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BIOLOGY OF A SPIDER MITE, *Tetranychus urticae* Koch, AND A PHYTOSEIID PREDATOR, *Proprioseiopsis lenis* (Corpuz & Rimando), AND ITS BIOLOGICAL CONTROL POTENTIAL[1]

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ABSTRACT

The life histories of the spider mite, *Tetranychus urticae* Koch, on *Rosa* sp. 'Bravo', and of the phytoseiid predator, *Proprioseiopsis lenis* (Corpuz & Rimando), were studied under ambient laboratory conditions, together with the biocontrol potential of *P. lenis*, using *T. urticae* larvae as prey. The mites underwent egg, larval, protonymphal, and deutonymphal stages before reaching the adult stage. For *T. urticae,* average durations (days) of life stages for female and male were: incubation, 3.43±0.11 and 3.63±0.11; larva, 1.70±0.24 and 1.68±0.09; protonymph, 1.63±0.07 and 1.72±0.12; and deutonymph, 1.83±0.09 and 2.23±0.29, respectively. The female completed development within 8.60±0.24, and the male, 9.22±0.35 days. Adult males live longer (16.31±1.34 days) than females (14.83±0.59 days). Arrhenotokous parthenogenesis and sexual reproduction were observed. Pre-oviposition, oviposition, and post-oviposition period were: 1.06±0.14, 10.08±0.72, and 3.70±0.14 days, respectively. Fecundity ranged from 11-126 eggs, and hatchability, 85.11-100%. Sex ratio was 2.13 females : 1 male. For *P. lenis*, all progenies were females; hence, it showed thelytokous parthenogenesis. Average durations (days) of stages were: incubation, 1.37±0.07; larva, 0.89±0.04; protonymph, 1.03±0.05; and deutonymph, 1.20±0.08. Development was completed within 4.50±0.12 days. Mean adult longevity was 20.45±1.50 days. Pre-oviposition, oviposition, and post-oviposition periods were: 1.95±0.22, 16.20±1.31, and 2.67±0.51 days, respectively. Fecundity ranged from 7-74 eggs and hatchability, 98-100%. *P. lenis* prefers *T. urticae* larvae as prey and could be satiated at 30 larvae per day. *P. lenis* has shorter developmental period, longer life span, longer oviposition period, and high egg hatchability relative to its prey – desirable features of effective predators.

Key words: biocontrol potential, life history, phytoseiids, *Proprioseiopsis lenis*, spider mites, *Tetranychus urticae*

INTRODUCTION

Spider mites are important pests of various crops including ornamentals. Outbreaks following WW II have been attributed to new cultural practices to increase yield and/or the intensive use of chemicals for the control of insect pests. Observations that spider mites remained under relatively good control in untreated areas illustrate that spider mite problems resulted from extensive misuse of agricultural techniques. The outbreaks created the impetus for interested workers to study plant-feeding mites and their possible effective predators such as phytoseiids. Researchers in many countries have set to evaluate the effectiveness of such predators on the basis of the predator's life history in relation to that of its prey, ability to attack its prey, and environmental tolerance (Kim & Lee, 1993).

Phytoseiids are free-living predatory mites occurring in terrestrial habitats throughout the world, from alpine and arctic tundra to tropical jungles (Chant, 1985). Most species are arboreal and seem specialized for living on portions of the plant above ground while some may hunt for prey on the ground and overlying litter (Corpuz-Raros, 1986). They, infrequently if ever, are parasitic or phoretic on other organisms (Chant, 1985). Most species have rather general habitats, although a few are highly specialized like *Macroseius biscutatus* Chant which is found only in the pitchers of the pitcher plant, *Sarracenia* sp. Phytoseiids are general predators, feeding on small arthropods like phytophagous mites and minute insects. Among the predatory mites, the phytoseiids are the most effective and widespread predators of plant-feeding mites (Jeppson et al., 1975). A large number of phytoseiids are now used as biological control agents in a number of agricultural ecosystems. Others are important factors in integrated pest management systems (Chant, 1985). Most species of phytoseiids are important predators of spider mites or the tetranychids; and some, of eriophyids (Abou-Awad & El-Banhawy, 1986). Phytoseiids are the best-known predators among the Acari and may easily be mass-reared and shipped (Overmeer, 1985).

