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Article

Life history and population growth parameters of the astigmatid mite *Histiostoma feroniarum* (Acari: Histiostomatidae) feeding on *Fusarium graminearum*

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Abstract

In this study, the life history and demographic parameters of *Histiostoma feroniarum* (Defour) on *Fusarium graminearum* Clade were studied under laboratory condition. The incubation, larval and nymphal periods and longevity of adults were observed to be 1.6, 2.56, 3.09 and 10.48 days, respectively. The sex ratio was 0.65. Pre-oviposition, oviposition and post-oviposition periods lasted 1.8, 8.27 and 0.66 days, respectively. The gross reproductive rate (*GRR*), net reproductive rate (R_0), intrinsic rate of increase (r_m), finite rate of increase (λ), mean generation time (T) and doubling time (DT) were calculated to be 110.56 females/female, 23.54 females/female, 0.195 day^{-1}, 1.215 day^{-1}, 16.23 days and 3.55 days, respectively. The results of this study reveal high potential of *H. feroniarum* as a major pest of laboratory cultures.

Key words: *Histiostoma feroniarum*, *Fusarium graminearum*, Life table, Population growth, Reproduction

Introduction

Histiostoma feroniarum [*Anoetus feroniarum*] (Defour) (Acari, Astigmata: Histiostomatidae) is known as a cosmopolitan species with a worldwide distribution, having a wide range of habitats including stored food (Ardeshir 2002), ornamental plants (Qin & Rohita 1996; Boczek & Blaszak 2005), some agricultural plants like alfalfa (Haddad Irani-Nejad *et al*. 2007), seeds, onions (Boczek & Blaszak 2005), compost and mushrooms (Rota & Bolchi 1974; Clift *et al.* 1995; Ignatowicz 2000), soil (Curry & Momen 1988; Boczek & Blaszak 2005), houses (Hurtado & Parini 1987), sewage filter-beds (Learner & Chawner 1998), on some insects (Ahmad 1974) and laboratory cultures (as we saw in our study). *Histiostoma feroniarum* was first reported in New Zealand from Auckland in 1940 (Qin & Rohitha 1996).

This species can be found in different stored products. As storage mites, they can cause significant weight loss of grains and oilseeds (Ardeshir 2002). Contamination of stored food by arthropods including this species may seriously endanger human health because of allergies (Hubert *et al.* 2003). Skubala *et al.*

(2006) studied the accidental acarophagy in humans and animals. They investigated the presence of mites in 90 food samples, including 24 different kinds of fruits, vegetables and mushrooms. During that study *H. feroniarum* was the most abundant species of Acaridida. It was observed that by washing in running water, only 48.6% and 50% of the total number of mites were removed from fruits and vegetables, respectively. This mite species is also a major pest of ornamental plants. Qin and Rohitha (1996) found this species on rotting tubers of *Sandersonia aurantiaca* Hook, a commercially important flower from New Zealand. Poe (1971) collected *H. feroniarum* during a study on the microfauna of gladiolus corms. During a faunastic study in 2005 that was carried out in the province of East Azerbaijan, Iran, this species was collected from the soil of alfalfa fields (Haddad Irani-Nejad *et al*. 2007). *H. feroniarum* has been observed frequently on a mushroom farm in the Italian province of Bergamo (Rota & Bolchi 1974). In studies in New South Wales, Australia, this species was commonly found in the baled straw used to produce mushroom compost (Clift *et al.* 1995). A huge number of this mite species were repeatedly found on mushroom. During an investigation on the mushroom *Lentinus edode* (Shiitake) in south region of Korea, *H. feroniarum* was also found to be the pest of this mushroom. A huge number of this mite species were found on mushroom lamella which caused significant damages (Kim and Hwang 1996). Also during the faunal survey of the oyster mushroom houses, Lewandowski *et al.* (1999) recorded this species frequently in the substrate used for cultivation of oyster mushroom, *Pleurotus ostereatus* (Jack) in Poland.

