Persian J. Acarol., 2025, Vol. 14, No. 1, pp. 27–39.
https://doi.org/10.22073/pja.v14i1.85955
Journal homepage: http://www.biotaxa.org/pja

PERSIAN JOURNAL OF ACAROLOGY

Article

Nutritional value of non-prey food sources for rearing of predatory mites *Neoseiulus cucumeris* and *Amblyseius swirskii* (Acari: Phytoseiidae)

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ABSTRACT

In this study, life table analysis was performed to evaluate the nutritional value of proso millet and saffron pollen grains as a dietary supplement for rearing and conservation of *Neoseiulus cucumeris* Oudemans and *Amblyseius swirskii* Athias-Henriot (Acari: Phytoseiidae). According to our results, developmental time did not differ between the two pollen diets for either predatory mite. *Amblyseius swirskii* completed immature development significantly faster than *N. cucumeris* on both pollen diets. Fecundity of both predator females, offered saffron pollen, was significantly higher than that of females given proso millet pollen, however, *N. cucumeris* females had higher fecundity than *A. swirskii* females. Comparisons between two predators indicated that *N. cucumeris* females had a higher R_0, *GRR*, *r*, and *λ* than *A. swirskii* on saffron and proso millet pollen. There were no significant differences in intrinsic rate of increase (*r*) and finite rate of increase (*λ*) of *N. cucumeris* between the two pollen diets, although significantly higher values of *r* and *λ* were observed in *A. swirskii* reared on saffron pollen than those fed on proso millet pollen. This suggests that saffron and proso millet pollen could be a viable alternative food source for these predators, particularly during times when prey in the field is scarce or absent. Additionally, our results indicate that saffron pollen can be effectively used for mass rearing and/or conservation of these predatory mites in biological programs.

KEYWORDS: Conservation, mass rearing, pollen, predatory mite, supplementary diet.

PAPER INFO.: Received: 04.06.2024, Accepted by: *A. Farazmand*, 25.11.2024, Published: 15.01.2025

INTRODUCTION

Use of predatory mites as a safe tool in pest management programs has been increasing due to the growing demand for alternatives to chemical pesticides (Gerson and Weintraub 2007). The species of the family Phytoseiidae are the most important plant-inhabiting predatory mites (Gerson and Weintraub 2012), which have received extensive interest worldwide since their biological importance in agriculture was clarified (Khanamani *et al*. 2017; Riahi *et al*. 2017). This important group has been classified into various types based on their diet and lifestyle (McMurtry *et al*. 2013). The generalist predators of this family are known to have flexibility in their feeding behaviors in such a way that in addition to arthropod prey of various groups, they feed on different non-prey food sources as well (Dalir *et al*. 2021a). They are capable of exploiting some

How to cite: Khanamani, M. & Dalir, S. (2025) Nutritional value of non-prey food sources for rearing of predatory mites *Neoseiulus cucumeris* and *Amblyseius swirskii* (Acari: Phytoseiidae). *Persian Journal of Acarology*, 14(1): 27–39.

alternative resources including fungal spores, plant-derived materials such as nectar, exudates, and pollen and even prey products, for instance, honeydew, especially during times of prey scarcity, resulting in higher reproductive rates and faster population growth (Wäckers and Van Rijn 2005; Lundgren 2009; Gerson and Weintraub 2012; Nguyen *et al*. 2014; Khanamani *et al*. 2017; Riahi *et al*. 2017; Kadkhodazadeh *et al*. 2021; Hashemi *et al*. 2021).

Their feeding capability on a variety of alternative diets can provide some important advantages for generalist phytoseiids in favor of biological control programs. For instance, this feature can reduce intraguild predation and cannibalism, probably by affecting both interspecific and intraspecific competitions (Janssen *et al*. 2003; Hoogerbrugge *et al*. 2011). Different feeding habits may also contribute to survival of predatory mites, particularly when their target prey gets scarce, a factor that could be more effective in successful biocontrol. On the other hand, the supply of high-quality supplementary foods such as pollen, can lead to the attraction of generalist predators to an agricultural system that (and consequently) may help to improve biocontrol programs (Eubanks and Denno 2000). In addition, pollen supplementation could be an important strategy to promote the predator's establishment and may have a stronger positive impact on predatory mite's performance to control pest population. It has been proven that pollen diet can successfully influence biological control of whiteflies (Nomikou *et al*. 2010), thrips (Ramakers 1990), and spider mites (McMurtry and Croft 1997). However, the nutritional profitability of pollens for predators may depend on different factors, such as the species or even the variety of plant from which the pollen grains are obtained, and also the predator species. Thus, phytoseiid mites may have a different developmental and reproductive response to different pollen sources (McMurtry and Croft 1997; van Rijn and Tanigoshi 1999; Goleva and Zebitz 2013; Ranabhat *et al*. 2014).

Predatory mites of the genera *Neoseiulus* Hughes and *Amblyseius* Berlese (Mesostigmata: Phytoseiidae) are considered as generalist predators and well-studied groups of natural enemies demonstrated to be efficient biological control agents of pestiferous mites, and a wide range of small insect pests in agricultural ecosystems worldwide (McMurtry and Croft 1997). Two of the most important species of this category including *Neoseiulus cucumeris* Oudemans and *Amblyseius swirskii* Athias-Henriot, in addition to being known as effective natural enemies of tiny arthropod pests (McMurtry *et al*. 2013), they have previously been found to have a high prey consumption potential (Dalir *et al*. 2021a, b). An important characteristic of these predatory species is the ability to feed, and subsequently, develop and reproduce on pollen diet, which this could insure their survival in the absence of arthropod prey (Riahi *et al*. 2017). Therefore, the initial introduction of *N. cucumeris* or *A. swirskii* into a greenhouse would be sufficient as they could survive the entire growing season without need for reintroduction (Weintraub *et al*. 2011; Calvo *et al*. 2012).