Ornamental plants, particularly roses and chrysanthemums, which comprise an important segment of agriculture especially in the Cordilleras, have steadily experienced epidemic infestations by spider mites since the El Nino period of 1997-1998. The polyphagous and cosmopolitan mite pest, *Tetranychus urticae* Koch, commonly known as the two-spotted spider mite, was reported as a widespread pest in commercial rose gardens in the provinces of Benguet, Laguna, and Cavite (Corpuz-Raros, 2001). It affects farming of *Rosa* spp. in diverse climates and causes important economic damage (Jimenez, 1999). Growers have no recourse but to chemically protect these high-value ornamentals where unblemished produce is a requirement. The potential of phytoseiids as predators of mite and other sap-sucking arthropod pests infesting various crops has been recognized. Their use as less environmentally destructive alternatives to chemical pest control should be considered. Prior to their utilization, particularly against pressing spider mite problems on roses, the naturally existing predator fauna need to be studied biologically and evaluated.

Biological studies on spider mites and phytoseiids as well as experiments on the utilization of phytoseiids for biological control of pests either in the field or in greenhouses under Philippine conditions are still wanting. Among 105 phytoseiid species currently known to occur in the Philippines, eight appear important, namely: *Typhlodromus contiguous* Chant, *Amblyseius phillipsi* Schicha, *A. largoensis* (Muma), *A. ovalis* (Evans), *A. asiaticus* (Evans), *A. tamatavensis* Blommers, *A. longispinosus* (Evans), and *Paraphytoseius multidentatus* Swirski & Shechter (Corpuz-Raros, 2002). Only *A. longispinosus* has been evaluated so far, and used successfully against the cassava spider mite, *Tetranychus kanzawai* Kishida, in commercial plantations of the Matling Industrial Corporation in Lanao del Sur (Vasquez & Gonzales, 1994).

This work highlighted the life history of the most common spider mite pest of roses, *T. urticae*, as well as the life history of the common phytoseiid mite inhabiting roses, *Proprioseiopsis lenis* (Corpuz & Rimando) and its voracity on *T. urticae*.

MATERIALS AND METHODS

The Test Mites

Tetranychus urticae and the phytoseiid predator, *P. lenis*, were requested from the former Acarology Laboratory, Crop Protection Cluster, (now Institute of Weed Science, Entomology and Plant Pathology), College of Agriculture and Food Science, University of the Philippines Los Baños.

The stock culture of *T. urticae* was maintained separately in the greenhouse and in the laboratory on potted roses and soybeans and water hyacinth held in water in suitable containers. *T. urticae* from potted roses was mass-produced in the greenhouse by clipping mite-infested leaves to more host plants to allow natural transfer of the herbivorous mite. In the laboratory, *T. urticae* was maintained on water hyacinth. Once the plants senesced or showed signs of decline due to mite feeding, the procedure was repeated. The plants were kept in cages to avoid infestation by other pests and possible predation, and to maintain a pure culture.

P. lenis was mass-produced in the laboratory using the flour mite, *Suidasia pontifica* Oudemans, as factitious prey following the dish method of Corpuz-Raros & Navasero (2002). A small amount of coconut coir dust was scattered on a rectangular dish lined with tissue paper to aerate the fine medium and avoid caking of the yeast, as well as to serve as oviposition substrate for the predators. Adult *P. lenis* from the pure stock were introduced to the rearing dishes containing a scoop of mixed stages of the flour mite. When adults of the next generation started to eclose, more prey for the predator or yeast for the prey were added. The stock was divided when populations became dense. The rearing cages were placed separately on a moat of water in a rectangular plastic vat with perforated cover and the vats were maintained in wooden shelves. The water on the moat serving as source of moisture for the predators was replaced every seven days. The process was repeated continuously to maintain the cultures of *P. lenis*.

Rearing Cages for Life History and Other Studies

The life history and other biological studies were conducted using the Munger or Huffaker cell described by Overmeer (1985), with slight modifications, as isolation arenas or rearing cages. The use of the cell allowed observations under a dissecting microscope and prevented possible escape of the mites.

The cell consists of a rectangular 4.0 x 8.0 x 0.5 cm thick plexiglass with a 3.0-cm circular hole at the center, and sandwiched by two glass plates of the same size as the plexiglass. One leaf disc was placed in between the bottom glass plate lined with three layers of 4.0 x 8.0 cm moistened tissue paper and the plexiglass, such that the leaf substrate formed the bottom of the inner side of the cage. The mite to be studied was placed in the circular hole and the cell was enclosed by placing the top glass precisely on the plexiglass and secured tightly at both ends with a clip.

Life History of *T. urticae*

Developmental rate. Male and female deutonymphs of *T. urticae* were collected from the stock culture and placed in pairs in previously prepared Munger cells, for mating and oviposition. This procedure ensured the use of eggs of known ages for developmental studies.