Curry & Momen (1988) studied the soil arthropod fauna of managed and unmanaged grasslands. *H. feroniarum* was one of the most frequent acarine species that was observed in grasslands with two years of management.

This species can cause respiratory syndromes like asthma and allergy (Szilman *et al*. 2006). During an investigation which was carried out by Sanchez Covista *et al.* (1999), *H. feroniarum* was recorded from the mite fauna of house dust in homes of patients with respiratory symptoms in the towns of Santa Cruz and La Laguna, Tenerife (Spain).

This mite is widespread and often abundant in sewage filter beds. This species characteristically has prolonged or frequent periods of reproduction. Therefore, they can respond rapidly to changes in the bed environment and they are able to persist despite continuous wash-out from the bed (Learner & Chawner 1998).

During an investigation which was carried out by Ahmad (1974) in the Buenos Aires, Coroba, La Pampa, Rio Negro and Santa Fe provinces of Argentina, it was shown that *H. feroniarum* attack the larvae of *Graphognathus leucoloma* (Boheman) (Col.: Curculionidae).

Laboratory cultures are other important food sources for this mite. They attack different fungal species like *Alternaria* spp., *Phythophtora* spp., *Pythium* spp. and *Rhizoctonia* spp. in laboratory cultures, to such a degree, that all cultures had to be destroyed (as we saw in our study).

Regardless of importance, however, no quantitative data are available on its development and population growth parameters of this mite species. The present study aims to determine these parameters.

Materials and methods

Mite rearing

Histiostoma feroniarum individuals were originally collected from media cultures of Plant Pathology Laboratory of Tarbiat Modares University, Tehran, Iran which were seriously attacked by this species. With several hundred mites from different media cultures of the laboratory a stock colony prepared. By transferring this colony to new cultures of *F. graminearum* Clade, subcolonies were created and the needed population prepared. All subcolonies were kept in growth chamber in the laboratory at 25±5°C, 60±5% R.H. and a photoperiod of 16L-8D h. This temperature and humidity were selected because this mite species had caused serious damages to different fungi cultures at this temperature and humidity. The mite individuals in the subcolonies were never below several hundred mites. One day prior to the start of all experiments, adult female mites were transferred to a new Petri dish. The next day, 50 newly oviposited eggs were collected to do the biological experiments.

Preparation of Fusarium graminearum culture media

For this purpose, a culture media of *F. graminearum* had been prepared. For obtaining a favorable food stock for mites and preventing mycelium growth of any other unwanted fungi, with a sterile needle *F. graminearum* was placed in the center of one new culture medium. It is better to wait until colony of this pathogenic fungus covers all of the Petri dish, in this way the risk of pollution with other fungi will be at minimum level. One day prior to start the experiments, rearing cages were filled with water agar. In the current study water agar was used in place of P.D.A. Water agar is translucent and this made studying the biological parameters of mites much easier. After several hours this pathogenic fungus was cultured in all cavities of the rearing cages.

Experiments

Fifty newly deposited eggs of *H. feroniarum* were isolated in separate cells and observed daily. All changes, beginning from eclosion to larva, through the nymphal stages, to emergence of adults, were recorded. After adults' emergence, they were paired; each pair (1♀+1♂) was placed into a separate rearing cage. Longevity of adult males and females was recorded and the number of deposited eggs was counted daily. For better counting, the newly laid eggs were removed daily from the rearing cages; fresh food was added if needed, for this purpose the mites were removed firstly, then the cavities were filled with new water agar and *F. graminearum*. In this study the sex ratio of adults was also recorded.

Statistical analysis

Statistical analysis of the relevant data (survivorship, fertility and life table parameters) was performed using Carey (1993) method. The formulae of the mentioned parameters have been shown in Tables 2 and 3.