Several studies have paid attention to the nutritional values of different pollens on *A. swirskii* (Lee HeungSu and Gillespie 2011; Riahi *et al*. 2017; Nemati *et al*. 2019; Ansari-Shiri *et al*. 2022; Hadadi *et al.* 2022) and *N. cucumeris* (Van Rijn and Tanigoshi 1999; Ranabhat *et al*. 2014; Yazdanpanah *et al*. 2021; Afshari-Nejad *et al*. 2023). Due the quality of pollen of different cultivars of different plants can have a different effect on the efficiency of different species of predatory mites and phytoseiid mite species differ in their ability to utilize pollen. Due the lack of study on the nutritional value of saffron and proso millet pollens on *N. cucumeris* and *A. swirskii* performance, this study was prepared.

MATERIALS AND METHODS

Pollen collection

Pollen grains were collected from saffron (*Crocus sativus* L., Iridaceae) and proso millet (*Panicum miliaceum* L., Poaceae) during the flowering season from plants at the campus of Faculty of Agriculture, Jiroft University, Kerman, Iran. The pollen grains were oven-dried (at 37 °C for 48 h), then frozen at −20 °C for long-term storage or refrigerated at 4 °C for up to 1 week during the experiments.

Culture of the predators

Neoseiulus cucumeris and *A. swirskii* specimens were purchased from Bio-Planet, Italy, in 2022.

The predators' colonies were established separately on artificial arenas consisting of a plastic sheet (20 × 15 × 0.1 cm) situated on water-saturated foam soaked in water in a plastic container (25 × 16 × 12 cm). The sheet was covered with tissue paper prolonged in the container where water was added daily to prevent mites from escaping. Shelter and oviposition places were supplied by the addition of some cotton thread in the center of each sheet. The colonies of the predatory mites were provided with heavily infested bean leaves with spider mites.

Experimental design

The predatory mites were reared separately on saffron and proso millet pollen grains for two generations before conducting the experiments in a growth chamber at 25 ± 1 °C, relative humidity of 60 ± 5%, and a 16: 8 h (L: D) photoperiod. To obtain the same-aged eggs, 100 mated female adults from the mentioned colonies were introduced to new arenas and removed after 24 h. The newborn eggs of the predators were transferred individually to the experimental units (Dalir *et al*. 2024a, b), up to 70 replicates per treatment. To investigate the influence of the different pollen diets on the predator's performance, after egg hatching, the respective test diet was offered as food (0.05 mg pollen/experimental unit). The units were monitored daily, and the developmental stage, and immature mortality were recorded. The exuviae existence on the sheets was used as a criterion for a successful molt to the next stage. After adult emergence, each newly emerged female was coupled with a male, and they were transferred to a new unit provided with the same food they were fed beforehand. During daily observations, the adults' longevity, fecundity, oviposition period, mortality, and adult lifespan were recorded until the death of the last individual. To prevent leaf decadence and maintain plant quality, the leaf pieces were replaced every alternate day. All experiments were performed at 25 ± 1 °C, 60 ± 5% RH, and a photoperiod of 16:8 h. (L: D).

Statistical analysis

The TWOSEX-MSChart program was used for data analysis according to the age-stage, two-sex life table theory (Chi and Liu 1985; Chi 2022). The means, as well as the standard errors of all parameters, were calculated by the bootstrap procedure using the mentioned program (Chi 2022). To obtain stable estimates 100,000 bootstraps were used. Mean comparisons of all parameters (duration of different life stages, fecundity, reproductive periods, longevities, and population growth parameters) were performed using the paired bootstrap test based on confidence interval.

RESULTS

Individuals of *N. cucumeris* and *A. swirskii* successfully developed from larva to adult when fed on both pollen grains (Table 1). Our results showed similarity in the incubation period, larval, protonymphal, and deutonymphal stages of both predators on the tested pollen grains (Table 1). Developmental time did not differ between the two pollen diets for either predatory mite. *Amblyseius swirskii* completed immature development significantly faster than *N. cucumeris* on both diets tested. There was no significant difference in the male longevity, female longevity and life span of *N. cucumeris* when reared on saffron and proso millet pollen grains (Table 1). The same results were obtained for *A. swirskii*. Adult females of *N. cucumeris* lived 64.41 days on average when fed saffron pollen, which was significantly longer than that of *A. swirskii* females with 55.58 days average longevity. Similarly, adult male longevity and life span of *N. cucumeris* were significantly higher than *A. swirskii* when saffron pollen was offered. The same results were observed when proso millet was offered (Table 1).

Individuals of *N. cucumeris* fed on saffron pollen had a significantly longer adult pre-oviposition period (APOP) than those fed on proso millet pollen, while this parameter was higher on the latter diet for *A. swirskii* (Table 1). Adult females of *N. cucumeris* laid their first eggs after 9.31 days on average when reared on saffron pollen, which was significantly longer than that of proso millet pollen with 8.74 days on average for pre-oviposition period. There were no significant differences in total pre-oviposition period between the two pollen diets for *A. swirskii*. Oviposition period of both predators did not differ between diets. Fecundity of both predator females offered saffron pollen was significantly higher than that of females given proso millet pollen. *Amblyseius swirskii* females had shorter oviposition periods, lower fecundity and laid their first eggs significantly sooner than *N. cucumeris* females (Table 1).

