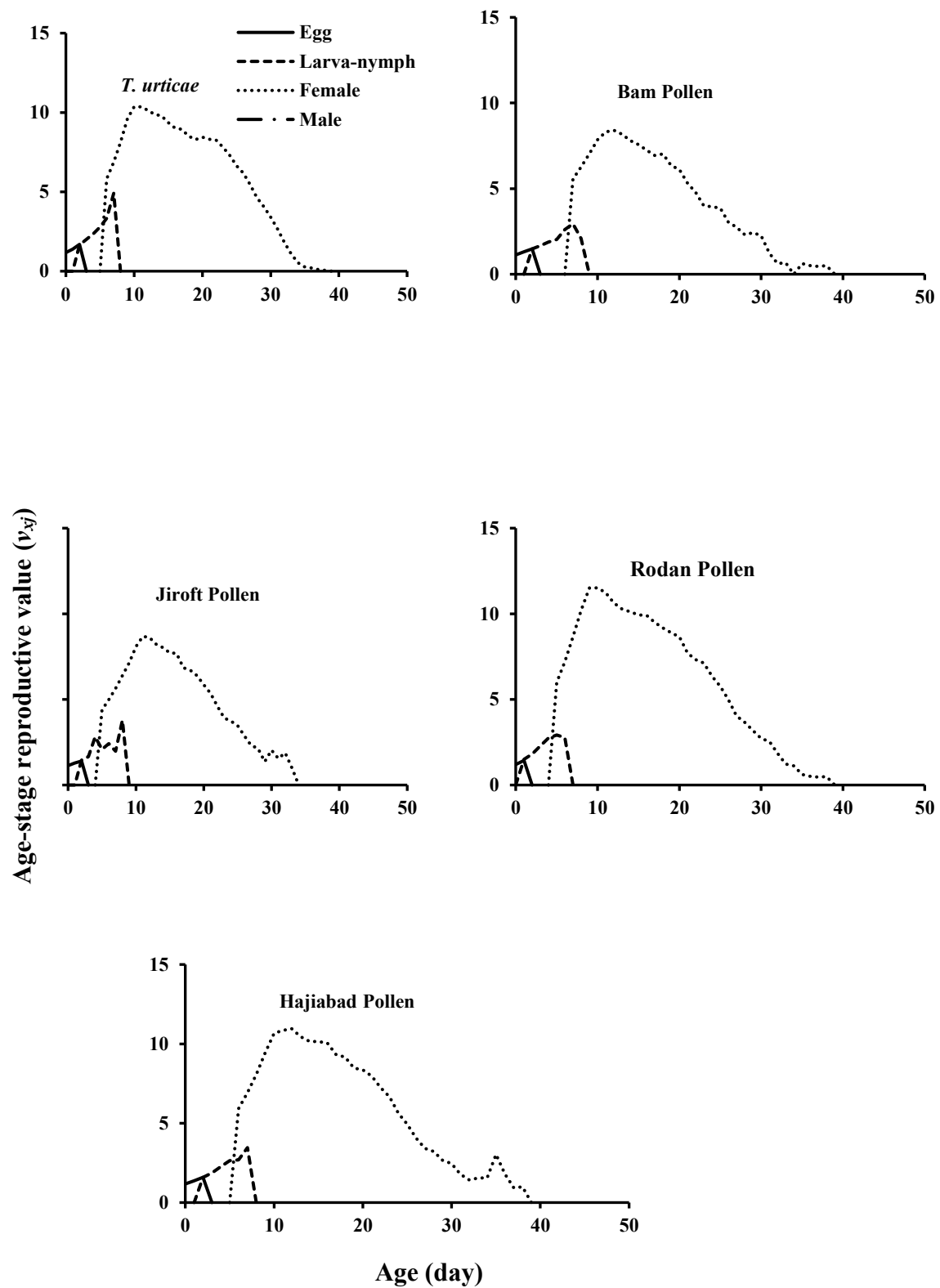


Figure 5. Age-stage reproductive value (v_{xj}) of *Amblyseius swirskii* reared on natural prey and date palm pollen from four different geographical locations.