Results

Immature survival and developmental time

Average immature developmental time lasted almost one week at 25°C (Table 1). The duration of the incubation period was very short. The larval and nymphal stages lasted 2.56±0.13 and 3.09±0.2 d, respectively. Less than half of the eggs reached the adult stage. Survival rate in the egg stage was higher than larval and nymphal stages (Fig. 1). Variability in larval and nymphal stage periods was low.

Table 1. Mean (±SE) duration of immature development and survival for *Histiostoma feroniarum* reared on *Fusarium graminearum* at 25±0.5°C, 60±5% R.H.

Developmental stage	n	Developmental time (days)	Survival rate (%)
Egg	45	1.60±0.07	90
Larva	32	2.56 ±0.13	71.1
Nymph	21	3.09±0.2	65.5
Egg to adult	21	7.21±0.42	42

Table 2. Reproduction parameters of *Histiostoma feroniarum* reared on *Fusarium graminearum* at laboratory conditions (25±0.5°C and 60±5% R.H.)

Parameters	Formula	Value	Unit
Gross fecundity rate	$\sum_{x=\alpha}^{\beta} M_x$	206.286	Eggs/female
Net fecundity rate	$\sum_{x=\alpha}^{\beta} L_x M_x$	40.64	Eggs/female
Gross fertility rate	$\sum_{x=\alpha}^{\beta} M_x h_x$	185.66	Eggs/female
Net fertility rate	$\sum_{x=\alpha}^{\beta} L_x M_x h_x$	36.58	Eggs/female
Mean eggs per day	$\frac{\sum_{x=\alpha}^{\beta} L_x M_x}{\sum_{x=\alpha}^{\beta} L_x}$	3.99	(Eggs/female /day)
Mean fertile eggs per day	$\frac{\sum_{x=\alpha}^{\beta} M_x h_x L_x}{\sum_{x=\alpha}^{\beta} L_x}$	3.59	(Eggs/female/day)

x= Age interval in days, α= age at start of reproduction, β= age at end of reproduction, L_x= Midpoint survival rate between x and x+1, M_x= Total number of eggs lay by the average females at age x, h_x= proportion of eggs' hatch for those eggs being laid at age x (Carey 1993).

Reproduction parameters

The average life span of males and females reared on *F. graminearum* was 19.75±3.35 and 16.77±1.6 d, respectively. Mean pre-oviposition, oviposition and post-oviposition periods were 1.8±0.12, 8.27±1.73 and 0.66±0.21 d, respectively. The mean fecundity of each female was 114.1±26.31 eggs, at an average hatch rate of 90%. A summary of the reproduction parameters of adults that developed and oviposited on *Fusarium graminearum* in the laboratory is given in Table 2. Survival for both male and female adults was very high, the longest lived individual died at day 36 and 31 for males and females, respectively. Increasing of egg production was started when adults aged 5 days (≥ 10 egg/female/d) and decreased steadily from day 16 (Fig. 2).

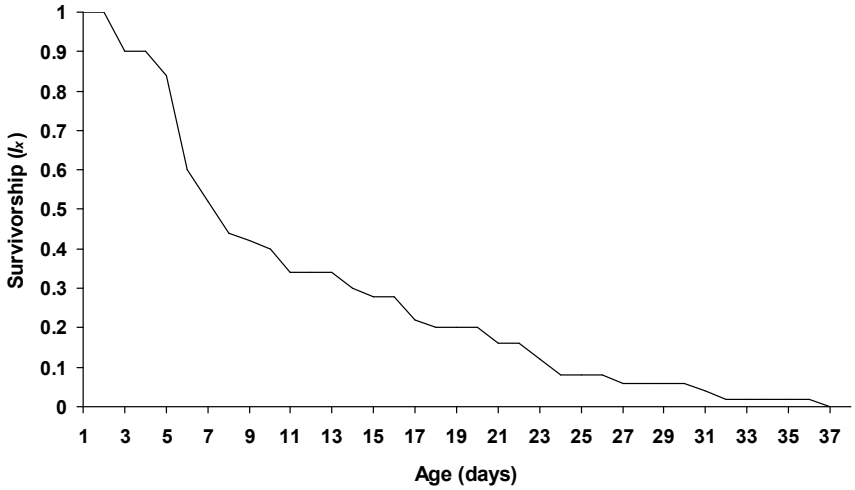

Figure 1. Survivorship (l_x) of *Histiostoma feroniarum* reared on *Fusarium graminearum*

