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Biology of *Typhlodromus bambusae* (Acari: Phytoseiidae), a predator of *Schizotetranychus nanjingensis* (Acari: Tetranychidae) injurious to bamboo in Fujian, China

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Abstract

Typhlodromus bambusae Ehara is a dominant predator species associated with the spider mite *Schizotetranychus nanjingensis* Ma & Yuan on the giant bamboo (*Phyllostachys pubscens*) in Fujian, China. In the field, increased densities of *T. bambusae* were associated with reduced densities of *S. nanjingensis* on bamboo leaves. Laboratory studies at 22-30°C on a diet of *S. nanjingensis* showed that females of *T. bambusae* completed a full egg-egg cycle in 7.5 days and mated females laid an average of 3.2 eggs per female per day. The number of female prey consumed by predator females increased with prey density very fast initially at prey densities of ≤5 but levelled off as prey density was further increased. Prey handling time was over 40% shorter and the rate of successful attack was twice higher at 28-30°C than at 22-24°C. When fed the pollen of *Luffa cylindrica* or eggs and larvae of *Tyrophagus putrescentiae*, *T. bambusae* females could not survive to lay eggs. However, predator females readily attacked females of *T. kanzawai* and were able to reproduce normally on this diet. *T. bambusae* could complete development on *T. kanzawai* as fast as on *S. nanjingensis*. The potential of *T. bambusae* as a biocontrol agent in integrated control of *S. nanjingensis* is discussed.

Key words: *Typhlodromus bambusae*, *Schizotetranychus nanjingensis*, life history, predation

Introduction

The spider mite *Schizotetranychus nanjingensis* Ma & Yuan is a common species on the giant bamboo (*Phyllostachys pubscens*) in southern China (Yu & Shi 1990; 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 second report on the biology and potential of predatory mites in spider mite control on bamboo. The first paper was on the predation of *Amblyseius longispinosus* Evans on *Aponychus corpuzae* Rimando (Zhang *et al*. 1998c).

Typhlodromus bambusae Ehara is a dominant predator species associated with *S. nanjingensis* on bamboo in Fujian. It was also reported to associate with *S. nanjingensis* on bamboos in the neighbouring province Zhejiang (Yin *et al*. 1996). Very little is known about the biology of *T. bambusae* and its role in spider mite control. Saito (1990a) reported on the life-history and feeding habit of this species feeding on the long seta form of *S. celarius* (Banks) [= *S. longus* Saito, 1990b) in Japan. This paper reports on the life cycle of *T. bambusae* feeding on *S. nanjingensis*, its functional responses to the density of *S. nanjingensis* females and its ability to feed on alternative foods.

Materials and methods

Materials

Typhlodromus bambusae and *S. nanjingensis* individuals used in this study were collected from bamboo leaves in Maqian Village, Dahu Town, Minhou County in Fujian (altitude 500 meters above sea level). Several hundred bamboo leaves were cut from bamboo trees on 14 and 24 October 1996. These leaves were brought back to the laboratory in large plastic boxes (10 x 20 x 8 cm) and examined under a dissecting microscope. Numbers of spider mites, their nests and predators were recorded. Behavioural interactions were noted whenever observed.

Excess leaves with mites were stored in plastic boxes at 5°C for observations and experiments in the future.

Predators and spider mites used in functional response experiments were collected from bamboo leaves in Changkeng Village, Nanping County (Fujian) during 2-3 November 1998.

Observations on life cycle

Petri dishes (diameter 12 cm) were used for rearing mites. A round foam plastic (diameter 9 cm) soaked in water were first placed in the dish. A piece of filter paper (diameter 8) was then placed on the foam plastic. A piece of bamboo leaf with an egg or a gravid female of *T. bambusae* was then placed onto the filter paper. An abundance of *S. nanjingensis* was then added to the leaf. A total of 15 replicates were prepared. Observations were made twice daily at 8:00 and 17:00. Records were made on the life stages of each predator individuals and their behaviours.

Functional response of predators to prey density

The experimental arena was similar to that in the above experiment. 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 conducted at low (22-24 °C) and high (28-30°C) temperatures. Parameters of functional responses were estimated using Woolf transformation of the disc equation advocated by Fan and Petitt (1994).

Tests of suitability of alternative foods

The experimental arena was similar to that in the first experiment except that a piece of black plastic membrane was used instead of filter paper and leaves of eggplant instead of leaves of bamboo. Larvae and eggs of *Tyrophagus putrescentiae* (Schrank), pollens of *Luffa cylindrica* and mobile stages of *Tetranychus kanzawai* Kishida were tested as food for *T. bambusae*. A female predator and an abundance of one of the above food were added to the arena. Twenty replicates were prepared for each treatment. Observations were made on whether the predator feed on the mites/pollens and whether they can lay eggs on them. The observations lasted for about 20 days and daily temperatures fluctuated between 28-30°C.