Using the tip of a moistened fine camel hair brush, day-old eggs were placed individually in previously prepared Munger cells. The eggs were observed at 6-hour intervals for hatching. The emerging larvae were observed for molting. The same procedure was followed for each stage until each individual reached the adult stage. When necessary, mites were transferred to newly prepared Munger cells to provide ample food supply. The presence of exuviae in the Munger cells was used as indicator of molting. The frequency of observation of the immature stages was the same as that of the egg stage.

The duration of each life stage was recorded. The feeding habit of *T. urticae* was also observed; all done using a dissecting microscope. Representative samples of the different stages were also preserved and mounted on glass slides using modified Hoyer's medium, for examination and observation under a compound microscope.

Sex ratio and mating behavior. Fifteen female deutonymphs of *T. urticae* that were soon to emerge were individually transferred with a mate in prepared Munger cells. One hundred newly laid eggs were isolated in newly prepared isolation arenas. These were allowed to hatch and develop to adult stage, after which they were examined carefully under a dissecting microscope for sex determination. The mating behavior exhibited by the adults was observed.

Oviposition behavior, fecundity, and egg hatchability. The pre-oviposition, oviposition, and post-oviposition periods of the females of *T. urticae* were determined. Likewise, the oviposition behavior exhibited by the adult females was observed. Females were transferred daily into newly prepared isolation arenas. Eggs laid were counted daily and recorded until the female died, and were allowed to hatch to determine hatchability.

In addition, parthenogenesis was determined by confining 10 female deutonymphs which were about to molt, separately into isolation arenas. The emerging adults were allowed to oviposit and the eggs were monitored for further development.

Adult longevity and habits. Emerging adults from the developmental studies were maintained in isolation arenas, and when necessary, transferred to newly prepared ones to provide ample supply of food. The longevity of both sexes were recorded. Peculiar habits of *T. urticae* adults were recorded.

Life History of *P. lenis*

Female *P. lenis* were collected from the stock cultures and placed in Munger cells with rose leaves as substratum, for oviposition. Data on the developmental rate, sex ratio, female fecundity, egg hatchability, durations of pre -oviposition, oviposition, and post oviposition periods, and adult longevity were gathered. The developing larvae were provided 20 *T. urticae* larvae while the protonymphs, deutonymphs, and adults were provided 50 larvae daily. The number of prey mites consumed daily by the immature and adult stages were recorded. The procedure for each specific parameter, as described above for *T. urticae*, was followed. All observations were undertaken under a dissecting microscope.

Predatory Capacity and Preferences for Prey Stages

Preferences for stages of *T. urticae*. A free-choice test was conducted to determine the preference of *P. lenis* for stages of *T. urticae* as prey. *T. urticae* was mass-produced in a staggered manner such that the different stages were readily available at the same time.

The prey and the predators were confined together inside improvised feeding arenas. Each arena consisted of a plastic foam cushion (14.5 cm diam x 1.0 inch-thick) fitted in a plastic Petri dish bottom as platform placed inside a circular translucent container (18.5 cm diam x 8.0 cm high). Sufficient amount of water was added to the container to saturate the foam. The edge of the platform was lined with moistened tissue paper as a source of drinking water for the mites. Rose leaves with petioles wrapped with moist cotton were arranged in a circular fashion on the platform. A mixture of 100 individuals each of the different stages, namely: egg, larva, protonymph, deutonymph, and adult female, of *T. urticae* were placed on the rose leaves, and offered to 10 actively laying females of *P. lenis* released at the center of the arena. The arena was secured by a perforated cover to provide aeration.

The number of prey fed upon was monitored by counting the remaining individuals of each respective stage of prey offered after 24-hr exposure to the predator. Observations were undertaken under a dissecting microscope. Means from four replications were computed to get the average number of prey consumed, and were compared statistically.

Voracity of *P. lenis* on *T. urticae*. Six different densities (one, 10, 20, 30, 40, and 50 individuals) of the preferred stage of *T. urticae* were introduced to newly emerged, 12-hr starved adult *P. lenis* females confined singly in isolation arenas. The number of prey consumed after 24 hrs was recorded. Means from four replications, each with five individual predators, were compared statistically.

RESULTS AND DISCUSSION

Life History of *T. urticae* on Rose Leaves

Development. *T. urticae* passes through egg, a larval, and two nymphal stages, namely: protonymph and deutonymph, before reaching the adult stage. Table 1 details the durations of the different developmental stages.

The incubation period of the eggs for the females and males are almost the same, ranging from 2.00-4.75 and 2.50-5.00 days with mean values of 3.43±0.11 and 3.63±0.11 days, respectively. The duration of the egg stage is the longest among the developmental stages and lasted for about twice the postembryonic stage. This is typical of mites (Malveda & Corpuz-Raros, 2006).

