International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 05-05-2022, Accepted: 21-05-2022, Published: 06-06-2022
Volume 7, Issue 6, 2022, Page No. 66-69

Evaluation of predatory potential of the mite *Amblyseius paraaerialis* muma (Acari: Phytoseiidae) on spider mite pests *Tetranychus urticae* Koch and *T. macfarlanei* baker and pritchard (Acari: Tetranychidae)

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Abstract
Tetranychid mites are gaining importance in India as major pests of vegetables and many other economically important crops. Control of these mites using conventional chemical pesticides is becoming a tough job as these creatures are developing pesticide resistance in a short time period. Phytoseiid mites are considered as effective biological control agents against plant mites. The objective of this study was to find out the predatory potential of Amblyseius paraaerialis on Tetranychus macfarlanei and Tetranychus urticae. Consumption of various life stages of T. macfarlanei and T. urticae by A. paraaerialis was observed. The rate of consumption of prey life stages by A. Paraaerialis was in the order Adult<Nymph<Larva<Egg. The results of this study suggest that A. paraaerialis could be considered as an effective biological control agent for T. macfarlanei and T. urticae.

Keywords: predatory potential, *Tetranychus*, biological control, phytoseiidae

Introduction
There are about 700 species of plant mites recorded from India, half of which are phytophagous (Gupta, 2012) [8]. The major plant feeding mites come under families Tetranychidae, Tenuipalpidae, Eriophyidae and Tarsonemidae. Tetranychid mites are considered as one of the most injurious mite pests of vegetable crops. They are also found in cereal crops, fruit plants and other economically important crops and are distributed throughout the world (Singh, 2013) [16]. Symptoms of feeding by Tetranychid mites begins with chlorotic spots on leaves. As infestation becomes more severe, leaves appear bronzed or silvery, become brittle, and may fall prematurely. Plants can be killed quite rapidly by this family (Vincenzo, 2016) [19]. In India, there developed an increasing concern on the damage caused by phytophagous mites in the agricultural fields. It was during 1980s, that the farmers were provided with the knowledge of severity of mite infestation through various government programs. Since then, efforts had been put to implement a number of pest management activities to control mite invasion. But the progression in this field was very slow. Accurate knowledge for identification of plant mites, nature of their feeding and the symptoms caused, are important in developing a defense strategy against mites. But there has been limited effort to develop these criteria in the ground level so that the farmers are benefited (Singh and Raghuraman, 2010) [15].
Biological control is considered as an important component of Integrated Pest Management (IPM) program (Vennila *et al*., 2016) [18]. This is an environmentally safe and efficient means of reducing pests by the use of their natural enemies. Identification of specific biological control agent is the key part in this approach (Markus *et al*., 2018) [10]. The predatory mites belonging to family Phytoseiidae play a very crucial role in natural control of plant mites and insects. This family constitutes three sub families and nearly 2250 known species (Moraes *et al*., 2004) [11]. *Amblyseius longispinosus*, *A.eharai*, *A.cucumeris*, *A.tetranychivorus*, *A. indicus and Phytoseiulus persimilis* are some of the predatory mites reported from India which are found to be effective predator against various Tetranychid mites (Usha, 2011; Pushpa & Rajnath 2018) [17, 13]. Prior to the current study, a survey was conducted in northern part of Kerala, India, to recognize the common predatory mites and pest mites on selected agricultural plants from the area. In this survey we could identify *Amblyseius paraaerialis* as one of the prevalent predatory mite species. Spider mites of the family Tetranychidae were found to be one of the most serious pest species infesting many of the economic crops grown in different agricultural fields. Among them *T. urticae* and *T. macfarlanei* were observed as the predominant mite pests infesting an array of agricultural plants leading to substantial yield loss every year. The study on the predatory efficacy of the predator species *A. paraaerialis* is scanty in India. It is in this scenario the present work was under taken and the predatory potential of the mite *A. paraaerialis* upon *T. urticae* and *T. macfarlanei*, two prominent mite pests of this area were studied and analysed.

