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Predation of *Amblyseius longispinosus* (Acari: Phytoseiidae) on *Schizotetranychus nanjingensis* (Acari: Tetranychidae), a spider mite injurious to bamboo in Fujian, China

YANXUAN ZHANG[1], ZHI-QIANG ZHANG[2], JIE JI[1] & JIANZHEN LIN[1]

[1] *Institute of Plant Protection, Fujian Academy of Agricultural Sciences, Fuzhou 350013, China*

[2] *CABI Bioscience, Silwood Park, Ascot, Berks SL5 7TA, UK and current address: Landcare Research, Private Bag 92-170, Auckland, New Zealand*

Abstract

Schizotetranychus nanjingensis Ma & Yuan is a mite pest injurious to the giant bamboo (*Phyllostachys pubscens*) in Fujian, China. The predatory mite *Amblyseius longispinosus* was explored as a potential biocontrol agent against *S. nanjingensis* in a series of experiments. Functional response experiments at six different temperatures showed that handling time (*Th*) generally decreased with temperature, whereas successful attack rate (*a*) increased with temperature and levelled off at >20° (Table 2). Judging by *a*/*Th* values, *A. longispinosus* was most efficient against *S. nanjingensis* at 30-35°C, about half as efficient at 20 and 25°C and performed poorly at 10-15°C. The rate of oviposition increased linearly with prey density. As expected, the number of eggs laid by predators increased linearly with the number of prey they consumed. With a fixed number of prey available, predation rates per predator decreased with predator density. The potential of *A. longispinosus* as a biocontrol agent against *A. nanjingensis* is discussed.

Key words: Predation, oviposition, predator-prey interaction, biological control, *Amblyseius longispinosus*, *Schizotetranychus nanjingensis*.

Introduction

The spider mite *Schizotetranychus nanjingensis* Ma & Yuan is a common species on the giant bamboo (*Phyllostachys pubscens*) in southern China (Yu & Shi 1991; Zhang *et al*. 1998a). This species has recently become an important mite pest on bamboo in Fujian (Zhang *et al*. 1998a, b). A series of studies on the biology and control of spider mites on bamboo in Fujian was initiated in 1996. This is the third report on the biology and potential of predatory mites in spider mite control on bamboo. In a previous paper, we examined the predation of *Amblyseius longispinosus* Evans on *Aponychus corpuzae* Rimando, another spider mite injurious to bamboo in Fujian (Zhang *et al*. 1998c). Another study examined the life history and feeding habits of *Typhlodromus bambusae* on *S. nanjingensis* (Zhang *et al*. 1999). In this paper, we examine the predation of *A. longispinosus* on *S. nanjingensis* to evaluate the potential of this predator as a biocontrol agent against the spider mite.

Amblyseius longispinosus is a common predatory mite species in China and South East Asia. When evaluating its potential as a predator of *A. corpuzae*, Zhang *et al*. (1998c) was not yet aware of its natural association with bamboo mites. Since then, our field surveys in several localities in Fujian showed that this predatory mite occurs naturally in association with *S nanjingensis*, *A. corpuzae* and eriophyid mites (e.g. *Aculus bambusae* Kuang), which either occur alone or in mixed populations. This paper reports on the predation of *A. longispinosus* on *S. nanjingensis*, especially its functional responses to the density of *S. nanjingensis* at different temperatures, its ovipositional response to prey density and interference response to its own density.

Materials and methods

Materials

Amblyseius longispinosus individuals used in this study were from a laboratory culture maintained in the Insectary of the Natural Enemies in the Institute of Plant Protection, Fujian Academy of Agricultural Sciences, Fuzhou.

Schizotetranychus nanjingensis individuals used in this study were collected from bamboo leaves in Changkeng Village, Dahuang Town, Nanping County in Fujian (altitude 200 meters). Several hundred bamboo leaves with *S. nanjingnesis* were cut from bamboo trees on 27 August 1998. More leaves were collected in Changkeng Village, Nanping County during 27-28 October 1998. These leaves were brought back to the laboratory in large plastic boxes (10 x 20 x 8 cm). Leaves with mites were stored in plastic boxes at 5°C.