After hatching, the mean duration of the immature stages for the female and male, respectively, were as follows: larval, 1.70±0.24 and 1.68±0.09; protonymphal, 1.63±0.07 and 1.72±0.12; and deutonymphal, 1.83±0.09 and 2.23±0.29 days. The deutonymphal stage appears to last longest among the immature stages.

Total developmental period, from egg to adult emergence was slightly longer in males, i.e., 6.50-12.25 (mean: 8.60±0.24) days for females, and 7.25-13.50 (mean: 9.22±0.35) days for males. The slightly longer developmental period of the males in this study might be attributed to handling such as during transfer to new and fresh substrate, which might have disturbed the development of the larvae and nymphs. In spider mites, males usually develop faster than do females (Bounfour & Tanigoshi, 2001; Riahi et al., 2013). In the experiment by Kumral et al. (2017) on *T. urticae* reared on different varieties of pepper, males had a shorter total developmental period. At eclosion, the posterior portion of the integument splits dorsally and the mite frees itself from the exuvium, while the latter is still attached to the substrate.

Table 1. Life history data (in days) of *T. urticae* on *Rosa* sp. 'Bravo' based on 38 surviving females and 30 males under ambient conditions.

Stage	Female		Male	
	Range	Mean ± SE	Range	Mean ± SE
I. Developmental Stages				
Egg (Incubation)	2.00-4.75	3.43±0.11	2.50-5.00	3.63±0.11
Larva	1.00-2.75	1.70±0.24	1.00-3.25	1.68±0.09
Nymphal Stages				
Protonymph	1.00-2.75	1.63±0.07	1.00-3.50	1.72±0.12
Deutonymph	1.00-3.25	1.83±0.09	0.75-6.50	2.23±0.29
Total Developmental Period	6.50-12.25	8.60±0.24	7.25-13.50	9.22±0.35
II. Post Development				
Adult Longevity	7.50-24.25	14.83±0.59	2.75-29.50	16.31±1.34
Fecundity	11.00-126.00	48.71±4.22	NA	NA
Pre-oviposition Period	5.00-5.50	1.06±0.14	NA	NA
Oviposition Period	4.00-22.00	10.08±0.72	NA	NA
Post-oviposition Period	0.25-7.50	3.70±0.14	NA	NA

SE = Standard Error; NA = Not Applicable

Sex Ratio and Mating Behavior of *T. urticae*.

Sex ratio is primarily dependent on the amount of sperm transferred to a female (Helle & Pijnacker, 1985). In this study, out of 100 eggs of mated females, 68 females and 32 males developed, giving a sex ratio of 2.13: 1. A sex ratio of 2.85 females: 1 male in *T. urticae* was recorded by Carey & Bradley (1982) in laboratory studies in California with cotton cotyledons as substrate. In *T. urticae* and many other bisexual tetranychids, one male to three females has been found very often and may be considered normal, and the first egg produced by a mated female is always a male and the egg is not fertilized (Helle & Pijnacker, 1985).

Adult males often remained within the immediate area of the quiescent female deutonymph. This is a male precopulatory behavior. These wandering males are perhaps guided by the silk webbing spun by the female (Penman & Cone, 1972) and a sex attractant (Cone at al., 1971) which makes the female increasingly attractive over time (Potter et al., 1976). One or more males often visit the quiescent deutonymph regularly, appearing to guard the soon-to-emerge female.

Prior to molt of the female deutonymph, the male remained on the female (Figure 1). Males guard quiescent deutonymph females and mate upon emergence of the female (Potter et al., 1976; Satoh et al., 2001; Oku, 2009).

It was postulated that the premature courting instinct, no doubt, is of value to the species in detaining the male until the female transforms and, obviously, the detention of males for mating purposes influences the number of females produced, which, in turn, has significant consequences for subsequent populations (Cone, 1985).

The male often aided the female in freeing herself from the exuvium. Once molting is finished or even before the female has fully come out of the anterior portion of the old skin, the male tries to effect mating. Mating usually starts with the male mounting the female, then moving backward with an attempt to go under the posterior of the female. At this point, the male appears to carry the female above himself with its legs clasping the female's legs. The male opisthosoma is strongly reflexed upward to bring the extruded aedeagus in contact with the female genital opening.

Duration of mating was short, taking place for about two minutes and maybe repeated briefly. After mating, females remain stationary for some time or immediately move away while the males move around within the area.