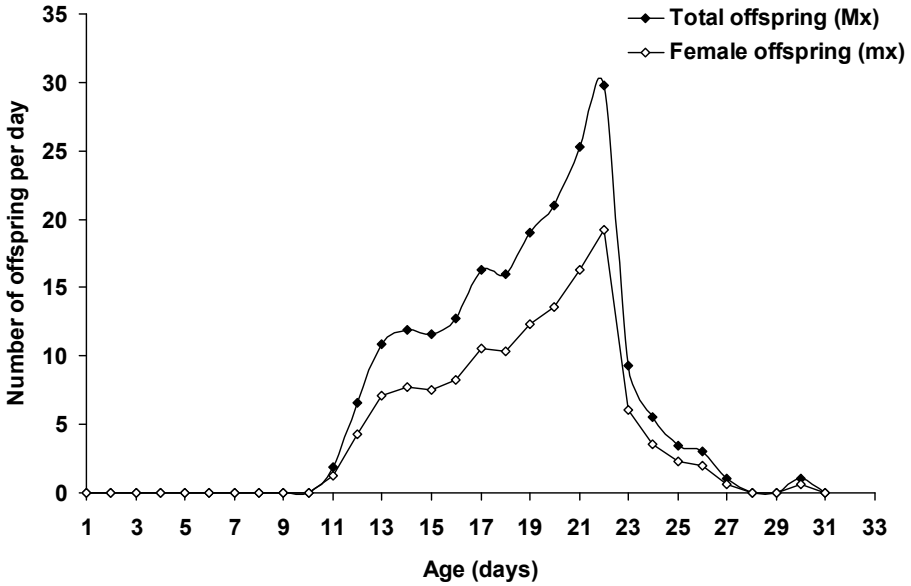

Figure 2. Daily reproduction of *Histiostoma feroniarum* reared on *Fusarium graminearum*

Life table Parameters

Table 3 presents the life table parameters and the stable age distribution. The intrinsic rate of increase and the net reproductive rate were 0.195 and 23.54, respectively. The intrinsic rate of birth and death were 0.290 and 0.095, respectively, indicating that 0.29 birth and 0.095 death per individual occurred daily in the population. The population size was estimated to doubled in 3.56 d., while the mean generation time was 16.23 d. Egg numbers were consisted the largest portion of the population, larvae and nymphs together represented less than half of the mite community, while the adults were only a small fraction of the total population. This shows the high reproduction potential of this mite species; in other words, immature stages constitute the major part of the population.

Table 3. Population growth parameters of *Histiostoma feroniarum* reared on *Fusarium. graminearum* at laboratory conditions (25±0.5°C and 60±5% R.H.)

Parameters	Formula	Value	Unit
Gross reproductive rate (GRR)	$\sum_{x=\alpha}^{\beta} m_x$	110.56	Females/female
Net reproductive rate (R_0)	$\sum_{x=\alpha}^{\beta} l_x m_x$	23.54	Females/female
Intrinsic rate of increase (r)	$\sum_{x=1}^{\omega} e^{-rx} l_x m_x = 1$	0.195	Day^{-1}
Finite rate of increase (λ)	e^r	1.215	Day^{-1}
Intrinsic rate of birth (b)	$\frac{1}{\sum_{x=1}^{\omega} l_x e^{-rx}}$	0.29	Females/female/day
Intrinsic rate of death (d)	b-r	0.095	Females/female/day
Doubling time (DT)	$\frac{\ln 2}{r_m}$	3.55	Days
Mean generation time (T)	$\frac{\ln R_0}{r_m}$	16.23	Days
Age distribution (%)	$\frac{e^{-rx} l_x}{\sum_{x=1}^{\omega} e^{-rx} l_x}$		%
Eggs		43.12%	
Larvae		26.36%	
Nymphs		21.34%	
Adults		9.18%	