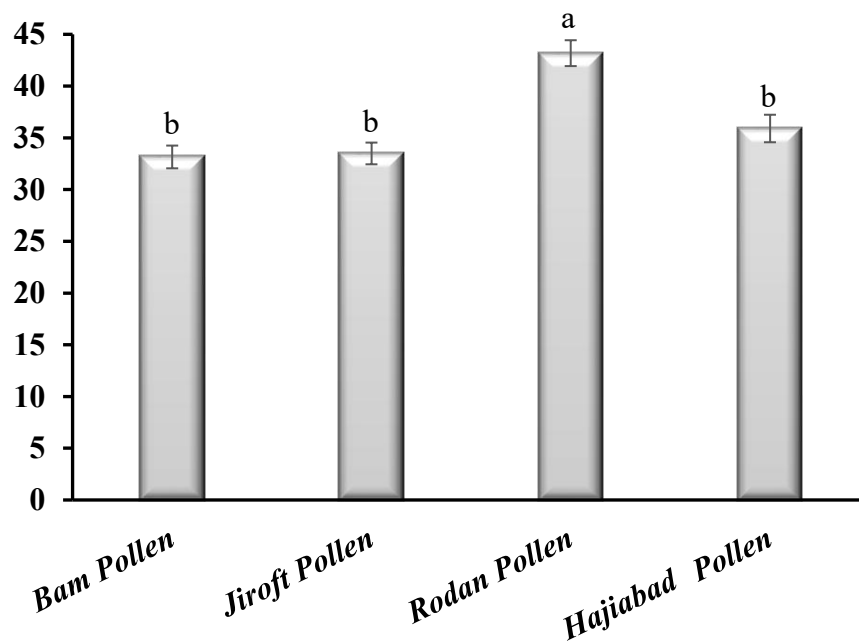


Figure 6. Protein contents (% w/w) of date palm pollen from four different geographical locations (Tukey, $P < 0.05$)

DISCUSSION

Phytoseiid mites play a major role in keeping herbivorous mite population density below economic injury level and decreasing their deleterious impact (Al-Azzazy and Alhewairini 2020; Dalir *et al.* 2024). Flexibility in feeding behavior, such as feeding on alternative prey or feeding on non-prey food sources, including pollen, fungal spores, and nectar has generally been observed in generalist phytoseiid mites (Overmeer 1985). Due to the high costs associated with maintaining and rearing generalist predatory mites using natural prey, plant pollens have been applied as a cost-effective and less laborious candidate for rearing various predatory mites (Riahi *et al.* 2017a; Khanamani *et al.* 2021). In the present study, we evaluated the nutritional quality of date palm pollen from four regions to identify an optimal alternative diet for the mass rearing of the predatory mite *A. swirskii*.

The results of the present study indicate that the predatory mite *A. swirskii* was able to successfully feed on date palm pollen from all four regions, and all tested pollens supported the complete development of the predator. Immature individuals in all treatments successfully reached adulthood, indicating that these pollens can serve as suitable alternative food sources. However, the duration of different life stages was strongly influenced by the quality of the pollens. Previous studies have reported comparable developmental durations for *A. swirskii* fed on date palm pollen (Abou-Elella *et al.* 2013; Riahi *et al.* 2017; Kadkhodazadeh *et al.* 2021). For example, Kadkhodazadeh *et al.* (2021) reported durations of egg, larval, protonymph, deutonymph, and pre-adult as 1.69, 1.03, 1.70, 1.22, and 5.57 days, respectively. Riahi *et al.* (2017a) reported the duration of the above stages for this predatory mite on date palm pollen as 2.2, 1.0, 2.0, 2.2, and 7.3 days, respectively. Differences in immature mortality and developmental time could be due to differences in quality of pollen grains, which cause differences in the food supply needed by mites. Differences in pollen morphology and/or secondary metabolites can be also the source of such differences.