Figure 1. Male *T. urticae* displaying precopulatory behavior by remaining above a female deutonymph (x 55) (scale bar: 200 μm).

Oviposition behavior, fecundity, and egg hatchability of *T. urticae*. The oviposition period of *T. urticae* followed a brief pre-oviposition period (Table 1). Pre-oviposition period lasted for 5.00-5.50 (mean: 1.06±0.14) days; oviposition period, 4.00-22.00 (mean: 10.08±0.72) days, and post-oviposition period, 0.25-7.50 (mean: 3.70±0.41) days.

The pre-oviposition period in Tetranychidae is brief, usually 1-2 days (Crooker, 1985). The seemingly longer pre-oviposition period demonstrated by *T. urticae* in this study may be due to handling factors during the transfer of the females to fresh substrate in the Munger cells. Disturbance of females at this stage might have delayed egg deposition. Oviposition period among spider mites varies greatly depending upon species and environmental conditions, but 10-15 days appears to be normal (Crooker, 1985). Adult *T. urticae* females laid 11.00-126.00 (mean: 48.71±4.22) eggs (Table 1). Hatchability ranged from 85.11-100%.

Parthenogenesis was also observed. From among 472 eggs laid by 10 unmated females, 99.36% hatchability was recorded, with all progeny being males. *T. urticae* exhibits the male-producing or arrhenotokous type of parthenogenesis. Parthenogenesis is a common mode of reproduction in mites found in several acarine orders and male-producing parthenogenesis is most frequently encountered (Helle & Pijnacker, 1985).

Longevity and habits of adults. Adult female and male *T. urticae* lived for 7.50-24.25 and 2.75-29.50 days, respectively (Table 1). Observations under normal conditions revealed that the males were always moving about, probably looking for possible mates, or settled near a female deutonymph. The females were found stationary most of the time, feeding or ovipositing.

Description of Life Stages of *T. urticae*

Egg. The eggs of *T. urticae* are round, shiny, appear colorless at first then become whitish, turning yellowish with age (Figure 2a). In the review by Tehri (2014), eggs of *T. urticae* are translucent and turn orange with age. Eggs are 134 µm in diameter. These are laid singly or in groups on the underside of the leaves. The red eyes become apparent when the egg is about to hatch.

Larva. Newly emerged larvae are minute, pale, becoming whitish to pale yellow upon emergence, and greenish with age. Black spots on each side of the body become apparent and the red eyes are very prominent (Figure 2b-c). This stage has three pairs of legs. Larvae of *T. urticae* measure about 200.83 x 142.31 µm.

Protonymph. The protonymph (Figure 2d) can be distinguished from the larva by the four pairs of legs and the bigger size. The characteristic melanic spots on each side of the body become larger and the yellow greenish color intensifies. Protonymphs measure about 263.34 x 175.56 µm.

Deutonymph. The deutonymphs (Figure 2e) measure about 405.65 x 244.72 µm. The spots on each side of the body become darker and bigger. As the deutonymphs grow, sexual dimorphism becomes more observable. Those that would become large and robust are females, and the smaller, tapered-form, males. The deutonymphs spent the latter period of this stage in a quiescent state before molting into the adult stage.

Adult. Adult females (Figure 2f) measure about 649.04 x 373.73 µm. These are robust and apparently bigger than the males (Figure 2g), which are about 405.65 x 202.16 µm. Males have a tapered posterior end.