α= age at start of reproduction, β= age at end of reproduction, ω= maximum age, l_x= survival rate at age x, m_x= number of female progeny produced by an average female at age x (Carey 1993).

Discussion

This study provides demographic data of *H. feroniarum* reared on *F. graminearum* (an important host for this mite in laboratories of plant pathology) in laboratory conditions at 25±0.5°C, 60±5% R.H. and a photoperiod of 16L-8D h. Although this mite can attack different fungi, several attempts to rear it on some fungi such as *Alternaria* in laboratory have failed. Rapid growth of this fungus might impede the movement of mites and it also may result in burying the larvae and nymphs. Furthermore, the colony of this fungus is very dark and made it almost impossible to study the biology of this translucent mite in such a dark colony. Moreover there were problems of other fungi like *Pythium.* The growth rate of *Pythium* is very slow and mites wouldn't have enough food for growth, development and reproduction. So mites were reared on an almost colorless fungus such as *F. graminearum* on a culture medium of water agar. The investigation was carried out at these temperature and humidity because they were the same temperature and humidity of plant pathology laboratory of Faculty of Agriculture at Tarbiat Modares University that had been seriously infested by this mite species.

The interaction between mites and fungal growth can be very important. Armitage and George (1986) investigated the effect of three species of mites upon fungal growth on wheat. For this purpose, they compared the growth of naturally occurring grain storage fungi on wheat infested with three commonest British grain storage mites, *Acarus siro* Linnaeus, *Glycyphagus destructor* (Schrank) and *Tyrophagus longior* (Gervais) with that on uninfected wheat weekly for a period of 20 weeks. The colonies of the *Aspergilus glaucus* Chevalieri were always smaller on grain infested with mites than on grain without any mite infestation. *Penecillium* spp. were always less numerous on grain which was infested with *A. siro* but it's necessary to say that other mites didn't have any effect on growth of these fungi species. In contrast, two fungi which are pathogenic to mites, *Aspergilus restricus* and *Wallemia sebi* (Fries)*,* were more abundant in the presence of certain mites. The former was associated with *G. destructor,* the latter with *G. destructor* and *A. siro.* They concluded that the three species of mites either feed on *A. glaucus* and *Penecillium* spp., or inhibit them by an unknown secretion. Also Parkinson (1990) investigated the population increase and damage by the same three mite species on wheat at 20°C and two humidities (75% and 90% R.H.). Both *A. siro* and *T. longior* had lower populations at lower humidity; at 75% R.H. the maximum number of these two mites colony were 3000 and 1000, respectively in comparison with 500 and 600 mites, respectively at 90% R.H. But *G. destructor* did make obviously higher growth than at 90% R.H. at the end of 20 weeks. At both humidities visible fungus was always less abundant on infested grain than the uninfected grain, and our data are in accordance with their findings that mites significantly limited the fungal growth.

Very few studies have been done on the biology of *H. feroniarum*. Liana (2005) investigated the influence of insemination at different life stages on female fitness of these mites. The results show that seminal fluids have a positive effect on female fitness. When delayed insemination occurs, such positive effect may not be observed due to a change in features of the sperm access system. In this investigation the longevity and fecundity of females inseminated 'naturally' were higher in comparison with females that received additional males that is likely because of harassment. In our experiments males inseminated the virgin females immediately after the last moulting, but there was also other containers for mass culture of mites