Functional response of predators to prey density

Petri dishes (diameter 12 cm) were used for rearing mites. A round foam plastic (diameter 9 cm) soaked in water was first placed in the dish. A piece of filter paper (diameter 8) was then placed on the foam plastic. An excised bamboo leaf of 3 x 3 cm was placed on the filter paper. Each leaf was then inoculated with 1, 5, 10, 15, 20 or 25 females of *S. nanjingensis*. A female predator was then added to the leaf. Eight replicates were prepared for each treatment. The numbers of prey consumed by predators at each density were recorded 24 hours after the start of the experiment. The entire experiment was repeated at 10, 15, 20, 25, 30 and 35°C.

Parameters of functional responses were estimated using the Woolf transformation of the disc equation advocated by Fan and Petitt (1994).

Ovipositional responses of predators to prey density

The experimental setup was similar to the above. The numbers of *S. nanjingensis* females per leaf were 1, 3, 5, 6, 9 and 12. A gravid female predator was then added to each leaf. The number of prey consumed and the number of eggs laid were counted every day (although those of the first and second day were not used in the analysis for the possible effects of previous feeding experience). The prey consumed by predators were replaced daily and eggs laid by predators were removed every day. The observations continued until the end of oviposition period. There were four replicates per prey density. The experiment was conducted at 28-30°C.

Response of predators to predator density

The experimental setup is similar to the above. The number of prey was fixed at 30 females of *S. nanjingensis* per leaf. The following number of predator females was introduced to each leaf: 1, 3, 5, 7 and 9. The number of prey consumed was counted 24 hours after the start of the experiment. There were four replicates for each predator density. The experiment was conducted at 28-30°C.

The data were fitted to Hassell & Varley's (1969) empirical model: $A = Q\,P^{-m}$ (2), where A is a measure of searching efficiency, P is predator density and Q and m are constants. The m value estimates the degree of interference among predators. Both constants were estimated by regressing log A on log P.

Results

Functional response of predators to prey density

The number of prey females consumed by predator females at each temperature generally increased with prey density initially but levelled off at higher prey densities (Table 1). Of interest are patterns seen at 30-35°C at higher densities; at 30°C, the number of prey consumed at the density of 25 was lower than at densities of 15 and 20; at 35°C, the numbers of prey consumed at the densities of 20 and 25 were lower than at the density of 15.

Functional responses at all temperatures approximated Holling type II model and estimated parameters of functional responses are shown in Table 2. Handling time generally decreased with temperature, whereas successful attack rate increased with temperature and levelled off at >20° (Table 2). Judging by *a/Th* values, *A. longispinosus* was most efficient against *S. nanjingensis* at 30-35°C, about half as efficient at 20 and 25°C and performed poorly at 10-15°C.

TABLE 1. Functional responses of *Amblyseius longispinosus* females to *Schizotetranychus nanjingensis* females at different temperatures; numbers of prey consumed in the form: mean±S.E.

Prey density	10°C	15°C	20°C	25°C	30°C	35°C
1	0.63±0.52	0.38±0.52	0.75±0.46	1.00±0	0.88±0.35	1.00±0
5	0.87±0.25	1.38±0.52	3.63±0.74	3.88 ±0.35	3.75±0.46	4.25±1.16
10	1.75±0.46	2.38±0.52	4.75±1.04	5.63±1.60	9.00±0.76	8.00±2.51
15	1.50±0.54	2.50±0.76	6.38±0.52	5.63±1.06	10.00±1.51	11.63±2.20
20	1.87±0.35	3.75±0.89	5.13±2.42	6.25±0.71	11.50±2.27	7.38±1.41
25	1.75±0.46	4.13±1.89	6.25±1.17	5.63±1.41	6.88±1.64	8.50±2.45

TABLE 2. Estimated parameters of functional responses of *Amblyseius longispinosus* females on *Schizotetranychus nanjingensis* females at different temperatures.

Parameters	10°C	15°C	20°C	25°C	30°C	35°C
Th	0.484	0.140	0.125	0.141	0.084	0.085
a	0.536	0.347	1.079	1.631	1.462	1.536
a/Th	1.107	2.478	8.630	11.570	17.405	18.072
Na	$\frac{0.536Nt}{1+0.259Nt}$	$\frac{0.347Nt}{1+0.049Nt}$	$\frac{1.079Nt}{1+0.135Nt}$	$\frac{1.631Nt}{1+0.230Nt}$	$\frac{1.462Nt}{1+0.123Nt}$	$\frac{1.536Nt}{1+0.131Nt}$

* *Na* = number of prey consumed; *Nt* = number of prey available; *Th* = handling time; *a* = successful attack rate (a measure of searching efficiency).

