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Biology and life table of the predatory mite *Euseius aizawai* (Acari: Phytoseiidae)

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Abstract

Pollens of 19 plant species were used as diets in a laboratory study of the life history of *Euseius aizawai* (Ehara & Bhandhufalck) (Acari: Phytoseiidae). The mite ingested pollens of all tested plant species and produced eggs. On eight of them the predator completed all developmental stages, with a life cycle of 5.47±0.88 to 6.95±1.61 days. The longest life-span of adults was observed when feeding on pollens of *Coriaria sinica, Zea mays*, mixed species and *Punica granatum*. Larvae had a higher survival rate (70% to 82%) when reared with the pollens of *Luffa cylindrica, Trachycarpu*s *excelsa, punica granatum* and *Betula platyphylla*. Longevity of adult females was longer with pollens of *Coriaria sinica, Zea mays* and mixed species. The oviposition period was from 15.05±4.05 to 25.55±15.25 days, the longest when feeding on pollens of *Zea mays*, mixed species and *Coriaria sinica*. Fecundity ranged from 23.50±13.50 to 54.50±19.50 per female and the highest was on pollens of mixed species, *Luffa cylindrica* and *Punica granatum.* The sex ratio (proportion of females) was highest when feeding on pollen of *Luffa cylindrica*. The most suitable range of humidities for egg hatching was 70% to 90%. The net reproduction rate of increase (R_0) was the highest on the pollen of *Luffa.cylindrica*, and the intrinsic rate of natural increase (r_m) and finite rate of increase (λ) were the highest on the pollen of *Trachycarpus excelsa.*

Key words: laboratory condition, *Euseius aizawai*, biology, life table, plant pollen

Introduction

The citrus red mite, *Panonychus citri* (McGregor), is a major pest of citrus in Guizhou Province, southwest China. Farmers have to spray more than eight times each year in order to control this mite, especially during the fruiting season, but the efficiency of chemical control is low due to the development of resistance to acaricides. In addition, the cost of labour for acaricide application is high. We therefore feel that it is necessary to search for a predator that is easy and cheap to produce for augmentative biocontrol.

Several predators of the family Phytoseiidae are known to attack the citrus red mite (Gerson 2003). In central Guizhou, *Euseius aizawai* (Ehara & Bhandhufalck) is an important natural enemy of *P. citri* in citrus orchards. This mite had been well conserved for controlling *P. ctiri* in citrus orchards in Guiyang, Guizhou, but little is known about its biology. In order to improve the use of this predator, we conducted observations and experiments with different plant pollens in the laboratory, and investigated the possibility for rearing this mite on the pollen of various plants for the augmentative control of the citrus red mite in citrus orchards.

This paper reports the biology and population life table parameters of *E. aizawai* in the laboratory, to provide a better basis for evaluating it as a predator of citrus red mite in citrus orchards in Guizhou, China.

Material and methods

Food sources

Panonychus citri was collected from a citrus orchard in Guizhou, China and was used for an experiment on prey choice in the laboratory.

Pollens were collected from the 19 plant species listed below:

Family	Species
1. *Pinaceae*	*Pinus massoniana*
2. *Solanaceae*	*Datura stramonium*
3. *Graminaceae*	*Zea mays*
4. *Fagaceae*	*Quercus glauca*
5. *Punicaceae*	*Punica granatum*
6. *Malvaceae*	*Althaea rosea*
7. *Betulaceae*	*Betula platyphylla*
8. *Palmaceae*	*Trachycarpus excelsa*
9. *Cucurbitaceae*	*Cucurbita moschata*
10. *Cucurbitaceae*	*Luffa cylindrica*
11. *Coriariaceae*	*Coriaria sinica*
12. *Chenopodiaceae*	*Kochia scoparia*
13. *Caprifoliaceae*	*Lonicera japonica*
14. C*ompositae*	*Chrysanthemum coronarium*
15. *Cruciferae*	*Brassica campestris*
16. *Leguminosae*	*Caesalpinia sepiaria*
17. *Oleaceae*	*Ligustrum lucidum*
18. Pap*ilionaceae*	*Pisum sativum*
19. *Euphorbiaceae*	*Ricinus communis*

All pollens were collected during the flowering season and stored in a refrigerator at 0–5°C for use after being dried in sunlight.

Laboratory conditions and methods

The study was conducted in a rearing room at 26±0.5°C, 75%RH and photoperiod of 12L: 12D. The rearing unit for the laboratory culture was a piece of round sponge fully soaked with water in a petri dish (12 cm diameter). The sponge was covered by a black cloth which was then covered by a plastic membrane. A piece of paper was placed in the centre of the membrane for holding pollen grains, which were replaced every other day. Cotton fibres were placed on the membrane for mite oviposition.