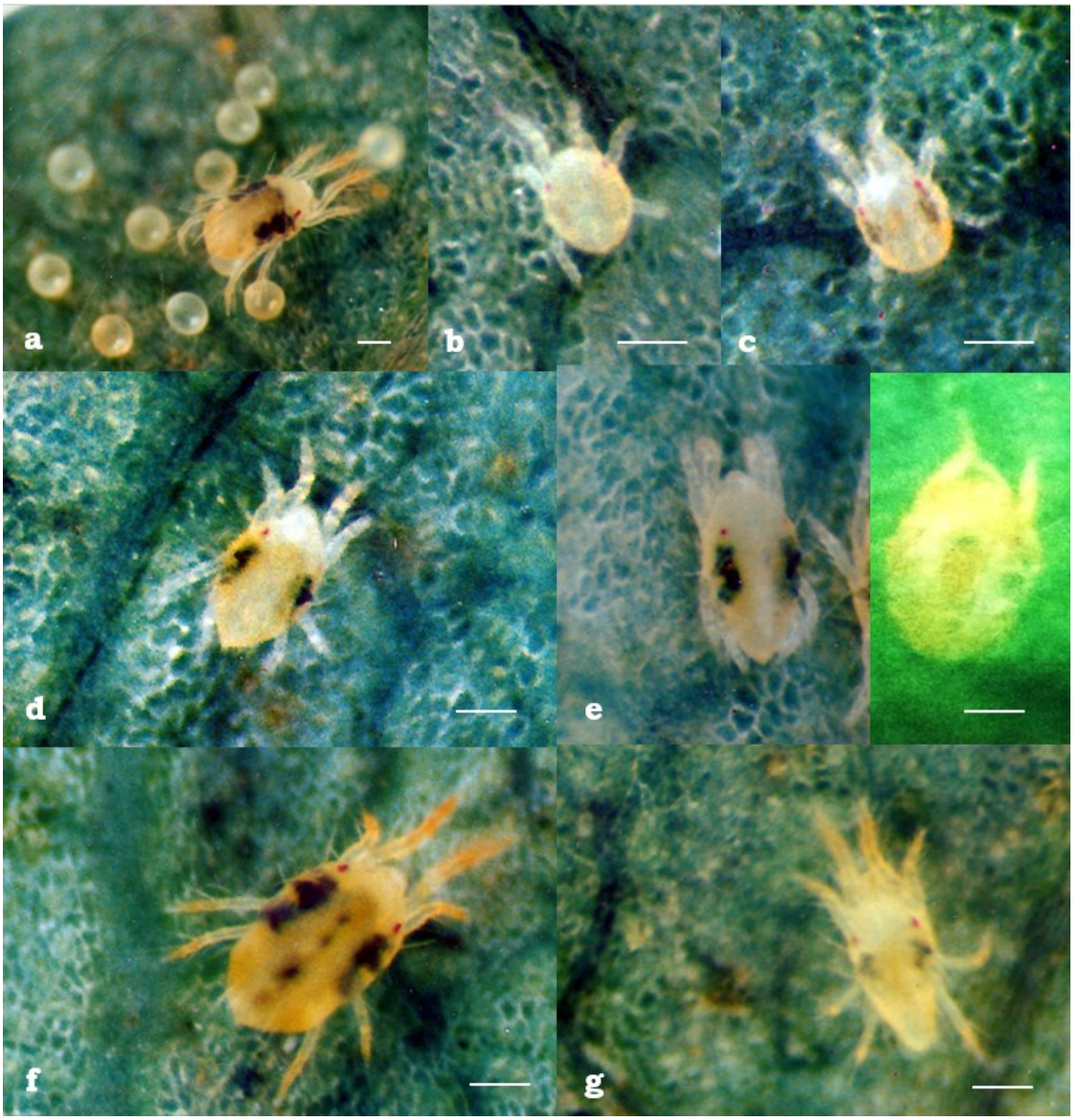

Figure 2. Life stages of *T. urticae*. **a.** newly laid (whitish) and older (yellowish) eggs (x 62). **b-c.** larvae: **b.** newly emerged, whitish to pale yellow (left) (x 64) and **c.** an older one showing characteristic spots on each side of the dorsum (right) (x 64). **d.** protonymph with very distinct spots on each side of the dorsum (x 64). **e.** deutonymphs in quiescent stage (x 64). **f.** female (x 60). **g.** male (x64) (scale bars: 100 μm)

Life History of *P. lenis* on *T. urticae* Larvae

Duration of development of *P. lenis*. *P. lenis* passes through the same developmental stages as do other Phytoseiidae. These stages include the egg, larva, protonymph, deutonymph, and adult. Larvae of *T. urticae* were provided as prey based on the stage-preference test conducted separately.

Table 2 summarizes the durations of the life stages. Incubation period ranges from 0.50-2.25 (mean: 1.37±0.07) days. The mean durations (days) of the three immature stages are as follows: larva, 0.89±0.04; protonymph, 1.03±0.05; and deutonymph, 1.20±0.08.

The total development period ranged from 3.25-5.75 (mean: 4.50±0.12) days. The egg stage had the longest duration among the developmental stages. Among the immature stages, the larval stage had the shortest duration.

Incubation period, durations of immature stages, and the total development period of *P. lenis* are more or less the same with the results obtained by Corpuz-Raros & Navasero (2002) when *T. piercei* McGregor, mainly eggs, were offered as prey to the same predator.

Fecundity, egg hatchability, and longevity. After molting into adults, *P. lenis* exhibited a pre-oviposition period ranging from 0.25-5.75 (mean: 1.95±0.22) days (Table 2).

The oviposition period lasted for 3.25-31.75 (mean: 16.20±1.31) days. After the last oviposition, adult females were observed to die immediately or even lasted for 10.50 days with an average of 2.67±0.51 days. *P. lenis* females laid 7.00-74.00 (mean: 36.48±2.83) eggs throughout their lifetime. Egg hatchability ranged from 97.96-100%.