that females and males were kept together, the mean number of egg-laying in those containers (10.05) were smaller than containers that were observed once a day for demographic data (15.87) and this is in accordance with Liana's investigation.
Czajkowska (2003) studied the development and population growth parameters of three acarid mites, *Tyrophagus putrescentiae* Schrank, *Tyrophagus neiswanderi* Jhonson et Bruce and *Rhizoglyphus echinopus* (Fumouze and Robin) on two particular forms of *F. oxysporium*, *F. oxysporium* f.sp. *lilii* and *F. oxysporium* f. sp. *tulipae,* at 25 °C and 85.89% R.H. According to the demographic parameters that were obtained by Czajkowska (2003) and in our study it can be concluded that *Fusarium* is a suitable food diet for all of these species. In both of these investigations, longevity of females was more than males.

Yousef *et al.* (1978) studied the life history parameters of *Histiostoma cataglyphi* Yousef *et* Metwally. In their study the egg incubation period lasted for an average of 1.1 days. The active larval, protonymphal and tritonymphal stages averaged 1.2, 0.74 and 1.24 days, respectively. The life cycle averaged 5-30 days, and the preoviposition, oviposition and postoviposition periods 0.60, 7.60 and 3.0 days, respectively. The developmental time in their study was similar to our data. The preoviposition and oviposition periods were shorter than our data, but the postoviposition period was longer than our data, but in the whole, the developmental and population growth parameters of these two histiostomatid mites were similar. They recorded 3.97 eggs/female/day at 25°C for *H. cataglyphi* that is very close to what has been calculated in our study (3.99). It shows that *F. graminearum* is an attractive and effective source of food for *H. feroniarum* allowing it a favorable life history, longevity, high fecundity and viability. Good food acceptance and high biological parameters including population increase of the species on *F. graminearum* can be used to conclude that it is a potential pest of laboratory cultures. This species appears to be the most important mite in suppressing *M. anisopliae* growth and sporulation on termite cadavers. This is in accordance with our findings which *H. feroniarum* in huge numbers attacked almost all cultures of plant pathology laboratory and inhibited their growth. More studies in the future are needed to investigate the effect of this mite species on different pathogenic fungi. It will be very useful if these mites can be used as a biological control agent against pathogenic fungi in agriculture. Mites are therefore an important variable in studies on fungal growth during grain drying and storage. In our study *H. feroniarum* had an important role in limiting the growth of *F. graminearum* by feeding on it.

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چکیده

در این بررسی، پارامترهای دموگرافیک کنه *Histiostoma feroniarum* (Defour) روی قارچ *Fusarium graminearum* Clade در شرایط آزمایشگاهی تعیین شد. طول دوره های جنینی، لاروی، پورگی و طول عمر بالغ‌ها به ترتیب ۱/۶، ۲/۵۶، ۳/۰۹ و ۱۰/۴۸ روز محاسبه شد. نسبت جنسی برابر با ۰/۶۵ به دست آمد. طول دوره‌های پیش از تخم‌ریزی، تخم‌ریزی و پس از تخم‌ریزی به ترتیب ۱/۸، ۸/۲۷ و ۰/۶۶ روز محاسبه شد. نرخ ناخالص تولید مثل (*GRR*) ۱۱۰/۵۶ تخم به ازای هر ماده در هر نسل و نرخ خالص تولید مثل (R_0) ۲۳/۵۴ تخم ماده به ازای هر ماده در هر نسل تعیین شد. نرخ ذاتی افزایش جمعیت (r_m)، نرخ متناهی رشد (λ)، میانگین مدت زمان یک نسل (T) و مدت زمان دو برابر شدن جمعیت (DT) به ترتیب ۰/۱۹۵ روز$^{-1}$، ۱/۲۱۵ روز$^{-1}$، ۱۶/۲۳ روز و ۳/۵۵ روز به دست آمد. نتایج این مطالعه نشان دهنده پتانسیل زیاد کنه *H. feroniarum* به عنوان آفت عمده محیط کشت‌های آزمایشگاهی است.