The Functional Response and Numerical Response of *Amblyseius cucumeris* (Acari: Phytoseiidae) on *Frankliniella occidentalis* (Thysanoptera: Thripidae)

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Abstract: The functional response and numerical response of female predatory mite *Amblyseius cucumeris* on first instar larvae of western flower thrips *Frankliniella occidentalis* were determined on impatiens and ivy geranium leaf disks in the laboratory at 25 ℃ and a 16 h light: 8 h dark photoperiod, and the numerical response was conducted on impatiens. Prey density ranged from 3 to 30 larvae per leaf disk. The result showed that the functional and numerical response followed Holling II model. The attack rates were 1.194 7 and 1.044 7, handling time (T_h) were 0.057 5 and 0.126 4 d respectively on impatiens and ivy geranium. The numerical response could be expressed as $N_a = 0.275\,5N/(1+0.183\,1N)$.

Key words: *Amblyseius cucumeris*; *Frankliniella occidentalis*; functional response; numerical response
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胡瓜钝绥螨对西花蓟马的功能反应和数值反应

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摘要: 在温度 25 ℃、光照 16 h的人工气候箱里研究了胡瓜钝绥螨雌成螨在凤仙花和天竺葵叶片上对西花蓟马 1龄若虫的功能反应, 以及胡瓜钝绥螨雌成螨在凤仙花叶片上的数值反应. 结果表明, 胡瓜钝绥螨对西花蓟马的功能反应和数值反应均为 HollingII 型. 在凤仙花和天竺葵上胡瓜钝绥螨的攻击效率分别为 1.194 7和 1.044 7, 处理时间分别为 0.057 5和 0.126 4 d. 数值反应方程为 $N_a=0.275\,5N/(1+0.183\,1N)$.

关键词: 胡瓜钝绥螨; 西花蓟马; 功能反应; 数值反应

Western flower thrips (WFT), *Frankliniella occidentalis* (Pergande), is the most serious pest and cause tremendous damage and economic injury in the world. It was first reported in China and caused serious damage in 2003[1-2]. WFT not only directly damage the flowers and foliages by feeding and oviposition, but also transmit tomato spotted wilt virus and impatiens necrotic spot virus, two serious viruses in vegetable and ornamental crops.

It is difficult to control WFT because it developped the insecticide resistance and had a large number of hosts[3]. The predatory mite *Amblyseius cucumeris* is an effective biological control agent for WFT[4-7]. Commercial availability gives a bright future to use the predatory mite. Impatiens and ivy geranium are the most economically important flowering ornamental crops. However, impatiens and ivy geranium frequently incur serious damages from WFT. The interactions of the predatory mite and WFT on the impatiens and ivy geranium have not been understood thoroughly, the functional and nu-

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merical response is one description of the predator and prey relationship, and is a basic for effectiveness of using the predator to control WFT. There is little work has been done on functional and numerical response of *A. cucumeris* on WFT[8-10].

A. cucumeris was introduced to China by Fudan university[11] and Institute of Plant Protection, the Academy of Agricultural Sciences of Fujian Province[12]. *A. cucumeris* could be mass reared and sold as product[12] to control spider mites in China. This study evaluated the predation efficiency of predatory mite *A. cucumeris* as a biological control agent of WFT, which can provide useful information of using *A. cucumeris* to control WFT in China.

1 Material and methods

1.1 Material

1.1.1 Predatory mite *A. cucumeris* was bought from koppert biological systems, Michigan, USA.

1.1.2 *Frankliniella occidentalis* (WFT) WFT colony was obtained from a virus-free laboratory colony maintained in the Department of Entomology, University of California-Davis. A colony was subsequently maintained in plastic containers on green bean in laboratories in the Department of Entomology, Kansas State University, USA. To obtain a uniform aged cohort of first instar larvae of WFT, the bean pods in which the eggs have been laid by adult WFT were collected every day to kept for eclosion. Only first instar larvae which in color of white were used as prey for predatory mites.

1.2 Methods

The experiment was conducted at 25 ℃, Photoperiod 16 h light ∶8 h dark at growth chamber in the Department of Entomology, Kansas State University, USA.