Observations on predator feeding citrus red mites

Feeding on prey: Each treatment consisted of 30 eggs, larvae, nymphs and adults of *P. citri*, plus one adult female of *E. aizawai*, placed together on a membrane in a 12 cm diameter petri dish. Three replicaties were observed and the number of *P. citri* consumed were recorded 24 hours after the start of the experiment.

Feeding on pollens: Rearing units were similar to those used in the former test, except for the size of the petri dishes (9 cm in diameter). Pollens from the 19 plant species mentioned above were used for each treatment, which consisted of 3 replicaties. Per treatment, 30 predator nymphs 1 to 2 days old were used, the control being a dish only with pure water, without pollens. Each treatment was examined on the seventh, tenth and fourteenth day, and the observations ended when all mites in the controls died. Plant pollens that had increased the number of *A .aizawai* by more than 36% by the tenth day were chosen for further experiments.

Developmental rate, survival rate, female longevity and feundity of E.aizawai

Pollen grains of seven plant species and 1 of mixed species (of equal parts from *Luffa cylindrical, Coriaria sinica, Betula platyphylla, Quercus glauca* and *Pinus massoniana*) were used as foods. The rearing unit was in a 12 cm diameter petri dish that had 5 pieces of 3 cm diameter membrane. Each type of pollen, plus a predator larva that had hatched within 3 hours was added to every small cell. Each treatment was in 30 replicates which were observed until all mites died. Developmental durations and survival rates were observed every 6 hours under a microscope and recorded. When they became adults the females were paired with males, and as they began to lay eggs, cotton fibres were placed onto the membrance. Observations were carried out at 9:00 every day and the recorded eggs were transferred to be reared in another dish. Hatching rate was observed for these eggs, and their sex ratio was determined when all mites became adults.

The influence of humidity on hatching

Different saturated salt solutions were made up (Winston and Bates, 1960), in order to create seven different relative humidities (RH) in sealed desiccators. The temperature was maintained at 26±0.5°C. Eggs laid within 3 hours were transferred onto a slide and then put into the desiccators for examining the rate of hatching. At least 51 eggs were examined per treatment.

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Life table analysis

Population parameters: A life table using time-specific survival rates (*lx*) and fecundity (m_x) for each 24 hours period was constructed for calculating the following life table parameters (Xia 1998; Liu *et al.* 2004; Ji *et al.* 2005):

Net reproduction rate of increase: $Ro=\Sigma l_x m_x$
Mean generation time (in days): $T=\Sigma l_x m_x^{-x}/Ro$
Intrinsic rate of increase: $r_m = InRo/T$
Finite rate of increase: $\lambda = e^{rm}$
Population doubling time (in days): $p.d.t=ln2/ r_m$

Population trend index (I): A life table was constructed for the experimental population on the basis of the observations of the survival of all immature, egg / female, and the sex ratio. The population trend indices were also calculated. .

Results

General observations on feeding habits

Feeding on citrus red mites: *E. aizawai* attacked all stages of the citrus red mite. When given a mixture of 30 individuals of each stage, each predator female consumed 5.8, 7.7, 4.6 and 2.5 eggs, larvae, nymphs and adults of prey, respectively, within 24 hours.

Feeding on plant pollen: *E. aizawai* fed on pollens from all 19 plants that were tested. The mites developed and oviposited normally. Thes plant pollens could thus be used as food for mass-rearing the predatory mites, either in the laboratory or in the field.

Developmental duration of E. aizawai

The development of *E. aizawai* consists of egg, larva, protonymph, duetonymph and adults. Data on the duration of the various developmental stages are presented in Table 1. *Euseius aizawai* completed its development on 7 plant pollens and the pollen mixture, but the duration of each developmental stage was different amongst the eight treatments. Durations of the egg stage were much longer than those of the larval, protonymphal and duetonymphal stages. It took 5.47±0.88 to 6.95±1.61 days for this species to complete a life cycle on the various pollens (Table 1) and the life cycle was shortest on the pollen mixture, which was the best for rearing this predator in the laboratory.

TABLE 1. Duration of the developmental stages of *Euseius aizawai* on the various pollens.