Table 1. Duration of different life stages (days) and reproductive parameters (± SE) of *Neoseiulus cucumeris* and *Amblyseius swirskii* on pollen diets.

Parameters	*Neoseiulus cucumeris*		*Amblyseius swirskii*	
	Saffron	Proso millet	Saffron	Proso millet
Egg	$2.41 \pm 0.09^{aA*}$	2.4 ± 0.09^{aA}	2.01 ± 0.06^{aB}	2.01 ± 0.07^{aB}
Larva	1.03 ± 0.03^{aA}	1.03 ± 0.03^{aA}	1.01 ± 0.01^{aA}	1.00 ± 0.00^{aA}
Protonymph	1.69 ± 0.08^{aA}	1.68 ± 0.09^{aA}	1.36 ± 0.08^{aB}	1.31 ± 0.09^{aB}
Deutonymph	1.44 ± 0.09^{aA}	1.39 ± 0.09^{aB}	1.55 ± 0.08^{aA}	1.53 ± 0.09^{aA}
Pre-adult	6.56 ± 0.10^{aA}	6.50 ± 0.14^{aA}	5.92 ± 0.07^{aB}	5.86 ± 0.06^{aB}
Male longevity	55.3 ± 5.16^{aA}	52.67 ± 5.96^{aA}	50.16 ± 5.51^{aB}	53.29 ± 5.01^{aA}
Female longevity	64.41 ± 4.57^{aA}	58.42 ± 4.91^{aA}	55.58 ± 6.07^{aB}	52.6 ± 4.96^{aB}
Life span	68.12 ± 3.59^{aA}	63.07 ± 3.83^{aA}	58.79 ± 4.06^{aB}	57.63 ± 3.47^{aB}
APOP	2.72 ± 0.14^{aA}	2.16 ± 0.12^{bA}	1.84 ± 0.08^{bB}	2.07 ± 0.18^{aA}
TPOP	9.31 ± 0.19^{aA}	8.74 ± 0.20^{bA}	7.68 ± 0.13^{aB}	7.87 ± 0.17^{aB}
Oviposition days	30.59 ± 1.18^{aA}	28.11 ± 1.44^{aA}	23.36 ± 1.95^{aB}	24.87 ± 2.19^{aB}
Fecundity (eggs)	57.42 ± 3.04^{aA}	43.26 ± 2.10^{bA}	39.79 ± 3.30^{aB}	33.4 ± 3.21^{bB}

* APOP, adult pre-ovipositional period; TPOP, total pre-ovipositional period (from egg to first oviposition).
* The means followed by different small letters in the same row show a significant difference between two pollens for each predator ($P < 0.05$, paired bootstrap test). Different capital letters in the same row show a significant difference between two predators for each pollen ($P < 0.05$, paired bootstrap test).

The age-stage specific survival rates (s_{xj}) of *A. swirskii* and *N. cucumeris* are shown in Figure 1. These curves represent the likelihood that recently laid eggs will survive to a certain age (x) and stage (j). The overlapping of the curves of predator stages indicates the variation in individual development. For females, the probability of newly oviposited eggs reaching the adult stage was 0.55 and 0.63 for *A. swirskii* and *N. cucumeris* on proso millet pollen, respectively. For males, the corresponding probabilities were 0.47 and 0.3, respectively. On saffron pollen, this parameter was 0.48 and 0.65 for females; and 0.46 and 0.29 for males, respectively.

Figure 2 shows the age-specific survival rate (l_x), the age-specific fecundity (m_x), and the age-stage specific fecundity (f_{xj}) of *N. cucumeris* and *A. swirskii* on both pollen diets. The f_{xj} curves represent the number of eggs laid per day by predator individuals at age x and stage j. The l_x of all treatments decreased with age, and the f_x and m_x values of *A. swirskii* and *N. cucumeris* reached their maximum on the 10th day (0.93 and 1.80) and on the 12th day (1.50 and 2.21) for the proso millet pollen, respectively (Fig. 2). These maximums were lower than those of the saffron pollen (1.02 and 2.05 for *A. swirskii* and 1.59 and 2.32 for *N. cucumeris*). Thus, a diet of saffron pollen was more conducive to the development and reproduction of both predators.