1.2.1 Rearing units Predatory mites reared individually on plastic surface substratum in petri dish, Canada balsam and castor bean oil (V∶V = 1.5∶1.0) was used around the edge as a barrier. To obtain mites for testing, female predators selected from colony were placed in petri dishes with first larvae of WFT, and let the female predators lay eggs for 8 h, newly oviposited eggs were collected and placed in petri dish, after hatting, individual of larvae was placed in petri dish and fed with enough first larvae of WFT until they reach to adult. A pair of newly emerged female and male were placed in new petri dish and supplied enough larvae of WFT for 2 d, then the WFT were deprived and let the predator hungry for 24 h.

1.2.2 Experimental units The predation trails were conducted on fresh impatiens (cultivar of 'Impulse Orange') and/or ivy geranium (cultivar of 'Sybil Holmes') leaf disk, the leaf was upside down on the water-saturated foam in petri dish. An arena of approximately 12 cm^2 was bordered by Canada balsam and castor bean oil (V∶V = 1.5∶1.0).

1.2.3 Functional response The different prey densities offered to a single female predatory mite were 3, 5, 10, 15, 20, 30. To obtain the required initial density of prey, the first instar larvae of WFT were transferred carefully to each leaf desk using a fine brush, a single adult female predatory mite which had been deprived food for 24 h was then placed on each leaf disk. After 24 h, the predation areas were examined to record the number of fed-upon WFT larvae. Controls (no predators) were set up for each prey density to check the natural mortality. There were 13 replicates per treatment.

1.2.4 Numerical response Each leaf was infested with one female predator and WFT at densities of 3, 5, 10, 15, 20 or 30 individuals. Before experiment, the female predators were maintained with conspecific males for 2 d to allow mating and supplied enough first instar larval WFT, then deprived food for 24 h, and the females were transferred to the plastic dishes. The predation areas were examined to record the number of fed-upon WFT larvae and eggs laid daily, then the female adult predators were removed into new leaf disks. The experiment lasted for 10 d. But the data on first three days were deleted, so the WFT consumed and the eggs laid were average of the data of seven days. Controls (no predators) were set up for each prey density to check the natural mortality. There were 13 replicates per treatment.

2 Results

2.1 Functional response

There was not any dead of WFT on control, which showed the natural mortality of WFT on impatiens and ivy geranium was zero.

The functional response data for the female adult *A. cucumeris* on first instar larvae was successfully fitted to the Holling II disk equation both on impatiens and ivy geranium (Tab. 1 and Fig. 1). The disc equation was $N_a/P = aNT/(1 + aT_hN)$. The N_a was the number of successful attacks per predator (P) during the special time period (T), which in this experiment was

1 d. N was the initial density of the prey offered, and a was attack rate. T_h was the time required to handle the prey. According to the data on table 1, the T_h was 0.057 5 and the a was 1.194 7 on impatiens, while T_h was 0.126 4 and the a was 1.044 7 on ivy geranium, so the equation could be expressed as: $N_a = 1.194\,7N / (1 + 0.068\,7N)$ ($R^2 = 0.963\,4$) and $N_a = 1.044\,7N / (1 + 0.132\,1N)$ ($R^2 = 0.994\,3$) on impatiens and ivy geranium respectively.

Tab. 1 Mean number of the first instar larvae of *Frankliniella occidentalis* killed by female adult of *A. cucumeris* at different *Frankliniella occidentalis* densities on impatiens and ivy geranium over 24 h period at 25 ℃

item	3	5	10	15	20	30
impatiens	2.85±0.10	4.77±0.17	8.77±0.39	9.08±0.75	9.30±0.53	9.23±0.36
ivy geranium	2.23±0.20	3.23±0.32	4.31±0.51	5.23±0.36	6.15±0.44	6.08±0.45

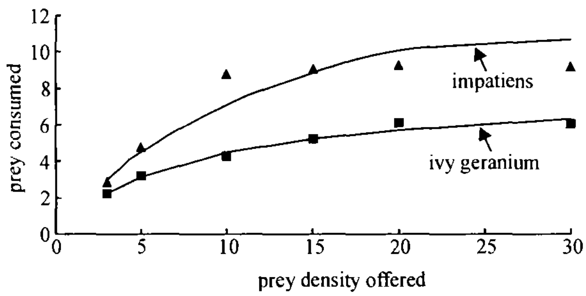

Fig 1 Functional response of female adult of *A. cucumeris* on the first instar larvae of *Frankliniella occidentalis* on the impatiens and ivy geranium

2.2 Numerical response

The numerical response of *A. cucumeris* on impatiens to increasing density reflected a type Ⅱ response (Tab. 2, Fig 2). The relationship could be expressed as $N_a = 0.275\,5N / (1 + 0.183\,1N)$ ($R^2 = 0.929\,7$). Moreover, there was a high correlation of eggs laid of *A. cucumeris* and WFT consumed, their relationship could be expressed as: $y = 0.224\,3 + 0.111\,0x$ ($R^2 = 0.880\,7$). Where x was the mean number of WFT consumed by per female predator per day, y was the mean number of eggs laid by per female predator per day.

