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Influence of Life Diet on the Biology and Demographic Parameters of *Agistemus olivi* Romeih, a Specific Predator of Eriophyid Pest Mites (Acari: Stigmaeidae and Eriophyidae)

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Abstrak: Pengaruh pelbagai diet hidup terhadap parameter biologi dan demografik pemangsa hama, *Agistemus olivi* Romeih, telah dikaji di makmal. *A. olivi* telah berjaya membiak dalam setiap hama eriophyid yang telah dikaji. *A. olive* yang makan *Aceria mangiferae* Sayed mengalami peningkatan pertumbuhan, yang menyebabkan masa generasi min yang terpendek dan merupakan makanan yang paling sesuai untuk oviposisi pemangsa, seperti yang telah ditunjukkan oleh nilai fecunditi dan kadar pembiakan. Memakan *Aculops lycopersici* (Massee) telah memberikan nilai fecunditi dan kadar pembiakan yang terendah; maka mangsa ini merupakan yang paling tidak sesuai untuk oviposisi of *A. olivi*. Memakan *Aculus fockeui* (Nalepa et Trouessart) dan *A. mangiferae* telah menghasilkan kadar peningkatan instrisik dan finite yang lebih tinggi untuk pemangsa berbanding dengan *A. lycopersici*, yang telah menunjukkan nilai yang terendah. Perbezaan ini perlu diambil kira untuk produksi kultur sihat *A. olivi*.

Kata kunci: *Agistemus olivi*, Hama Eriophyid, Biologi, Parameter Demografik

Abstract: The influence of various life diets on the biology and demographic parameters of the predatory mite, *Agistemus olivi* Romeih, was studied under laboratory conditions. *A. olivi* successfully developed and reproduced on all of the tested eriophyid mites. Feeding on *Aceria mangiferae* Sayed enhanced the development of *A. olivi*, resulted in the shortest mean generation time and was the most commensurate food for the ovipostion of the predator, as exhibited by the highest fecundity and net reproductive rate. Preying on *Aculops lycopersici* (Massee) gave the lowest fecundity and net reproductive rate; therefore, this prey was the least suitable for the oviposition of *A. olivi*. Preying on *Aculus fockeui* (Nalepa et Trouessart) and *A. mangiferae* produced higher intrinsic rates of increase and finite rates of increase for the predator in comparison to *A. lycopersici*, which showed the lowest value. These differences in response to various eriophyid pests should be considered for the production of healthy cultures of *A. olivi*.

Keywords: *Agistemus olivi*, Eriophyid Mites, Biology, Demographic Parameters

INTRODUCTION

The mites of the Eriophyidae family are among the most specialised plant feeders. Although the plant symptoms of their feeding range from simple russeting to complex gall formation, the host-mite relationships often appear to be rather specific and probably reflect a high degree of specialisation (Jeppson *et al*. 1975).

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The tomato rust mite, *Aculops lycopersici* (Massee), is a serious pest throughout the Mediterranean region, whereas the mango bud mite, *Aceria mangifera* Sayed, is reported to attack the buds and inflorescence of mango, *Mangifera indica* L (Anacardiaceae) (Ochoa *et al*. 1994). Another eriophyid mite, *Aculus fockeui* (Nalepa et Trouessort), injures peach leaves and reduces the sugar content of the fruit, and the damaged trees have a lower vigour due to post-harvest defoliation, which results in lower fruit quality in the following year (Kondo & Hiramatsu 1999).

Predacious mites in the Stigmaeidae family are important natural enemies of several phytophagous mite pests on various crops (Gomaa 1968; Santos 1976). *Agistemus* and *Zetzellia* (Acari: Stigmaeidae), which are both common genera of the Stigmaeidae family, are polyphagous predators that have potential in the control of various tetranychid and eriophyid pests (e.g., El-Badry *et al*. 1969; Goldarazena *et al*. 2004; Khodayari *et al*. 2008). *Agistemus exsertus* Gonzalez, one of the most common stigmaeid mites in Egypt, is known as an egg predator of various tetranychoid mites (El-Badry *et al.* 1969; Oomen 1982; El-Bagoury *et al.* 1989). Research by Momen (2001), Romeih *et al.* (2004), El-Sawi and Momen (2006) and Momen and El-Sawi (2006) indicated that various insect eggs of the Pyralidae, Diaspididae, Noctuidae and Gelechiidae families were commensurate prey for the development and oviposition of *A. exsertus.*

Due to their size, slow movement and, therefore, ease of capture, eriophyid mites provide a better source of food for the development of stigmaeid mites than do tetranychid mites (Thistlewood *et al*. 1996). *Agistemus exsertus* has been reported as an excellent predator of the ploughman's spikenard gall mite, *Aceria dioscoridis* (Soliman & Abou-Awad) (El-Bagoury & Reda 1985), *A. lycopersici* (Osman & Zaki 1986), *Eriophyes olivi* Zaher and Abou-Awad (El-Laithy 1998), *Colomerus vitis* (Pagenstecher) (Osman *et al*. 1991), *Eriophes ficus* (Cotte) and *Rhyncaphytoptus ficifoliae* Keifer, all of which are eriophyids (Abou-Awad *et al*. 1998a).