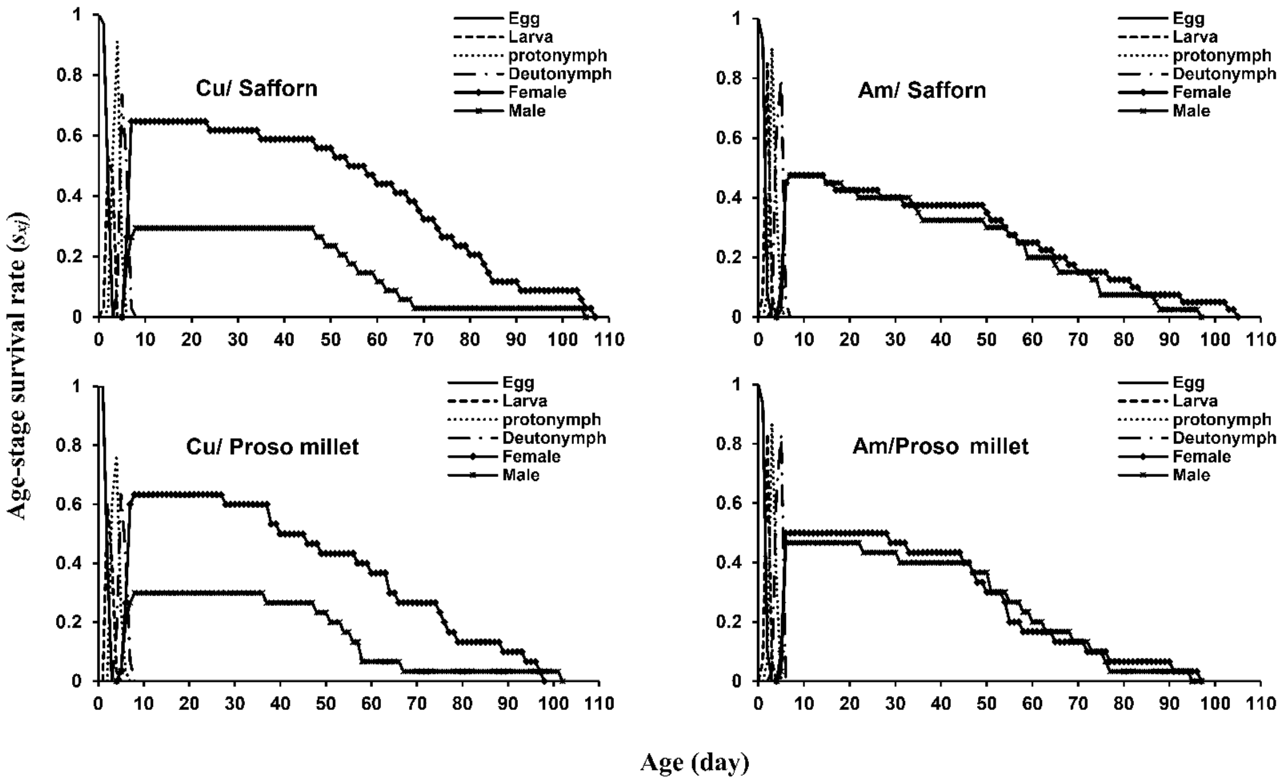

Figure 1. Age-stage survival rate (s_{xj}) of *Neoseiulus cucumeris* and *Amblyseius swirskii* on pollen of proso millet and saffron.

In all treatments, the value of e_{xj} decreased (Fig. 3). For *A. swirskii*, the maximum mean lifetime values were 56.1 and 56.9, on saffron and proso millet pollen, respectively. This parameter was 64.41 and 59.17 days, for *N. cucumeris*, respectively. At age zero, the v_{xj} values of *A. swirskii* individuals that were fed saffron and proso millet pollen were 1.20 and 1.19, respectively, while it was 1.21 on both diets for *N. cucumeris* (Fig. 4). The maximum value of the v_{xj} curve increased with age and developmental stage, with the highest peak reached on the 11th and 9th day for the individuals of *N. cucumeris* (12.0 and 11.08 on saffron and proso millet pollen, respectively) and *A. swirskii* (10.28 and 9.28 on saffron and proso millet pollen, respectively), respectively. Female adults reared on saffron pollen exhibited the highest v_{xj} value (Fig. 4).

Net reproductive rate (R_0) and gross reproductive rate (*GRR*) of *N. cucumeris* offered saffron pollen were significantly higher than that of females given proso millet pollen, whereas in *A. swirskii* these parameters did not differ between pollen grains (Table 2). There were no significant differences in intrinsic rate of increase (r) and finite rate of increase (λ) of *N. cucumeris* between the two pollen diets, although significantly higher values of r and λ were observed in *A. swirskii* reread on saffron pollen than those fed on proso millet pollen. Females of *N. cucumeris* reared on saffron pollen had a longer mean generation time (T) than those fed on proso millet pollen, while no significant differences were found in this parameter between the two diets for *A. swirskii*. Comparisons between the two predators indicated that *N. cucumeris* females had a higher R_0, *GRR*, r, and λ, and longer T than *A. swirskii* on saffron and proso millet pollen (Table 2).

