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Predatory Credentials of *Neoseiulus longispinosus* (Evans) (Acari: Phytoseiidae) on Two Spotted Spider Mite *Tetranychus urticae* Koch (Acari: Tetranychidae)

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ABSTRACT: Two spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae) is a destructive polyphagous pest of many agricultural crops and effective control using biocontrol agents is still a challenge. Prey stage preference and feeding potential of active stages of the predatory mite, *Neoseiulus longispinosus* were studied under laboratory conditions of 23°±1-28±1° temperature and 70-80% RH using different stages of prey mite *T. urticae*. Prey stage preference was studied by providing all the prey stages together on a leaf bit. Larva of predatory mite, *N. longispinosus* was a non- feeding stage and did not consume any prey in its developmental time of 12.35 h. Protonymph showed greater preference for larval stage of *T. urticae*, while deutonymph showed equal preference for egg, larva and deutonymph. Adult predatory mite preferred more of eggs followed by larva, protonymph, deutonymph and adult. In feeding potential study, the active stages of predatory mite were offered with all the prey stages individually, where, protonymph of *N. longispinosus* consumed 1.70±0.30 eggs, 2.60±0.30 larvae, 2.10±0.17 nymphs (protonymph+deutonymph) and did not feed on the adult stage. Similarly, deutonymph of the predatory mite consumed 3.70±0.65 eggs, 4.20±0.41 larvae, 3.50±0.50 nymphs and 0.40±0.16 adults. Adult predatory mite consumed a total of 220.0± 6.93 eggs, 231.90±22.59 larvae, 130.40±3.83 nymphs and 54.60±5.26 prey adults in its lifetime.

Keywords: Predatory mite**,** Feeding preference, Feeding potential, *Neoseiulus longispinosus*, *Tetranychus urticae.*

INTRODUCTION

In the present context, because of environmental contamination by excessive use of pesticide, the risk for human and animal health, and phytotoxicity, it has become extremely necessary to use environment friendly measures such as biological control other than chemically-synthesized pesticide to combat mite pests. Phytoseiid mites are well known natural enemies of phytophagous mites on wide range of habitats. They have high reproductive potential, rapid rate of development, female-biased sex ratio equivalent to their prey. They respond numerically to increased prey density, and can easily be mass-reared (Hoy, 2011). Among phytoseiids, *Neoseiulus longispinosus* (Evans) is more often associated with the colony of phytophagous mites on many cultivated crops in Asian countries and the Indian subcontinent. It is widely distributed in India and proved to be an effective predator on tetranychid mites (Mallik, 1999).

Two spotted spider mite, *Tetranychus urticae* is one of the most destructive tetranychid mite pest of agricultural crops with more than 1000 reported host plants belonging to more than 250 plant families (Migeon *et al*., 2014). Many of these host plants represent major crops including vegetables and fruits, but also corn, soybean and cotton. Pest status of *T. urticae* on greenhouse vegetable, ornamental crops and horticultural crops are well documented (Tehri, 2014). *Tetranychus urticae* has the ability to increase its reproduction rate and increase its populations in a shorter time when exposed to sublethal pesticide levels (Hoy, 2011).

Several studies have been conducted to test the prey stage preference of different phytoseiid predatory mites on different spider mite species: *Neoseiulus longispinosus* on *T. urticae* (Jayasinghe and Mallik, 2015), on *T. neocaledonicus* (Jyothis and Ramani 2019), on *Oligonychus coffeae* (Rahman *et al.*, 2011); *Neoseiulus idaeus* on *T. urticae* (Reichert *et al*., 2016); *Phytoseius plumifer* on *T. urticae* (Khodayari *et al.*, 2016); *Neoseiulus californicus* on *T. urticae* (Rezaie *et al*., 2017); *Amblyseius swirskii* & *N. californicus* on *T. urticae* (Akyazi *et al*., 2019); *Neoseiulus californicus* on *T. urticae* (Kaur and Zalom 2019). The feeding potential of the phytoseiid predatory mite, *N. longispinosus* on *T. urticae* has also been studied by Jeyarani *et al*. (2012); Sanchit and Shukla (2016); Song *et al.* (2016); Rao *et al*. (2017). But there are differences in respect of the prey stages preferred and the number of prey stages consumed by a particular predatory mite species among different studies. This study aimed at investigating the feeding preference and feeding potential of *N. longispinosus* on two spotted spider mite, *T. urticae*.