Agistemus olivi Romeih was first recorded in Egypt; however, with the exception of the report by Abou-Awad *et al*. (2010), no studies have been published on the relationship between the diets and biological aspects of the predator. *A. olivi* was found to be an excellent predator of the eriophyids, *Aceria oleae* Nalepa and *Tegolophus hassani* Keifer, but it failed to develop on the eggs and active stages of tetranychid mites or pollen grains (Abou-Awad *et al*. 2010). More attempts should be made to overcome these difficulties, and further studies on the feeding habits of *A. olivi* might provide a better understanding of some of the factors affecting its abundance in the field.

The objective of this study was to evaluate the relative nutritional value of *A. mangiferae, A. fockeui* and *A. lycopersici* (Eriophyidae) as natural or alternative food sources for the stigmaeid mite, *A. olivi*. In particular, the reproductive potential and demographic parameters of *A. olivi* were evaluated and compared under laboratory conditions using the active stages of eriophyid mites as the prey.

MATERIALS AND METHODS

Host and Stigmaeid Predatory Mite Culture

The predatory mite, *A. olivi*, was collected from the leaves of peach, mango and, rarely, tomato plants and reared on the leaves of mulberry, *Morus albe* L. These mites were fed the active stages of *A. fockeui* in the laboratory at 30±1ºC, 75±5% relative humidity (RH) and 12:12 h (light:dark). Adult *A. olivi* females were transferred to mulberry leaf discs, provided with active stages of *A. fockeui* and allowed to oviposit for 24 h. The newly deposited eggs were used for the different test diets.

Test Diets

To study the effect of various prey on the biology of *A. olivi*, the eriophyid pest mites of the Eriophyidae family, *A. mangiferae* and *A. fockeui*, from infected peach (*Prunus persica* [Stokes] [Rosaceae]) leaves and *A. lycopersici* from tomato (*Lycopersicon esculentum* Mill. [Solanaceae]) leaves were selected. These host prey mites have always been associated with various predacious mites of the Stigmaeidae and Phytoseiidae families and constitute hosts for the biocontrol of mite pests.

Effect of diets on the development, reproduction and demographic parameters

Leaf discs (2 cm in diameter) of *M. albe* were placed upside-down on wet cotton pads in Petri dishes. Eggs of *A. olivi* were transferred singly to each leaf disc, and the newly hatched larvae were supplied with a small leaf disc (0.25 cm in diameter) that were heavily infested with eriophyid mites or one outer bract infested with mango bud mite as food. The developmental periods of the different stages of the predator were recorded every 12 h. Newly emerged females were allowed to copulate with males within 24 h, and they were confined individually on leaf discs. The oviposition was observed daily, and the longevity and sex ratio of the progeny were calculated. The leaf substrate was replaced with a fresh one every 5 days.

Twenty eggs of *A. olivi* were used for testing each prey species. All of the experiments were conducted under laboratory conditions of 30±1ºC, 75±5% RH and 12:12 h (light:dark).

A total of 15 individuals (replicates) of *A. olivi* per *A. fockeui* and *A. lycopersici* and 17 individuals per *A. mangiferae* were analysed using 1-way ANOVA; the treatment means were compared by Tukey HSD at a 5% probability level. The demographic parameters were calculated using the Life 48 Computer Program (Abou-Setta *et al.* 1986), and their definitions were those proposed by Birch (1948).

RESULTS

Effect of Diets on Biological Aspects

The predatory mite, *A. olivi* successfully developed and reproduced on all of the tested eriophyid mites (Table 1). The mean developmental period from egg to adult (life cycle) was significantly affected by the eriophyid species tested.

The longest mean oviposition period (24.33 days) was recorded when *A. fockeui* was used, whereas *A. mangiferae* and *A. lycopersici* resulted in the shortest mean oviposition durations (20.70 and 20.26 days). A similar trend was observed for female longevity (duration of the adult stage), whereas the mites feeding on *A. mangiferae* showed the shortest life span (life cycle + adult longevity). The mean total number of eggs/female of *A. live* was the highest on *A. mangiferae* and *A. fockeui* (Table 2). In contrast, the lowest number of deposited eggs was recorded on *A. lycopersici*. A similar trend was observed for the mean daily number of eggs/female.