The predatory mite individuals were able to lay eggs with a high hatching rate by feeding on all four date palm pollens. However, significant differences were observed in the values of reproductive parameters depending on the pollen's geographical origin. Kadkhodazadeh *et al.* (2021) reported a fecundity of 31.22 eggs for *A. swirskii* fed date palm pollen. Riahi *et al.* (2017a) reported the fecundity of this predatory mite on date palm pollen as 7.8 eggs, which is less than the values mentioned in this study.

These differences (despite using the same dietary pollen) may be related to differences in the date palm variety (cultivar) used, genetic variation of predator populations, experimental conditions, and different geographical origins of pollen.

The quality and quantity of food resources during the immature stage are primary factors that determine reproductive performance in adulthood (Awmack and Leather 2002). Based on the nutritional value of the pollens evaluated in this study for the reproductive performance of the predatory mite, the tested date palm pollens can be classified into three categories: (1) highly suitable: Rodan pollen; (2) suitable: Hajiabad pollen, and (3) moderately suitable: Jiroft and Bam pollens. Therefore, none of the tested pollens are poor or toxic and can all be used in mass rearing programs of the predatory mite.

Estimating life table parameters, especially the intrinsic rate of increase (r), is a suitable tool for comparing the nutritional value of a diet for predatory mites, as more favorable diet leads to higher values in population growth rates, which leads to better growth of the predatory mite population. Estimation of r depends on three key variables: fecundity (m_x), age-specific survival rate (l_x), and age (x), which is measured in days (Birch 1948). In this study, the individuals reared on Rodan pollen exhibited the greatest fecundity, the highest immature survival rate, and the shortest developmental time. Consequently, the highest r was obtained with this pollen treatment. These findings indicate that pollen collected from the Rodan region is the most suitable date palm pollen for rearing the predatory mite. The pollen collected from Bam and Jiroft regions had a lower quality than pollen from Rodan and Hajiabad. Although these pollens supported complete development and reproduction, their fecundity and survival rates were lower than the other regions. Nevertheless, these pollens can be classified as moderately suitable because mites fed on them exhibited population growth rates ranging from 0.117 to 0.123 day⁻¹ and produced approximately 20 eggs per female per generation.

The protein content of pollen is believed to be one of the best indicators for nutritive quality as it is closely linked to the performance of the consumers (Roulston *et al.* 2000; Khanamani *et al.* 2017a). As one of the most important nutritional components in arthropods, protein plays a fundamental role in growth, the development of reproductive organs, enzyme synthesis, and the enhancement of oviposition capacity (Roulston *et al.* 2000). The individuals reared on Rodan pollen had high growth rate due to its high nutritional quality, especially due to the high protein content. However, differences in protein content of date palm pollen in different regions may be related to the differences in climatic conditions (e.g., temperature, humidity, and altitude), soil characteristics, and orchard management practices.

The observed variation in the quality of date palm pollen from different regions, as well as its pronounced effect on the biological performance of the predatory mite, indicates that pollen quality is not solely determined by plant species. Instead, the chemical composition and nutritional value of pollen can be significantly influenced by the climatic and geographical conditions of the production site, such as temperature, humidity, soil type, environmental stresses, and altitude (Roulston *et al.* 2000; Human and Nicolson 2006). These factors can directly affect pollen quality and indirectly impact the biological performance of the consumer, in this case, the predatory mite.

In conclusion, this study's findings demonstrate that date palm pollen is a suitable and accessible food source for mass-rearing the predatory mite *A. swirskii*. However, its quality is significantly influenced by geographical condition of the date palm-growing region. Rodan pollen was identified as the most desirable pollen among the evaluated pollens in terms of protein content and nutritional value for the predator. Therefore, it can be recommended as a good alternate food source for the commercial production of this predator. This study is an important step toward utilizing local resources and optimizing biological control agent production in Iran.