Tab. 2 The Mean number of eggs laid and the first instar larvae of *Frankliniella occidentalis* (WFT) killed by female adult of *A. cucumeris* per day at different *Frankliniella occidentalis* densities on impatiens

item	3	5	10	15	20	30
WFT consumed	2.92±0.04	4.60±0.06	8.02±0.30	6.90±0.23	9.22±0.25	8.74±0.28
eggs laid	0.55±0.05	0.64±0.06	1.13±0.05	1.18±0.06	1.20±0.06	1.13±0.05

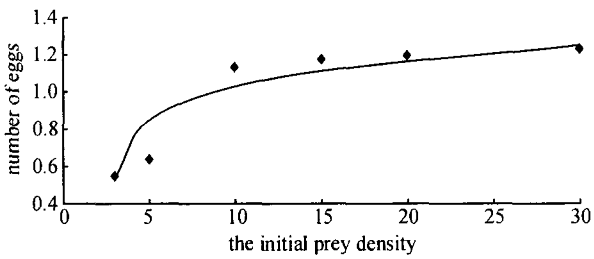

Fig 2 The mean number of eggs laid per predator per day at different *Frankliniella occidentalis* densities

3 Discussion

The functional response exhibited by *A. cucumeris* was reasonably well described by Holling Ⅱ model. The functional responses of *A. cucumeris* to various stages of *Polyphagotarsonemus latus*[11], WFT[8,10] all followed Holling Ⅱ model. In the present study, the functional response curve reached a plateau at 10 and 6 WFT larvae, which was the maximum number that could be eaten on impatiens and ivy geranium leaves in 24 h respectively. Ship and Whitfied[8] suggested that a maximum of 10 and 7 first instar WFT could be eaten on sweet pepper and cucumber leaf disk respectively. The different in the prey consumed among plants suggested that the plant traits influence the prey predator interaction[8,13-14]. For example, the density of trichomes on leaf may disrupt the movement of predator and prey. The impatiens leaves are naturally smooth and free of leaf hairs, which maybe benefit the mite activity, while there were many trichomes on ivy geranium, this might be the reason the WFT consumed fewer than on impatiens.

In the results, the attack rate (a) was 1.194 7 on impatiens and 1.044 7 on ivy geranium, which were bigger than 0.967 4 (on cucumber) and 0.870 (on sweet pepper), the handing time T_h was 0.057 5 on impatiens, which was similar to 0.062 on sweet pepper, T_h was 0.126 4 on ivy geranium which was similar to 0.124 on cucumber[8]. The big attack rate and lower handing time indicated that *A. cucumeris* was effective predator on impatiens and ivy geranium. What's more, the attack rate was bigger and handing time was lower on impatiens than on ivy geranium indicated that A. cucumeris was more effective predator on impatiens than ivy geranium.

A. cucumeris killed WFT by piercing the larvae and sucking out the body contents. It was the most effective against the small first instar stage. The second instar thrips and thrips adults would attack the predatory mites by striking out with its abdomen. In addition, thrips excreted a wet substance that covers predatory mites, the mites then spend time cleaning themselves instead of attacking thrips[15]. However, it has the advantage of being mass reared in large numbers, which make it suited for inundative release and widespread used.

The experimental area of the leaf disk in laboratory was relatively small, and only one surface exposed, which made it easy for predator to find its prey. Furthermore, in nature, various life stages of prey and predator coexist, and several prey as well as predator species may appear simultaneously on a single leaf and /or plant. Therefore, these laboratory results may not exactly correspond to the nature situation, but would be useful for assess the population dynamics and evaluating the predator controlling ability. It would be interesting to investigate how the responses of predators found in laboratory studies with simple single predator-single prey systems, reflected their responses in nature in which systems are likely to be more complex, and further studies for A. cucumeris and WFT should be conducted under both laboratory and nature conditions.

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