Table 1: Mean developmental period (days) of *A. olivi* females fed active stages of various eriophyid mite species.

Parameter	Eriophyid mites						Calculated F value
	Aceria mangiferae		*Aculops fockeui*		*Aculops lycopersici*		
	Mean	SE	Mean	SE	Mean	SE	
Egg	2.65b	0.12	2.33ba	0.12	2.20a	0.11	3.897*
Larva	2.35	0.12	2.33	0.13	2.47	0.13	0.316
Quiescent	0.79b	0.05	0.80b	0.05	1.23a	0.06	18.48**
Protonymph	1.79b	0.06	1.81b	0.05	2.23a	0.09	11.97**
Quiescent	0.71b	0.04	0.58b	0.03	1.20a	0.06	42.73**
Deutonymph	1.80b	0.06	1.71b	0.50	2.53a	0.13	26.78**
Quiescent	0.67b	0.05	0.79b	0.05	1.20a	0.06	25.13**
Total immatures	8.11b	0.18	8.07b	0.16	10.86a	0.20	30.12**
Life cycle	10.77b	0.23	10.40b	0.22	13.07a	0.28	34.08**
Preoviposition period	1.53	0.12	1.67	0.12	1.87	0.05	2.41
Oviposition period	20.70b	0.58	24.33a	0.89	20.26b	0.81	8.38**
Postoviposition period	3.41	0.29	2.53	0.16	3.40	0.29	0.361
Female longevity	25.35b	0.48	28.53a	0.93	25.53b	0.81	5.58**
Life span	35.90a	0.52	38.94b	0.97	38.60b	0.78	4.94**

Notes: *significant at p=0.05; ** highly significant at p=0.01
means within rows followed by the same letter are not significantly different at p=0.05 (*) and 0.01 (**)

Table 2: Demographic parameters of *A. olivi* females fed active stages of various eriophyid mite species.

Parameter	Eriophyid mites						Calculated F value
	Aceria mangiferae		*Aculops fockeui*		*Aculops lycopersici*		
	Mean	SE	Mean	SE	Mean	SE	
Mean total fecundity (eggs/female)	123.70a	2.67	116.07a	1.96	73.67b	2.02	136.94**
Daily no. of eggs/ female	6.12a	0.21	4.85b	0.19	3.69c	0.14	41.24**
Net reproductive rate (Ro)	92.779		83.376		35.36		
Mean generation time (*T*)	17.188		17.720		20.001		
Intrinsic rate of increase (r_m)	0.263		0.249		0.178		
Finite rate of increase (λ)	1.301		1.283		1.195		
Sex ratio (females/ total)	0.75		0.80		0.60		

Notes: ** highly significant at *p*=0.01
** means within rows followed by the same letter are not significantly different at *p*=0.01 (**)

Effect of Diets on Demographic Parameters

The shortest mean generation time (*T*, 17.18 days) of *A. olivi* was found using *A. mangiferae* compared to the longest mean per period (20.0 days) on *A. lycopersici* (Table 2). The highest value of the net reproductive rate (R_o) was 92.77 expectant females/female of *A. olive* on *A. mangiferae*, whereas the lowest value was 35.36 expectant females/female on *A. lycopersici*. A similar trend was observed with the intrinsic rate of natural increase (r_m) and, subsequently, the finite rates of increase (λ) were the highest (0.26 and 1.30, respectively) when individuals preyed on the mango bud mite, *A. mangifera*.

DISCUSSION

It is well-known that members of the Stigmaeidae family show considerable variation in their feeding habits and have diets that include pollen grains, scale insects, moth eggs and phytophagous mites (Abo-ElGhar *et al*. 1969; El-Badry *et al*. 1969; El-Bagoury *et al*. 1989; El-Sawi & Momen 2006; Momen & El-Sawi 2006; Abou-Awad *et al*. 2010). These species' dependence on animal food in the form of phytophagous mites varies considerably by species, mostly because of their innate characteristics but possibly also because of the relative availability of different food sources in the environment.

Therefore, food traits are excellent predictors of the direct mutualism between the diets and natural enemies of plant consumers (McMurtry & Croft 1997).