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تنوع جغرافیایی در کیفیت گرده نخل و اثرات آن بر عملکرد زیستی *Amblyseius swirskii* (Acari: Phytoseiidae)

محمد امین زارعی^۱ | مصطفی خانامانی^{۱*} | مهدی ضیاءالدینی^۲ | مسلم بسیج^۱

۱. گروه گیاه‌پزشکی، دانشکده کشاورزی، دانشگاه جیرفت، کرمان، ایران؛ رایانامه: m.khanamani@ujiroft.ac.ir

۲. گروه گیاه‌پزشکی، دانشکده کشاورزی، دانشگاه ولی عصر رفسنجان، کرمان، ایران؛ رایانامه: ziaaddini@vru.ac.ir

* نویسنده مسئول

✉ m.khanamani@ujiroft.ac.ir

چکیده

گرده نخل به دلیل ارزش غذایی زیاد، در دسترس بودن و اثرهای مثبت بر عملکرد شکارگرها، در بین انواع مختلف گرده توجه زیادی را به خود جلب کرده است. با این حال، کیفیت غذایی گرده نخل می‌تواند بسته به منشأ جغرافیایی آن به مقدار زیادی متفاوت باشد. بنابراین، این مطالعه به منظور ارزیابی تأثیر گرده نخل جمع‌آوری شده از مناطق مختلف بر پراسنجه‌های زیستی کنه شکارگر *Amblyseius swirskii* Athias-Henriot انجام شد. نمونه‌های گرده از چهار منطقه بم و جیرفت (استان کرمان) و رودان و حاجی‌آباد (استان هرمزگان) در جنوب ایران جمع‌آوری شدند. کوتاه‌ترین دوره پیش از بلوغ روی گرده رودان (۶/۳۸ روز) و طولانی‌ترین دوره روی گرده جیرفت (۷/۷۱ روز) و بم (۷/۶۹ روز) مشاهده شد. باروری افراد پرورش یافته روی گرده نخل رودان (۴۰/۶۲ تخم/ماده) به‌طور معنی‌داری بیشتر از مقادیر به‌دست آمده برای افراد پرورش یافته روی سایر تیمارهای غذایی بود. بیشترین مرگ و میر پیش از بلوغ مربوط به افراد پرورش یافته روی گرده نخل بم (و بعد از آن جیرفت) بود. بیشترین مقدار ذاتی افزایش جمعیت (r) و مقدار متناهی افزایش جمعیت (λ) مربوط به افراد تغذیه کرده از گرده نخل رودان بود (به ترتیب ۰/۱۸۱ بر روز و ۱/۱۹۹ بر روز) در حالی که کمترین مقدار این پراسنجه‌ها مربوط به افراد پرورش یافته روی گرده بم بود (به ترتیب ۰/۱۱۷ بر روز و ۱/۱۲۴ بر روز). بیشترین مقادیر خالص تولیدمثل (R_0) و ناخالص تولیدمثل (GRR) روی گرده نخل رودان و کمترین مقادیر این پراسنجه‌ها روی گرده‌های نخل بم و جیرفت مشاهده شد. کوتاه‌ترین مدت زمان طول یک نسل (T) مربوط به افراد پرورش یافته روی گرده نخل رودان (۱۶/۴۵ روز) بود در حالی که مدت زمان این دوره روی سایر تیمارها تفاوت معنی‌داری با یکدیگر نداشت. بیشترین مقدار پروتئین مربوط به گرده نخل رودان (۴۳/۱۸ درصد) بود که اختلاف معنی‌داری با سایر گرده‌ها داشت. یافته‌های این پژوهش نشان می‌دهد که شرایط جغرافیایی محل پرورش نخل می‌تواند به طور مستقیم بر کیفیت گرده و به طور غیرمستقیم بر عملکرد بیولوژیک هر نای شکارگر تأثیر بگذارد.

واژگان کلیدی: مهار زیستی، جدول زندگی، تولید انبوه، هرناهای فیتوزئید، دانه گرده.

دریافت

۳۰ فروردین ۱۴۰۵

پذیرش

۱۰ شهریور ۱۴۰۵

انتشار

۲۳ مهر ۱۴۰۵

دبیر تخصصی

آ. فرازمند

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