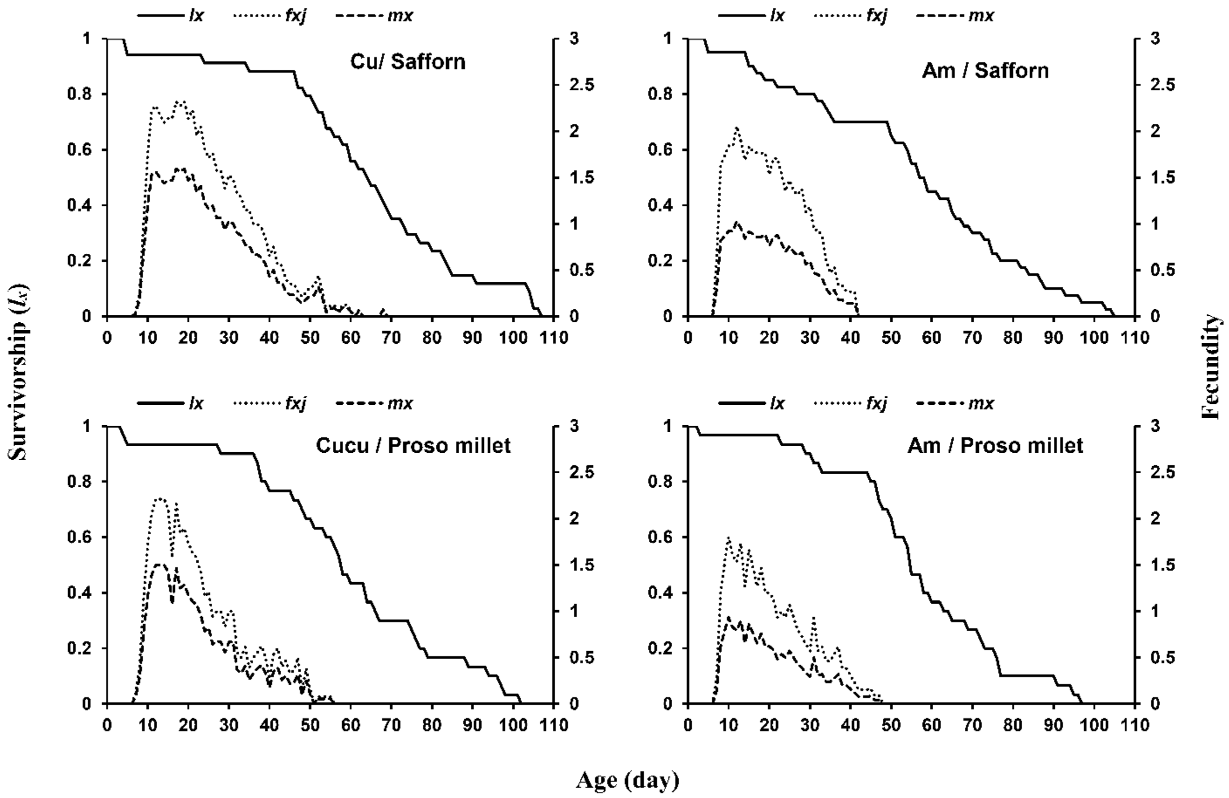

Figure 2. Age-specific survivorship (l_x), age specific fecundity (m_x) and age-stage specific fecundity (f_{xj}) of *Neoseiulus cucumeris* and *Amblyseius swirskii* on pollen of proso millet and saffron.

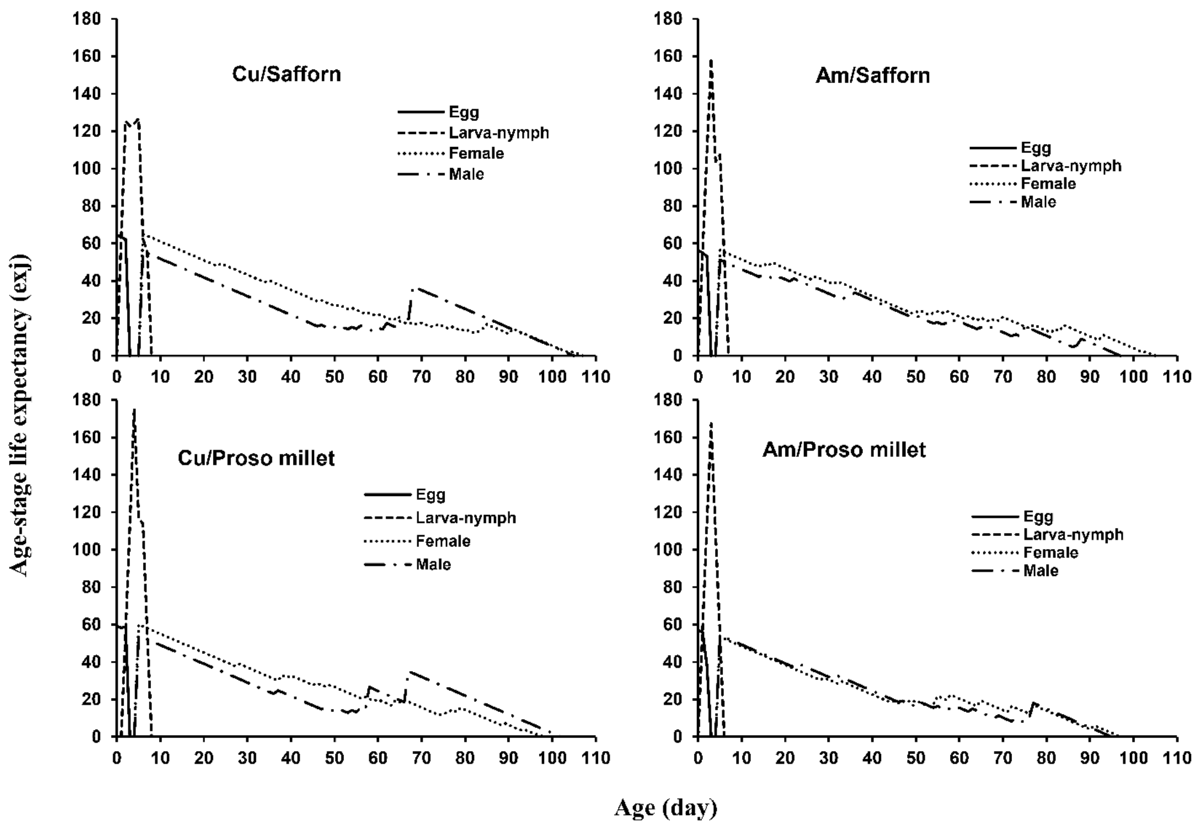

Figure 3. Age- stage life expectancy (e_{xj}) of *Neoseiulus cucumeris* and *Amblyseius swirskii* on pollen of proso millet and saffron.