The adults lived for 6.00-40.00 (mean: 20.24±1.50) days. No males developed from the culture. This is expected because the stock culture used in the study was apparently infected with *Wolbachia* (Corpuz-Raros, 2005), a group of cytoplasmically inherited bacteria that alter reproduction in their hosts, including induction of parthenogenesis, reproductive incompatibility, feminization of genetic males, and male killing (Werren, 1997; Werren & Benkeboom, 1998).

Table 2. Life history (in days) of *P. lenis* reared on *T. urticae* larvae based on 33 surviving individuals under ambient conditions.

Stage	Female	
	Range	Mean ± SE
I. Developmental Stages		
Egg (Incubation)	0.50 – 2.25	1.37±0.07
Larva	0.50 – 1.25	0.89±0.04
Nymphal Stages		
Protonymph	0.50 – 1.25	1.03±0.05
Deutonymph	0.50 – 3.25	1.20±0.08
Total Developmental Period	3.25 – 5.75	4.50±0.12
II. Post Development		
Adult Longevity	6.00 – 40.00	20.45±1.50
Fecundity	7.00 – 74.00	36.48±2.83
Pre-oviposition Period	0.25 – 5.75	1.95±0.22
Oviposition Period	3.25 – 31.75	16.20±1.31
Post-oviposition Period	0.00 – 10.50	2.67±0.51

SE = Standard Error

Description of the Life Stages of *P. lenis*

Egg. The eggs of *P. lenis* are oval, transparent when newly laid, almost clear and moist, turning yellowish when about to hatch. Eggs measure 130.34 µm. These are laid either singly and scattered on the leaf surface inside the Munger cells or in small clusters. Some were also laid on the edges of the hole of the Munger cells and even on the top glass cover of the rearing cell.

Larva. The larva is the six-legged stage that emerges from the egg. It is almost colorless and moves slowly. Larvae measure 307.23 x 142.32 µm.

Protonymph. The protonymph is readily distinguished from the larva by the presence of four pairs of legs. They are soft, shiny, and creamy white when newly molted, turning light brown with age. The protonymphs measure 344.47 x 148.96 µm.

Deutonymph. Deutonymphs are darker and bigger than the previous stage, measuring 481.46 x 220.78 µm.

Adult. The adults are reddish brown, with a rounded posterior end and measure 565.25 x 247. 38 µm. The adults are very active, running very fast within the rearing cells.

Predatory Habits of *P. lenis* on *T. urticae* Larvae

The predatory habits exhibited by *P. lenis* on *T. urticae* were observed from the voracity tests conducted. The adult *P. lenis* was noted actively wandering around inside the Munger cells. Once *P. lenis* encountered its prey, it grasped and held it by its chelicerae. It pierced through any point of the body of the prey, either anteriorly, posteriorly, or laterally. This pattern of attack maybe due to the fact that phytoseiids are blind and are guided only by kairomones in finding their prey. In an instant, the predator sucked the contents out of the body, leaving a completely shrivelled prey. Then it moved away and tried to capture another prey.

Consumption of Ovipositing *P. lenis* Among Different Stages of Prey

The number of *T. urticae* individuals of different stages consumed by *P. lenis* after 24-hr exposure period differed significantly (Table 3). Larvae and protonymphs were preferred by *P. lenis* over the other three stages in four trials. In two trials each, larvae and protonymphs were consumed most, relative to the other stages. However, if the means of the total number of prey consumed are considered, the larval stage is the most preferred. Most probably, this is because larvae are smaller and less active than the other stages. Their small size seemed manageable to the predator.

***P. lenis* Consumption of *T. urticae* to Complete Development**

During the life history study of *P. lenis*, total prey consumption to complete development was also determined. The average number of prey consumed by the immature stages of *P. lenis* to complete their development (Table 4) were as follows: larva, 8.88±0.36; protonymph, 12.73±0.70; and deutonymph, 23.79±1.31. Adult *P. lenis* consumed daily an average of 46.14±0.39 *T. urticae* larvae. As expected, the consumption increased as the predator became older and bigger. The predator consumed a total of 79.20-118.13 *T. urticae* larvae during its entire lifetime.

Table 3. Number of prey individuals consumed by 10 ovipositing *P. lenis* among different stages of *T. urticae*.