To test the duration of immature stages of *T. bambusae* feeding on *T. kanzawai*, an egg of *T. bambusae* and 10 females of *T. kanzawai* were added to each arena. Twenty replicates were prepared. Observations on the development of *T. bambusae* were made twice each day at 8:00 and 17:00.

Field survey

On 14 October 1996, a random sample of 15 leaves was taken from a bamboo forest in Dahu Village. Ten days later, another sample of 30 leaves was taken from the same forest. On the same day, another sample of 50 leaves was taken from a nearby forest. The number of spider mite nests, the number of spider mites and the number of predatory mites per leaf were counted for both samples.

Results

General observations on life cycle and behaviour

The development of *T. bambusae* follows the typical pattern in the Phytoseiidae: egg, larva, protonymph, deutonymph and adult. When feeding on *S. nanjingensis*, egg stage (1.7 days) lasted longer than larval stage (1.0 day) and nymphal stages (0.8 days) at room temperatures of 22-30°C (Table 1). Immature survival rate was 100% in the laboratory when an abundance of food was provided. Females accounted for 73% of all 41 adults observed, with a female/male ratio of 2.7. After a short pre-oviposition period (3.2 days), mated females laid an average of 3.2 eggs per day (n = 26), with minimum zero and maximum 8 per day. Unmated females were not observed to lay eggs.

TABLE 1. Duration of life stages of *Typhlodromus bambusae* feeding on *Schizotetranychus nanjingensis* females (temperatures 22-30°C).

Life stage	No observed	Mean duration (max.-min.) in days	
Egg	51	1.7	(0.5-3.0)
Larva	53	1.0	(0.5-1.5)
Protonymph	100	0.8	(0.5-1.0)
Deutonymph	100	0.8	(0.5-1.5)
Pre-oviposition	100	3.2	(2.0-5.0)

Typhlodromus bambusae females feed on all stages of *S. nanjingensis*. Protonymphs of *T. bambusae* were observed to attack successfully females of *S. nanjingensis* twice of their size. One predator was observed to take a total of 20 females and two eggs of *S. nanjingensis* in four days during development from larva to adult. An adult female of *T. bambusae* consumed a *S. nanjingensis* adult female in 15-20 minutes.

Field survey of a bamboo forest in Dahu Village, Minhou County on 14 and 24 October 1996 showed that the density of *S. nanjingensis* decreased from 30 to 9 mites per leaf, whereas that of *T. bambusae* increased from 0.5 to 0.9 per leaf (Table 2); these differences were statistically significant ($P<0.05$). On 24 October, predator density was higher at site B than site A, whereas spider mite density was significantly lower at site B than site A, although spider mite nest densities were similar at both sites (Table 2).

TABLE 2. Numbers of *Schizotetranychus nanjingensis* and its woven nests on bamboo leaves with different densities of *Typhlodromus bambusae* (Dahu Village 1996). Data are in the format of mean ± S.E.

Date	Sites	Sample size	*S. nanjingensis*	Nests/leaf	*T. bambusae*
14 October 1996	A	15	29.9±1.4	11.5±8.2	0.5±0.3
24 October 1996	A	30	9.0±2.5	6.4±0.7	0.9±0.2
24 October 1996	B	47	0.8±0.4	5.4±1.0	1.2±0.2

Functional response of predator females to prey density

The number of female prey consumed by predator females increased with prey density initially very fast but soon levelled off (Table 3). Functional responses at two temperatures approximate Holling Type II responses (Table 4). Handling time was about over 40% shorter and the rate of successful attack was more than twice higher at 28-30°C than at 22-24°C (Table 4).

TABLE 3. Functional responses of *Thphlodromus bambusae* females to *Schizotetranychus nanjingensi*s females at different temperatures; numbers of prey consumed in the format: Mean±SE.

Temperature	Prey density (mites per leaf)					
	1	5	10	15	20	25
22-24°C	0.25±0.46	2.75±0.46	2.13±0.35	2.88±0.64	2.75±1.39	3.38±0.92
28-30°C	1.00±0	4.13±0.35	5.25±0.89	5.13 ±1.13	6.00±1.67	7.38±0.74

TABLE 4. Functional responses of *Typhlodromus bambusae* females on *Schizotetranychus nanjingensis* females at two temperatures with estimated parameters.