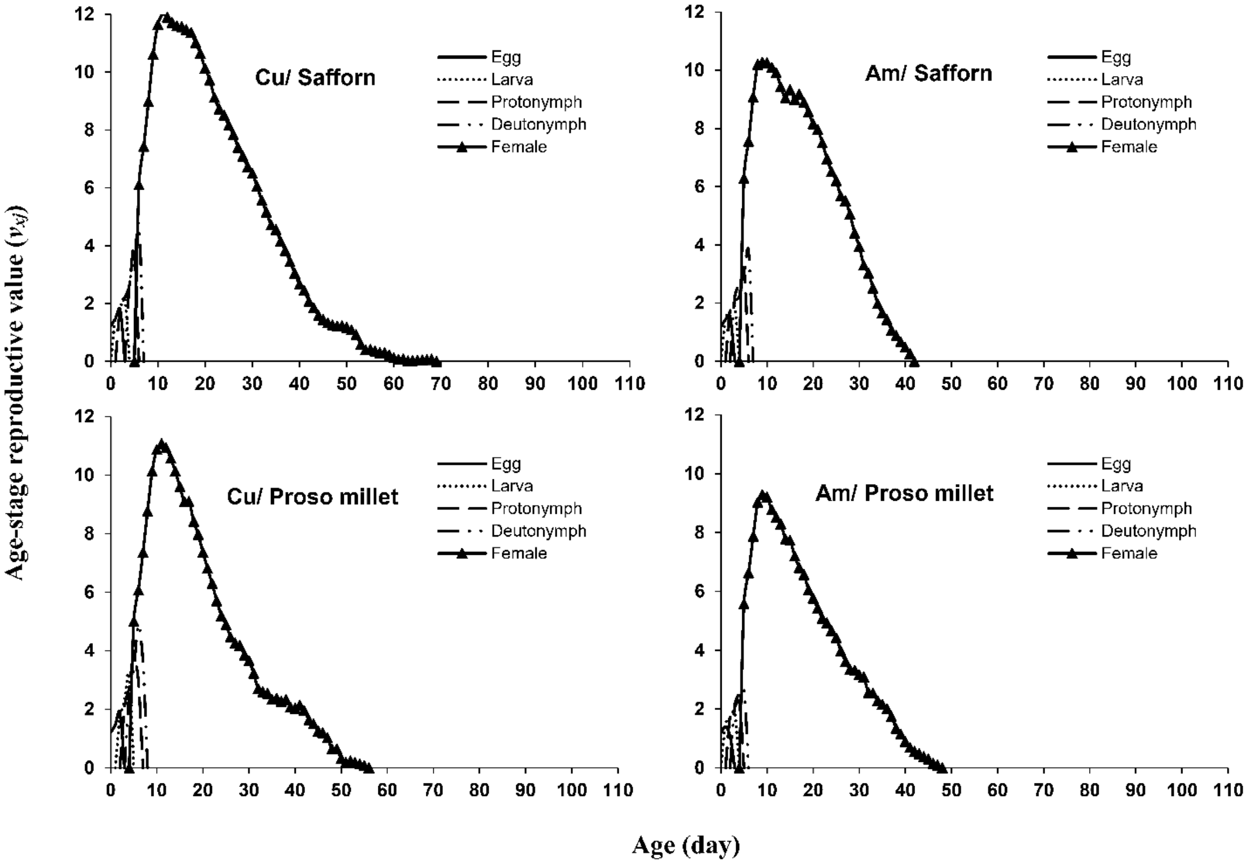

Figure 4. Age-stage-specific reproductive value (v_{xj}) of *Neoseiulus cucumeris* and *Amblyseius swirskii* on pollen of proso millet and saffron.

Table 2. The mean (± SE) population growth parameters of *Neoseiulus cucumeris* and *Amblyseius swirskii* on pollen diets.

	Neoseiulus cucumeris		*Amblyseius swirskii*	
Parameters	**Saffron**	**Proso millet**	**Saffron**	**Proso millet**
r (day^{-1})	$0.195 \pm 0.009^{aA*}$	0.191 ± 0.010^{aA}	0.181 ± 0.013^{aB}	0.169 ± 0.014^{bB}
λ (day^{-1})	1.216 ± 0.011^{aA}	1.211 ± 0.012^{aA}	1.199 ± 0.015^{aB}	1.185 ± 0.017^{bB}
GRR (offspring)	40.69 ± 5.32^{aA}	30.26 ± 4.24^{bA}	21.93 ± 3.90^{aB}	17.85 ± 3.61^{aB}
***R*₀** (offspring)	37.16 ± 5.09^{aA}	27.40 ± 4.01^{bA}	18.90 ± 3.49^{aB}	16.70 ± 3.43^{aB}
T (day)	18.42 ± 0.44^{aA}	17.23 ± 0.38^{bA}	16.09 ± 0.38^{aB}	16.44 ± 0.42^{aB}

* The means followed by different small letters in the same row show a significant difference between two pollens for each predator ($P < 0.05$, paired bootstrap test). Different capital letters in the same row show a significant difference between two predators for each pollen ($P < 0.05$, paired bootstrap test). *GRR*: gross reproductive rate; R_0: net reproductive rate; *r*: intrinsic rate of increase; λ: finite rate of increase; *T*: mean generation time.