Plant pollen	Egg	Larva	Protonymph	Duetonymph	Pre-oviposition	Life cycle	Adult life-span
B. platyphylla	2.02±0.19	0.96±0.29	1.24±0.27	1.15±0.44	1.33±0.50	6.34±2.02	16.8±6.2
T. excelsa	1.73±0.40	1.09±0.12	0.86±0.15	1.11±0.40	1.13±0.42	5.82±1.57	24.8±13.0
C. sinica	1.80±0.17	1.06±0.19	1.19±0.48	1.34±0.38	1.49±0.22	6.95±1.61	39.7±23.6
L. lucidum	1.71±0.24	1.02±0.15	1.21±0.50	1.11±0.14	1.35±0.40	6.76±1.12	21.0±7.7
P. granatum	1.86±0.36	1.08±0.41	1.03±0.36	1.09±0.38	1.11±0.40	6.16±1.90	26.0±15.3
Z. mays	1.89±0.28	0.92±0.13	1.02±0.27	1.23±0.27	1.02±0.27	6.08±1.22	31.5±21.0
L. cylindrica	1.92±0.21	1.06±0.31	1.13±0.50	0.88±0.25	1.32±0.19	6.30±1.45	24.3±13.0
Mixture*	1.65±0.27	1.06±0.19	0.84±0.13	0.88±0.17	1.05±0.13	5.47±0.88	29.1±15.7

* Mixture: pollens of *L. cylindrica, B. platyphylla, C. sinica, Q. glauca* and *P. massoniana,* in equal parts.

Survival rate of A.aizawai

The survival rate of the various developmental stages differed among different pollen treatments. Survial rates of egg, protonymph and duetonymph were higher than that of the larval stage, the highest survival rate reaching only 82.00% on *L. cylindrca*. Overall survial rate was highest on the pollen mixture (Table 2).

TABLE 2. Survival rates of each developmental stage of *Euseius aizawai* on the various pollens.

Plant pollens	Eggs	Larva	Protonymph	Duetonymph	% adult over 15days
B. platyphylla	87.84	70.00	81.67	81.67	21.43
Texcelsa	86.67	76.67	100.00	100.00	40.00
C. sinica	84.61	40.00	91.67	81.67	55.56
L. lucidum	88.88	50.00	100.00	86.67	38.46
P. granatum	89.29	73.00	90.91	95.00	27.78
Z. mays	92.86	53.00	81.25	76.92	30.00
L. cylindrica	98.04	82.00	78.05	84.38	38.46
Mixture	82.76	40.00	83.33	100.00	66.67

Longevity and fecundity of adult female of E. aizawai

Mating and oviposition: Mating accurs as soon as the male and female *A.aizawai* emerge as adults. The male holds the female below her idiosoma during pairing. The eggs produced by fertilized females gave rise to both male and female offspring. Females prefer to lay eggs on the fibres of cotton placed on plastic arenas in the laboratory.

Longevity and fecundity: Longevity and fecundity differed on the different pollens (Table 3). The longevity of adult females ranged from 18.08±6.22 to 41.09±22.44 days, the shortest being on pollen of *B. platyphylla* and the longest on pollen of *C. sinica*. The pre-oviposition period ranged from 1.02±0.27 to 1.49±0.22 days, the shortest being recorded on pollen of *Z. mays* (Table 3). The length of the oviposition perriod was the most important factor determining the reproductive ability; it was only 15.05±4.05 on pollen of *B. platyphylla,* and longest, 25.55±15.25 days, on pollen of *Z. mays*. The fecundities of females reared on mixed pollens and on the pollen of *L. cylindrica* were significantly higher than those on the other pollens, with a daily production rate of 3.00±2.00 and 3.50±2.50 eggs/female/day, and a sex ratio of 1.81:1 and 2.25:1, respectively. Mixed pollens and pollen of *L. cylindrica* were thus considered as the most suitable food resource for the maximal fecundity of *E. aizawai.* Adult females can lay a large number of eggs during the oviposition period, which makes it possible for the mite to rapidly develop a large population.

TABLE 3. Longevity and fecundity of females of *Euseius aizawai* on the various pollens.