Materials and Methods

The predatory and prey mites required for this study were collected from various agricultural fields of Kannur district, Kerala. Sufficient numbers of *A. paraaerialis* were procured from the leaves of the chilli plants, *Capsicum annum* and *C. frutescence.* The mite pest *T. urticae* were collected from the leaves of tapioca plant, *Manihot esculentus* which is an important host of these mites. *T. macfarlanei* was collected from leaves of brinjal, *Solanum melongena*, where it was presenting immense damage with visible symptoms. Separate cultures were maintained in the lab for these three mite species. The leaves of tapioca were taken as rearing medium for *T. urticae* and leaves of brinjal were taken for *T. macfarlanei*. The predator was reared on leaves of chilli plants. For culturing the mites, the leaves were placed on wet sponge blocks of 3 cm thickness placed in plastic trays. Sufficient water level was maintained in the trays to get adequate dampness to the sponge blocks. The cultured mites were studied and identification was confirmed using taxonomic keys (Gupta, 1985) [7] as well as by expert opinion. For getting the pure cultures of mites, a single adult female mite was first introduced into the leaf discs. The predatory mites were supplied with different life stages of prey mites to maintain their population. Both the prey and predatory mites were carefully examined and maintained without any possible contamination.

The feeding experiments were conducted with 4cm² tapioca leaf discs kept on wet cotton pad in petri dishes of 9 cm diameter. 15 numbers each of different stages of prey mites *viz*., egg, larva, nymph and adult were introduced into these leaf discs. Then a single adult female predatory mite was released in to each of the leaf discs. Observations made while the predator feed on prey mites. The number of prey stage consumed were recorded at the end of 24 hrs. This experiment was repeated 25 times and was conducted at room temperature of 28±2°C and 70±5% humidity. Based on the observed data, the percentage of consumption was calculated using the formula, (Ne/N0) x 100; where 'Ne' is the number of prey stage consumed, 'N0' is the total number of prey stage given. The data obtained were subjected to ANOVA using SPSS software.

Results

Percentage consumption of *A. paraaerialis* on various life stages of *T. macfarlanei* and *T. urticae* are presented in Table 1. Figure 1 gives data on the number of different prey stages consumed within a period of 24 hours. Consumption of various life stages of *T. macfarlanei* by *A. paraaerialis* was as follows. After 24 hours, *A. paraaerialis* consumed 7.48±0.18eggs, 5.52±0.22 larvae, 3.68±0.17 nymphs and 1.6±0.1 adults. Rate of consumption was 49.84±1.99 on eggs, 36.84±1.51 on larvae, 24.6±1.14 on nymphs and 10.6±0.6 on adults of *T. macfarlanei.* After the 24-hour predatory time with *T. urticae*, *A. paraaerialis* preyed upon 8.31±0.32 eggs, 5.53±0.42 larvae, 2.81±0.54 nymphs and 1.62±0.13 adults. Here the rate of consumption was 55.42±2.17 on eggs, 37±2.79 on larvae, 18.68±0.95 on nymphs and 10.75±0.75 on adults.

Table 1: Percentage of consumption (Mean SEM) of *A. paraaerialis* on different life stages of *T. macfarlanei* and *T. urticae*

Predator	Prey	Prey life stage	(*Ne/N0*)x100
A. paraaerialis	*T. macfarlanei*	Egg	49.84±1.99
		Larva	36.84±1.51
		Nymph	24.60±1.14
		Adult	10.60±0.60
	T. urticae	Egg	55.42±2.17
		Larva	37±2.79
		Nymph	18.68±0.95
		Adult	10.75±0.75

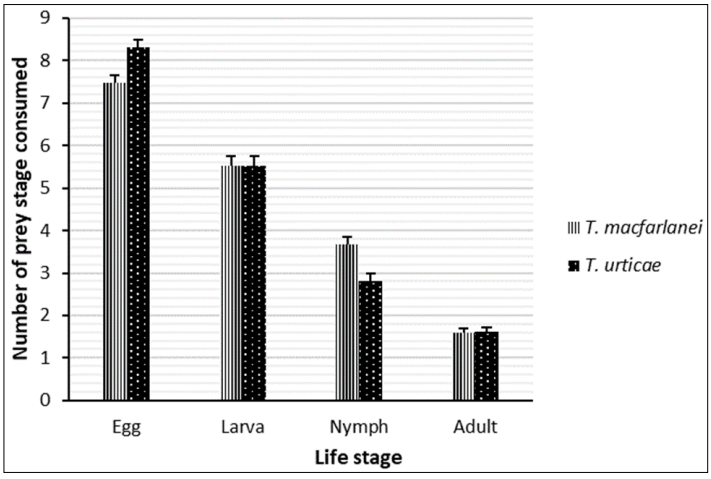

Fig 1: Number of prey stage consumed by *A. Paraaerialis* per 24 hrs on different life stages of *T. Macfarlanei* and *T. urticae*