DISCUSSION

Demographic parameters are useful and reliable indicators for describing the quality of pollen grains and factitious prey as food for generalist phytoseiid mites (Khanamani *et al*. 2017, 2021). Various phytoseiid species have shown significant differences in these parameters, which are attributed to variations in food quality. This study determined the life history traits of two phytoseiid mites on two different types of pollen grains. Consistent with previous research, we confirmed that the performance of predatory mites is influenced by both the type of pollen and the species of predator (Riahi *et al*. 2016; Khanamani *et al*. 2017; Nemati *et al*. 2019; Kadkhodazadeh *et al*. 2021; Eini *et al*. 2022;

Naqshbandi *et al*. 2023). In our experiment, both the juvenile stages and adult predators were able to feed on any type of pollen offered. Furthermore, by the comparisons between our results and previous studies saffron pollen is a better food source for both predators compared to their natural prey, *Tetranychus urticae* Koch (Dalir *et al*. 2024a, b).

Our results showed that providing saffron pollen to both *A. swirskii* and *N. cucumeris* resulted in the same level of immature and adult development as providing them with proso millet pollen. Additionally, we found that saffron pollen is a suitable diet for *A. swirskii*, as it led to a significant increase in fecundity and intrinsic rate of increase, while also reducing the pre-oviposition period compared to proso millet pollen. Although supplying saffron pollen resulted in the same population growth rates in *N. cucumeris* as supplying proso millet pollen, the predatory mite exhibited higher oviposition and reproductive rates when fed saffron pollen rather than proso millet pollen. Therefore, saffron pollen proved to be of high quality during both juvenile and maturity of *N. cucumeris* and *A. swirskii*. In line with our findings, other researchers have also identified this pollen as suitable food for *Neoseiulus californicus* (McGregor) (Eini *et al*. 2022) and *N. cucumeris* (Naqshbandi *et al*. 2023).

The total developmental time from egg to adult emergence and total pre-oviposition period in *N. cucumeris* on tested pollens were longer than *A. swirskii*. In addition, the developmental time of *N. cucumeris* and *A. swirskii* individuals fed on *T. urticae* (8.11 and 7.97 days, respectively) was significantly longer than those reared on *Frankliniella occidentalis* (Pergande) (6.89 and 7.09 days, respectively) (Dalir *et al*. 2024a, b). Regarding the adult longevity, oviposition period, fecundity, and growth rate of the two phytoseiid mites, on both pollen gains, *A. swirskii* showed a shorter duration of the adult stage and oviposition period, as well as lower fecundity and population growth rates than *N. cucumeris*. Also, *A. swirskii* had a shorter life span, as well as lower fecundity and population growth rates than *N. cucumeris* on both natural prey (*T. urticae* and *F. occidentalis*) (Dalir *et al*. 2024a, b). This indicates that the supply of *N. cucumeris* nymphs positively influenced postembryonic development. In addition, this predator had a better performance on saffron and proso millet pollen grains than *A. swirskii*. The suitability of pollen is dependent on the mite species and the type of pollen (Ranabhat *et al*. 2014). Successful pollen-feeding relies on the compatibility of mouthpart and pollen morphology, as well as the mites' digestive metabolism. Thus, it appears that *N. cucumeris* is more efficient in digesting nutrients and other food components in these grains compared to *A. swirskii*. This could be due to a better match between its mouthpart morphology and the morphology of saffron and proso millet pollen grains. However, more research is needed to fully understand these aspects.

McMurtry and Croft (1997) demonstrated that the intrinsic rate of increase of Phytoseiidae can be below 0.1, but it increases to 0.25 when fed on spider mites or pollen. For example, Nguyen *et al*. (2015) reported that the intrinsic rate of increase for *N. cucumeris* was 0.185 day^{-1} when fed on *Typha latifolia* L. pollen. Other studies (van Rijn and Tanigoshi 1999; Ranabhat *et al*. 2014; Yazdanpanah *et al*. 2021; Afshari-Nejad *et al*. 2023; Naqshbandi *et al*. 2023) have shown that when these predators feed on pollen from different sources such as apple, birch, Christmas cactus, horse-chestnut, maize, tulip, castor pollen, *Panicum miliaceum* L., *Punica granatum* L., *Eruca sativa* (Jarjeer), *Chenopodium album* L., *Chaenomeles cathayensis* (Hemsley), *Datura stramonium* L., or *Caesalpinia gilliesii* (Hooker), the intrinsic rate of increase decreases to values ranging from −0.097 to 0.156 day^{-1}. However, in our study, the calculated *r*-values were higher than those reported in the aforementioned studies, although they were slightly lower than the value of 0.208 reported by van Rijn and Tanigoshi (1999) when the predator was offered pollen from broad bean (*Vicia faba* L.). Similarly, there was a significant variation (ranging from −0.10119 to 0.17984 day^{-1}) in the intrinsic rate of increase values of *A. swirskii* found in different studies on various pollen grains (Goleva and Zebitz 2013; Riahi *et al*. 2016, 2017; Nemati *et al*. 2019). In the present study, the highest intrinsic rate of increase of *A. swirskii* was estimated for individuals fed on saffron pollen (0.181 day^{-1}), surpassing the rates reported in the aforementioned studies. The conflicting findings of the various studies may be due to differences in the food sources consumed by the predator at different stages of its lifespan, variations in experimental conditions (such as temperature), and disparities in the statistical analyses used.