Ovipositional responses of predators to prey density

The number of eggs laid per day per predator (Y) increased linearly with prey density (X) (Table 3); the relationship can be described as $Y = -0.327 + 0.335\ X$ ($r = 992$; $P = 0.008$). One female prey was just enough to sustain the predator and no eggs were laid at this density. This species laid a maximum of seven eggs per day at 12 *S. nanjingensis* females per leaf disk. Within the range that was examined, oviposition rate increased linearly with predation rate; the relationship between oviposition rate (Y) and predation rate (Z) can be described as $Z = 1.05 + 1.80Y$ ($r = 0.985$; $P = 0.028$).

TABLE 3. Ovipositional responses of *Amblyseius longispinosus* females to density of *Schizotetranychus nanjingensis* females at 28-30°C.

Density	1	3	6	9	12
Rate of oviposition	0	0.50±0.53	2.0±1.69	2.63±1.06	3.63±1.69
Rate of predation	1±0	1.63±0.52	5.00±1.85	6.38±1.06	7.00±3.07

Response of predators to predator density

With a fixed number of prey available (30 females per leaf), predation rates per predator decreased with predator density (Table 4). The relationship can be described by the equation: $A = 6.34 P^{-0.38}$ ($r = 0.96$), where A relates to *per capita* searching efficiency and P is predator density.

TABLE 4. Per capita rate of predation of *Amblyseius longispinosus* females on *Schizotetranychus nanjingensis* females in relation to predator density at 28-30°C.

Predator density	1	3	5	7	9
Rate of predation	6.75±1.71	3.60±1.24	3.55±1.93	3.30±1.53	2.74±0.23

Discussion

Amblyseius longispinosus occurs naturally in association with *S. nanjingensis*, although it is not as common as *T. bambusae* on the giant bamboo. However, *A. longispinosus* is a much well studied species than *T. bambusae* and can be easily reared in laboratory in large numbers. It is for this reason that we examined its potential as a predator against *S. nanjingensis*. Although we have never observed *A. longispinosus* feeding on *S nanjingensis* in the field, in this study we showed that it readily attacked all stages of *S. nanjingensis* and responded rapidly to the density of *S. nanjingensis* both functionally and numerically.

Our study showed that predation on *S. nanjingensis* by *A. longispinosus* was less sensitive to temperature than that by *T. bambusae*. Successful attack rate by *A. longispinosus* was 1.079 at 20°C and 1.462 at 30°, whereas that by *T. bambusae* was 0.349 at 22-24°C and 1.174 at 28-30° (Zhang *et al*. 1999). The differences of predation rates between the two species are more obvious at lower temperatures; e.g. at 25 prey per disc, *A. longispinosus* consumed on average 5-6 prey whereas *T. bambusae* consumed on average 3 prey.

Of interest are *A. longispinosus* predation patterns seen at 30-35°C at higher densities; at 30°C, the number of prey consumed at the density of 25 was lower than at densities of 15 and 20; at 35°C, the numbers of prey consumed at the densities of 20 and 25 were lower than at the density of 15. It is possible that the reduced rate of successful attack at higher prey densities may result from the density dependent interference or defensive behaviour by spider mites. A related spider mite species, *Schizotetranychus longus* Saito, 1990b, was showed to counter-attack its predator, *T. bambusae* (Saito 1986a,b).

A. longispinosus laid an average of 3.6 eggs per day with a maximum of seven eggs per day feeding on *S. nanjingensis* females, whereas *T. bambusae* laid an average of 3.2 days with a maximum of 8 eggs per day. The comparable high reproductive rates for both predators indicates that *S. nanjingensis* is a highly suitable food for *A. lognispinosus*.

It is unknown why *A. longispinosus* is so rare on bamboo. It is possible that this species is predominately a species that thrives on lower plants and the canopy of the giant bamboo is too high (dry) for this species. *T. bambusae* does well high on the trees because its ability of penetrating the webnests of *S. nanjingensis*, which provide a more suitable micro-environment. Future studies should examine the ability of *A. longispinosus* to invade webnests of *S. nanjingensis*.

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