Stage of Prey	Prey Density	Number of Prey Consumed				
		R1	R2	R3	R4	Mean[1]
Egg	100	64	50	30	34	44.50[c]
Larva	100	66	92	75	51	71.00[a]
Protonymph	100	81	43	69	55	62.00[b]
Deutonymph	100	9	4	7	3	5.75[d]
Adult Female	100	1	0	0	3	1.00[e]

[1] Means in a column followed by common letter are not significantly different at 5% level of significance

Table 4. Consumption of *T. urticae* by *P. lenis* to complete its development*.

Stage of *P. lenis*	Number of *T. urticae* Larvae Consumed	
	Range	Mean ± S.E.
Larva	6.00 – 12.00	8.88±0.36
Protonymph	5.00 – 20.00	12.73±0.70
Deutonymph	12.00 – 47.00	23.79±1.31
Adult	38.00 – 48.00	46.14±0.39

*Based on 33 individuals of *P. lenis* where larvae and protonymphs were provided 20 *T. urticae* daily; deutonymphs and adults were provided 50 *T. urticae* larvae daily.

In a review by Sabelis (1985a), phytoseiids may or may not feed as larvae. However, in this study, *P. lenis* larvae were found feeding on the prey in contrast to the non-feeding larva of *Neoseiulus calorai* (Corpuz & Rimando) (=*Amblyseius calorai*) observed by Malveda & Corpuz-Raros (2006).

Consumption by *P. lenis* vs. Prey Density

In a separate study, *P. lenis* females were provided different densities of the preferred stage (larva) of the prey to test its consumption rate. The number of *T. urticae* larvae consumed by an adult *P. lenis* after 24 hr differed significantly (Table 5). From a prey density of 30, an adult *P. lenis* consumed an average of 22.90 *T. urticae* larvae. The data show that in a day, a female *P. lenis* could be satiated with about 23 *T. urticae* larvae. These results are not far from those of Navasero & Corpuz-Raros (2005) where from a prey density of 40 *T. urticae* larvae offered to a female *P. lenis*, an average consumption of 28 was recorded.

Ecological Fitness of *P. lenis* as a Predator

Concepts of ecological fitness vary and there are at least three sorts (Peacock, 2011). One of them essentially refers to the organism's traits and how such traits correspond to various aspects of the environment in which the organism is living. The ecological fitness of *P. lenis* as a predator of the spider mite, *T. urticae*, is indicated by its relative rate of development, fecundity, duration of oviposition period, and hatchability of eggs compared to those of its prey (Table 6). The total developmental period of *P. lenis* is shorter (4.50±0.12 days) than *T. urticae*. This short developmental period is an ideal characteristic of a predator so that its population could increase in a shorter period of time, assuming that all conditions necessary for its development are met.

Table 5. Number of *T. urticae* larvae consumed by newly emerged, 24-hr starved *P. lenis* females over a 24-hr exposure period[1]

Density of Prey Offered	No. of Prey Consumed/Predator	
	Range	Mean[2]
1	0.00 – 1.00	0.95[d]
10	5.00 – 10.00	6.75[c]
20	3.00 – 13.00	8.10[bc]
30	11.00 – 30.00	22.90[a]
40	4.00 – 23.00	12.80[b]
50	4.00 – 23.00	10.10[b]

[1]20 replications, corresponding to *P. lenis* individuals tested separately
[2]Means in a column followed by a common letter are not significantly different at 5% level of significance

Table 6. Ecological fitness of *P. lenis* as a predator of *T. urticae*.

Fitness Traits	Mite Species	
	Pest (*T. urticae*)	Predator (*P. lenis*)
Total Development Period (days)	8.60±0.24	4.50±0.12
Longevity (days)	14.83±0.59	20.45±1.50
Fecundity (days)	48.71±4.22	36.48±2.83
Oviposition Period (days)	10.08±0.72	16.20±1.31
Egg Hatchability (%)	85.00 - 100	98.00 - 100

In addition, adult females of *P. lenis* survived longer than the pest. This indicates that the existence of *P. lenis* for a longer period would mean more prey eaten. This substantiates the report that, as biological control agents, phytoseiid predators have the ability to increase in population more rapidly than their prey, disperse actively, and survive in the absence of their prey (Schreiver & Camporese, 1990).

The number of eggs laid by *P. lenis* is slightly lower than *T. urticae*. According to Sabelis (1985b), the fecundity of phytoseiids is generally lower than that of their tetranychid prey, especially *Tetranychus* species. The duration of the oviposition period is longer in *P. lenis* relative to *T. urticae*. Finally, the lower limit of the egg hatchability in *P. lenis* is higher than *T. urticae*. Therefore, the above positive fitness traits of *P. lenis* make it an effective predator of *T. urticae.*

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