Comparisons between the performance of *N. cucumeris* on tested pollens in this study, and two natural prey species (Dalir *et al*. 2024b) showed that individuals fed with saffron and proso millet pollen had longer longevity, APOP, and reproductive periods. They also had lower r and λ compared to *F. occidentalis*. The same comparison between pollen diets and *T. urticae* indicated that the mites developed faster, lasted longer, and had a faster growth rate on pollen diets compared to *T. urticae*. In addition, in contrast to the feeding of *A. swirskii* on *F. occidentalis* (Dalir *et al*. 2024a), which resulted in a higher population growth rate than the pollen grains tested here, rearing *A. swirskii* on *T. urticae* caused slower pre-adult development and lower growth rates (Dalir *et al*. 2024a). Therefore, *F. occidentalis* and *T. urticae* seem to be of high and poor nutritional quality, respectively, for both predatory mites compared to the pollen grains tested in this study. In addition, the population growth rate of *N. cucumeris* in this study (0.191 and 0.195 day^{-1}) was higher than its growth rate on natural prey such as *T. urticae* (0.147 day^{-1}) (van Rijn and Tanigoshi 1999). It was also higher than its growth rate on factitious prey like *Ephestia kuehniella* Zeller, *Sitotroga cerealella* (Olivier), and *Spodoptera littoralis* (Boisduval) (0.126, 0.110, and 0.085 day^{-1}, respectively) (Al-Shemmary 2018), as well as *Tyrophagus putrescentiae* (Schrank) (0.096 day^{-1}) (Yazdanpanah *et al*. 2022). Similarly, the growth rate of *A. swirskii* on the pollen grains tested here is higher than the values recorded on natural prey, including *T. urticae* (Riahi *et al*. 2016, 2017), *Panonychus citri* (McGregor) (Ji *et al*. 2013), and *Thrips tabaci* (Lindeman) (Wimmer *et al*. 2008). This suggests that saffron and proso millet pollen could be viable alternative food sources for these predators, particularly during times when prey in the field are scarce or absent. Additionally, our results show that saffron pollen can be effectively used for mass rearing of these predatory mites in laboratory settings.

ACKNOWLEDGMENTS

The support of this research by the Department of Plant Protection, University of Jiroft, Kerman, Iran, is greatly appreciated.

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ارزش غذایی منابع غیر شکار برای پرورش کنه‌های شکارگر *Neoseiulus cucumeris* و *Amblyseius swirskii* (Acari: Phytoseiidae)

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چکیده

در این پژوهش، به منظور ارزیابی ارزش غذایی دانه‌های گرده ارزن و زعفران به عنوان مکمل‌های غذایی برای پرورش و حفاظت از کنه‌های شکارگر *Neoseiulus cucumeris* Athias-Henriot و *Amblyseius swirskii* Athias-Henriot (Acari: Phytoseiidae)، مطالعات جدول زندگی انجام شد. بر اساس این نتایج، طول دوره نابالغ برای هرکدام از شکارگرها روی دو رژیم غذایی گرده تفاوت معنی‌داری نداشت. به هر حال کنه شکارگر *A. swirskii* طول دوره نابالغ خود را روی هر دو گرده مورد بررسی زودتر از کنه *N. cucumeris* کامل کرد. باروری ماده‌های هر دو شکارگر تغذیه کرده از گرده زعفران به مقدار زیادی بیشتر از ماده‌های تغذیه کرده از گردهٔ ارزن بود، با این حال، ماده‌های *N. cucumeris* باروری بیشتری نسبت به ماده‌های *A. swirskii* داشتند. مقایسه بین دو شکارگر نشان داد که *N. cucumeris* روی هر دو گرده زعفران و ارزن مقادیر بالاتری از R_0، *GRR*، *r* و *λ* نسبت به *A. swirskii* داشت. اختلاف معنی‌داری در نرخ ذاتی افزایش جمعیت (*r*) و نرخ متناهی افزایش جمعیت (*λ*) کنه شکارگر *N. cucumeris* بین دو رژیم غذایی گرده وجود نداشت اگرچه به طور معنی‌داری مقادیر بیشتری از نرخ ذاتی افزایش جمعیت (*r*) و نرخ متناهی افزایش جمعیت (*λ*) در کنه‌های *A. swirskii* پرورش یافته روی گرده زعفران نسبت به افراد تغذیه شده با گردهٔ ارزن مشاهده شد. این نشان می‌دهد که گرده زعفران و ارزن می‌تواند یک منبع غذایی جایگزین مناسب برای این شکارگرها باشد، به ویژه در مواقعی که طعمه در مزرعه کمیاب است یا وجود ندارد. افزون بر این، نتایج حاصل نشان می‌دهد که گرده زعفران می‌تواند به طور موثر برای پرورش انبوه و/یا حفاظت از این کنه‌های شکارگر در برنامه‌های زیستی استفاده شود.

واژگان کلیدی: حفاظت، پرورش انبوه، گرده، کنه شکارگر، رژیم غذایی مکمل.

اطلاعات مقاله: تاریخ دریافت: ۱۴۰۳/۳/۱۵، تاریخ پذیرش توسط *آ. فرازمند*: ۱۴۰۳/۹/۵، تاریخ چاپ: ۱۴۰۳/۱۰/۲۶