Parameters	22-24°C	28-30°C
Th	0.202	0.114
a	0.394	1.174
a/*Th*	1.949	10.296
Na	$\frac{0.394Nt}{1 + 0.080Nt}$	$\frac{1.174Nt}{1 + 0.134Nt}$

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

Suitability of alternative foods

When fed pollens of *L. cylindrica*, *T. bambusae* females either escaped or died within eight days without laying any eggs. When fed eggs and larvae of *T. putrescentiae*, *T. bambusae* females could feed on prey eggs but did not like them and 90% of them escaped; none survived to lay eggs. However, predator females readily attacked females of *T. kanzawai* and were able to reproduce normally on this diet. *T. bambusae* could complete life cycle on *T. kanzawai* as fast as on *S. nanjingensis*. (Table 5).

It was observed that *Typhlodromus bambusae* females preferred to feed on *S. nanjingensis* when the latter was provided along with *T. kanzawai*. When given only *T. kanzawai*, they preferred larvae and nymphs to adults.

TABLE 5. Development of *Typhlodromus bambusae* immatures on *Tetranychus kanzawai* females in the laboratory. (n = 20; temperatures 28-30°C).

Life stage	Rate of survival (%)	Mean duration (max.-min.) in days	
Egg	100	1.6	(1.0-2.0)
Larva	100	0.9	(0.5-1.0)
Protonymph	100	0.7	(0.6-1.0)
Deutonymph	100	0.7	(0.5-2.0)
Pre-oviposition	100	2.0	(2.0-2.0)

Discussion

Although only two papers have been published on the life history of *T. bambusae* (Saito 1990a and this paper), it is apparent that there is noticable variation in life history traits among populations in Japan and Fujian, China. Egg-adult developmental time of *T. bambusae* is shorter in the Fujian population (4.2 days 22-30°C) than in the Japanese population (6.1 days for males and 7.3 for females at 25±1°C; Saito 1990a), so is the egg-egg life cycle (7.5 versus 8.9 days), both feeding on their natural prey *Schizotetranychus* mites. The sex ratio of the experimental population is slightly more female-biased in the Fujian population (F:M = 73:27) than in the Japanese population (F:M = 61:39; Saito 1990). The daily oviposition rate of *T. bambusae* is higher in the Fujian population (3.2) than in the Japanese population (1.7; Saito 1990a). These differences may reflect geographical variation between the Chinese and Japanese populations.

Saito (1990a) found that *T. bambusae* laid more eggs when fed *S. longus* than *S. recki* Ehara or *A. corpuzae* and he suggested that *T. bambusae* is adapted to searching for *S. longus* in their webnest. *S. nanjingensis* likewise construct webnests similar to those of *S. longus*. Our field survey showed that they are always found in the webnests of *S. nanjingensis*.

Our tests on alternative food showed that *T. bambusae* readily attacked *T. kanzawai* and developed as fast as it did on *S. nanjingensis*, but it suffered high mortality on *T. putrescentiae* and failed to reproduce on this diet. Based on the results of this study and that of Saito (1990a), in terms of the degree of polyphagy, *T. bambusae* is more similar to type II predators than type III predators of McMurtry and Croft (1997)'s classification of life-styles of phytoseiid species, although they suggested that *T. bambusae* might represent a type outside the four types they proposed, considering the special adaptation of this mite to spider mites with webnests.

Saito (1990a) reported that *T. bambusae* females consumed an average of 8.44 eggs of *S. longus*, 5.32 eggs of *S. recki* and 8.92 eggs of *A. corpuzae* in two days. We observed one predator consuming a total of 20 females and two eggs of *S. nanjingensis* in four days during development from larva to adult. An adult female of *T. bambusae* consumed a *S. nanjingensis* adult female in 15-20 minutes and the number of female prey consumed per day increased with prey density as in type II functional responses. The observed maximum prey intake per day was 8 *S. najingensis* females at 28-30°C.

Our preliminary field observation revealed that increased densities of *T. bambusae* were associated with reduced densities of *S. nanjingensis* on bamboo leaves, although this occurred too late in the season. Some kind of augmentation early in the season is therefore necessary for successful biocontrol of *S. nanjingensis*. The fact that *T. bambusae* readily attacked *T. kanzawai* and developed as fast as it did on *S. nanjingensis* suggests that there is the possibility of rearing it in mass numbers in the insectary for field release. We have studied the possible use of *A. longispinosus* against *N. nanjinensis* (Zhang *et al*. 1999) as the former is mush easier to rear than *T. bambusae*. However, releasing predatory mites in bamboo forests can be quite an expansive and difficult task. An alternative is the conservation of *T. bambusae* in the forests. Weather the maintenance of a lower vegetation in bamboo forests or a mixture of other trees with bamboo might encourage predatory mites is unknown and should be the subject of future studies.

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