Plant pollens	Longevity	Oviposition period	Oviposition amount	Eggs/female/day	Sex ratio Female:Male	female%
B. platyphylla	18.08±6.22	15.05±4.05	31.00±10.00	2.50±1.50	1.71:1	63.15
T. excelsa	25.97±13.80	21.00±11.00	33.50±5.50	2.50±1.50	1.52:1	60.33
C. sinica	41.09±22.44	17.75±7.25	33.50±19.50	2.50±1.50	1.14:1	53.33
L. lucidum	22.38±8.09	16.50±5.50	23.50±13.50	2.00±1.00	0.94:1	48.43
P. granatum	27.11±15.67	18.90±7.90	47.50±25.50	3.00±2.00	1.19:1	54.44
Z. mays	32.42±21.16	25.55±15.25	34.00±15.00	3.00±2.00	1.25:1	55.55
L. cylindrica	25.52±13.17	18.85±5.64	50.50±19.50	3.50±2.50	2.25:1	60.92
Mixture	30.05±5.60	21.00±10.00	54.50±19.50	3.00±2.00	1.81:1	64.44

The effect of humidity on hatching

The egg hatching rates of *E. aizawai* under various RH levels are presented in Table 4. The hatching rate increased with the increase in relative humidity; when RH rates were 70%–90%, the hatching rate ranged from 91.43% to 100.00%. Therefore 70%–90% RH rates were considered as optimal for egg hatching. When the RH reached 100%, hatching rate decreased drastically. On the other hand, the hatching rate was 26.76 % at relative humidity of 40%.

TABLE 4. Effect of relative humidity on the egg hatching rate of *Euseius aizawai* feeding on *L. cylindrica*.

Relative humdity %	40	50	60	70	80	90	100
No. (examined)	71	124	125	105	51	66	124
No. (hatched)	19	89	93	96	50	66	96
Hatching rate (%)	26.76	71.77	74.40	91.43	98.04	100.00	77.42

Population life table parameters of E. aizawai

Population parameters were calculated and are listed in Table 5, which indicates that different plant pollens exerted great influence on the population parameters of *E. aizawa*i. Both the net reproductive rate (R_0) and the intrinsic rate of natural increase (r_m) were, respectively, more than one and zero, which showed that these pollens can promote the population increase of this mite. But the net reproductive rates on mixed pollens and pollens of *L. cylindrica*, *T. excelsa* and *P. granatum* were greater than on other pollens, which agreed with results of previous analyses. The mean longevity of a generation on mixed pollens and pollen of *C. sinica, Z .mays, L. cylindrica* and *P. granatum* was longer than those of the other pollens. Both the intrinsic rate of natural increase (r_m) and the finite rate of increase (λ) on pollens of *T. excelsa, P. platyphylla, L. cylindrica, C. sinica, P. granatum* and mixed pollens were higher than on those of the other pollens, and population doubling time (*p.d.t*) with these plant pollens was shorter.

TABLE 5. Population life table parameters of *Euseius aizawai* on the various pollens.

Plant pollens	R_o	T	r_m	λ	P.d.t	I
B. platyphylla	9.3335	12.6	0.1767	1.1932	3.92	8.41
T. excelsa	12.1339	13.4	0.1856	1.2039	3.74	9.32
C. sinica	7.3670	16.9	0.1185	1.1258	5.85	4.38
L. lucidum	5.6080	14.9	0.1156	1.1225	6.00	3.73
P. granatum	11.3916	15.4	0.1577	1.1708	4.40	11.11
Z. mays	6.7675	16.0	0.1196	1.1270	5.80	5.93
L. cylindrica	13.6364	15.8	0.1651	1.1795	4.20	13.29
Mixture	13.4939	17.3	0.1503	1.1621	4.61	3.91

Discussion

Many species of *Euseius* are generalist predators that perform well on pollens (Type VI predatory according to McMurtry & Croft 1997). The use of pollen as a diet of these mites has greatly facilitated their mass-rearing. In Guizhou, *Euseius nicholsi* (Ehara & Lee), which was a biocontrol agent of *Eotetranychus kankitus* Ehara, which was successfully reared on pollen of several plant species (Zhi *et al.*, 1998).

Euseius aizawai is a natural enemy preying on pest mites on leaves of citrus and can control the citrus red mite infesting citrus orchards in central Guizhou. In this study, we showed that this predatory mite fed on pollens of all 19 tested plant species. Thus, these plant pollens may be used as food for mass-rearing the predatory mite, either in the laboratory or in the field. *Euseius aizawai* reared on plant pollens in the laboratory may be released for controlling citrus red mites in citrus orchards. The flowering plants growing by the side of citrus orchards should be protected and may provide pollens for predatory mites when the spider mite numbers are low in the field.

Although *E. aizawai* reproduced on all pollens, its developmental duration, survival rate, life cycle, longevity and feundity differed with different plant pollens. The intrinsic of natural increase (r_m) on pollen of *T. excelsa* was the highest indicating that the pollen of *T. excelsa* is the best for laboratory mass-rearing of this predatory mite.

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