Aceria mangiferae accelerated the development of the immature stages of the predatory mite, *A. olivi*, and showed the shortest mean generation time (*T*) and a higher fecundity. Conversely, the longest means of the developmental duration and generation time for the predator were recorded on *A. lycopersici*. This observation may be explained by differences in the levels of specific nutrients provided by the three eriophyid species. When *A. olivi* fed on such eriophyid prey as the active stages of *A. oleae* and *T. hassani*, the developmental period and total eggs deposited by the females were notably comparable to the present results using *A. mangiferae* and *A. fockeui* (Abou-Awad *et al*. 2010). Similarly, phytoseiid species showed different development, reproduction and efficiency according to the various prey eriophyid mites: certain phytoseiid species are specialists in their feeding on eriophyid mites, whereas tetranychid mites were supplementary food (Abou-Awad *et al*. 1998b; Momen & Hussein 1999; Momen *et al.* 2004). Other phytoseiids are known to feed on eriophyid mites but do not reproduce or develop (McMurtry & Scriven 1964; Swirski *et al.* 1967). The feeding habits of *A. olivi* are similar to those of two phytoseiid mite species: various eriophyid mites promote a faster development of *Proprioseiopsis lindquisti* (Schuster and Pritchard) (Momen 1999) and *Typhlodromus transvaalensis* (Momen & Hussein 1999), whereas tetranychid mites retard the development of these predators.

Obligatory predators, such as *A. olivi*, are distinguished by whether they survive by preying upon one or more species of mites belonging to the same family. For instance, the most important species of this group, *Phytoseiulus persimilis* (Athias-Henriot) (Phytoseiidae), preys mainly upon *Tetranychus urticae* Koch and occasionally preys upon *Panonychus citri* (McGregor). Akimov and Starovir (1978) compared the digestive system of *P. persimilis* to that of two species of facultative generic predators, and they found that *P. persimilis* has only two posterior diverticula, whereas there are four in the other species. Such a reduction in structures is considered an adaptation to the specialised predation used to increase the amount of ingested food, thereby exploiting the volumetric capacity of the intestine to its utmost.

The present study indicated that *A. lycopersici* was the least suitable food source for the oviposition of the predator; feeding on this prey resulted in the lowest mean total fecundity and net reproductive rate (Ro). Tomato plants are known to be unfavourable for predatory mites, owing to their hairiness and trichome exudates. Possible reasons for the relative low fecundity observed include the inherent characteristics of or the inadequacy of rust mites as a food source for oviposition. According to the terminology of Overmeer (1985), the term ‘alternative food’ was suggested for *A. lycopersici*, whereas the recommended primary food was *A. mangiferae* and *A. fockeui*. Alternative food can be of importance because it may help the predator to maintain itself in a locality when the primary food is low. Additionally, alternative food may be valuable for rearing predators in the laboratory.

The intrinsic rate of increase (r_m) of a predacious mite is one of the most important criteria for evaluating its effectiveness as a biological control agent against phytophagous mites. The mango bud mite exhibited the highest r_m value for *A. olivi*, whereas the tomato rust mite showed the lowest value. It seems that individuals of *A. mangiferae* are more suitable as eriophyiform eriophyid prey than fusiform eriophyids (*A. lycopersici* and *A. fockeui*), as has been reported also by Abou-Awad *et al.* (2000, 2010) for phytoseiid and stigmaeid mites.

A. olivi would need to consume many individuals of the minute *A. mangiferae* to favour a high conversion of food into egg biomass to result in higher intrinsic rate of increase. *A. mangiferae* is a vermiform species with a flexible, elongated, non-arcuated aspect that often features many narrow annuli (Lindquist 1996). The prodorsal shield is not well developed, and the gnathosoma appears prognathous; these body adaptations facilitate the consumption of many *A. mangiferae* individuals. Fusiform species (*A. fockui* and *A. lycopersici*) have a more developed prodorsal shield, the gnathosoma is ipognathous, and they have a more-arcuated body and show a series of thicker and less flexible annuli on the dorsal region. Such dorsal annuli protect mites against the loss of water and severe predation by predators (Ragusa & Tsolakis 2000).

In general, the active stages of the eriophyid mites favoured the full expression of the reproductive potential of the specialist predator, *A. olivi*. It has been reported that some of the eriophyid mites are characterised by a desirable protein content. A polypeptide analysis revealed that the eriophyid mite, *A. dioscorides*, has a most important protein content, both in number (11 polypeptides) or in total molecular weight (682 kD), which enhanced the fertility of an ascid mite when reared on *A. dioscorides* compared to tetranychid mite prey (Abou-Awad *et al.* 2001). Conversely, Sabelis (1996) reported that eriophyids had a low nutritional quality and a low profitability when compared with other prey. In addition, the toxins in eriophyids may be repellent to some phytoseiid predators.

CONCLUSION

The results from the present study indicated that the predacious stigmaeid mite, *A. olivi*, responds differently to the various eriophyid mites tested. This different response should be considered as enhancing the role of the predator in biological control programmes. However, the success of *A. olivi* as a biological control agent will depend both on its life history parameters on various eriophyid pests and on how the different characteristics of the host leaf-inhabiting eriophyid prey affects its ability to locate and capture the prey or its functional response, which is a factor that requires further study.

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