Discussion

A. paraaerialis was an active feeder during our experiment. It was found moving all around the leaf disc and was constantly checking its prey. When it came in contact with prey, it quickly grabbed them with its fore leg and pedipalp. The prey body was punctured by its chelicerae and actively sucked out the internal contents. The predator often made more than one incision on the body of prey mites. After making the first incision and sucking out the contents partially, the predator left the prey for a while and then came back to make another incision at a different region. Finally, the predator left behind the blotched and shrunken body of prey mites once it finished feeding. When the predator fed on the prey eggs, it punctured the egg shell imbibed the contents and emptied the eggs within 1-2 minutes, leaving behind the shrunken and crinkled egg case.

The rate of consumption of prey life stages of *T. macfarlaeni* and *T. urticae* by *A. paraaerialis* was in the order Adult<Nymph<Larva<Egg (Table 1). There was a significant increase (p<0.05) in consumption of eggs when compared to adult stages of both the preys (Figure 1). Similarly, the increase in rate of consumption from adult to nymph stage and larva to egg was also found statistically significant (p<0.05). *A. paraaerialis* exhibited higher preference towards the egg stages of *T. urticae* than that of the *T. macfarlanei*. But when the nymphal stages were given, *A. paraaerialis* consumed greater number of *T. macfarlanei* nymph stages in comparison with *T. urticae*. In both these cases the differences were statistically significant ((p<0.05). The difference in the predatory preference towards the adult and larval stages of both the prey mites were not statistically significant (p>0.05).

In general, the predator's consumption rate is inversely related to the size of life stage (Ali *et al.*, 2011) [1]. Justifying this observation, in our study, there was a decrease in the prey consumption rate from egg to adult stage. The higher consumption rate on eggs compared to the other stages might be due to the fact that the weight of eggs is less than other stages and thus predators need to feed on a greater number of eggs to get the same amount of nutrients (Ganjisaffar and Perring, 2015) [6]. The observations of experiments conducted with *Typhlodromus (Anthoseius) divergentis* on the life stages of *T. urticae* supported the fact that the size of the prey does influence the predator. The smaller sized prey was always found as the choice of preference in these experiments (Naeem *et al*., 2017) [12]. Similar results were observed in the feeding experiments conducted by Jyothis and Ramani (2019) [9] on *Neoseiulus longispinosus* against the life stages of *T. neocaledonicus*. The higher preference of the predator towards the egg stage of the prey could be of various reasons. Besides the smaller size, the egg stage preference could be due to the thin outer layer/chorion of the egg, static nature of the egg or the general tendency of the predator to prey upon the smallest opponent (Carrillo and Pena, 2012; Ganjisaffar and Perring, 2015) [6].

Instances of variant behavior of predatory mites were also reported. In the case of *Kampimodromus aberrans* (Oudemans), the larval consumption was significantly more than the prey eggs (Broufas *et al*., 2007) [3]. In a study, *Neoseiulus californicus* (McGregor) was able to prey on *T. urticae* and *Thrips tabaci* Lindeman, but the presence of both the prey species resulted in a preference of one prey species. *N. californicus* preferred *T. urticae* as prey and consumptive rate of *T. tabaci* in the presence of *T. urticae* was very low (Rahmani *et al*. 2016) [14]. There were species like *Neoseiulus barkeri* (Hughes) and *Neoseiulus cucumeris* that did not show any prey stage preference (Blackwood *et al*. 2004). Same study also showed that *Amblyseius andersoni* Chant, *Euseius finlandicus* (Oudemans) and *Euseius hibisci* (Chant) showed preference to the larvae of *T. urticae* rather than the eggs.

T. macfarlanei and *T. urticae* were the two prominent phytophagous mites recovered in a survey conducted in the northern part of Kerala (Chithralekha and Sheela, 2019) [5]. In the present work, we found that the predatory mite *A. paraaerialis* could be a very effective controlling agent of these plant mites. The performance of *A. paraaerialis* as a vigorous feeder on all life stages of prey mites indicate that this species could be an excellent candidate in developing an efficient bio control program.

This study provides an insight into the behavioral pattern of the predatory mite *A. paraaerialis*, and its potential to check the population of the notorious spider mite pests attacking several agricultural plants. Further studies have to be conducted in field conditions also, so that this predator species could be used commercially as a biocontrol agent against these mite pests.

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