MATERIAL AND METHODS

A. Stock culture of the predatory mite, Neoseiulus longispinosus

Stock culture of the predatory mite, *N. longispinosus* maintained on spider mite infested French bean plantsin the polycarbonate house of All India Network Project on Agricultural Acarology, University of Agricultural Sciences, GKVK Campus, Bengaluru, Karnataka was used in the present study. A small nucleus culture of the predatory mite from the polycarbonate house was further reared on *T. urticae* (prey mite) infested detached-French bean leaves placed on wet foam in polyethylene trays in the laboratory. The prey mites on French bean plants in the polycarbonate house were used for feeding by the predatory mites in the laboratory. The foam was kept moist, by watering daily to prevent the escape of the predatory mites and thus sufficient stock culture of the predatory mite was available throughout experimentation.

B. Stock culture of the prey mite, Tetranychus urticae

The nucleus culture of *T. urticae* maintained in the All India Network Project on Agricultural Acarology laboratory was used in the present study. A small nucleus culture of *T. urticae* obtained from the project was reared on excised mulberry leaf bits placed on wet foam in polyethylene trays in the laboratory. The mulberry leaf bits were removed and replaced with fresh bits every 5-6 days and the trays were watered daily to keep the foam wet enough to retain the succulency of the leaves. Sufficient stock culture of the prey mite was made available throughout the study for experimentation.

C. Feeding preference of Neoseiulus longispinosus on different life stages of Tetranychus urticae

The preference of feeding by the predatory mite, *N. longispinosus* for different life stages of prey mite *T. urticae* was studied by offering known number of each life stage of the prey mite together, on the mulberry leaf arena. Different life stages of the prey mites were offered to individual larva, protonymph, deutonymph and the adult predatory mite. Fresh mulberry leaves were cut into bits of 2 cm^2 each, were placed abaxial side up on wet foam placed in 12″×10″ polyethylene trays. 30 leaf bits served as 30 replications. To each leaf bit, known number of each life stage of the prey mite *i.e.,* egg, larva, protonymph, deutonymph and adults was released along with one neonate larva of the predatory mite. The number of different life stages of the prey mite consumed by the predatory mite in its larval, protonymphal, deutonymphal and the adult stages was recorded. As the feeding requirement of different life stages of the predatory mite vary, the number of prey stages offered to each feeding stage of the predatory mite was decided so that the number offered were always in excess than they would consume. In order to maintain the humidity and to prevent the escape of the prey and predatory mites, the foam was kept moist by watering daily. In case of the immature life stages of the predatory mite *viz.,* larva, protonymph and the deutonymph, the number of preys consumed in the respective stages and for the adult predatory mites, the prey consumed in 24 h period was recorded. Dead remines of the prey mites fed by the predatory mites were removed and replaced with fresh stages from the stock culture, every 24 h, to ensure prey mite availability throughout the experimentation. When a single female predatory mite was released on a leaf bit, a high rate of escape of the predatory females from the experimental arena was observed and to overcome this, two adult female predatory mites were released per leaf bit and the mean prey consumed by each predatory mite was calculated.

From the data obtained, percent consumption was calculated using the formula:

$$N_e/N_0 \times 100$$

where, N_e = Number of prey stages consumed

N_0 = Number of prey stages offered

D. Feeding potential of Neoseiulus longispinosus on Tetranychus urticae

The study was conducted to know the number of prey mites a predatory mite could consume in its life stages individually and in its entire life time starting from larva to the end of adult stage. The stages of the prey mite *viz.,* eggs, larvae, nymphs (protonymph+deutonymph) and adults were offered separately to the predatory mite, right from its larval stage to adult stage and the number of prey stages consumed was recorded. Additionally, a treatment with all the four stages of the prey mite together was also included for comparison. For experimentation, the experimental arena with mulberry leaf bit was arranged as in the previous experiment. The experiment consisted of five treatments. In the first treatment, only the eggs of the prey mite were offered to the predatory mites, in the second treatment only the larval stages, in the third treatment only the nymphal stages (protonymph+deutonymph), in the fourth treatment only the adult stages were offered and in the fifth treatment all the four stages of the prey mite were offered together in equal proportion. Known number of prey stages, as detailed in different treatments were transferred to each leaf bit along with one neonate larva of the predatory mite and the predatory mite was allowed to feed on prey mites during its developmental period and adult hood till it died naturally. To the larval and protonymphal stages of the predatory mite, 6 prey eggs/ larvae/ nymphs/ adults were provided for the first four treatments and 2 individuals of each stage together for the fifth treatment. Likewise, to the deutonymphal stage of the predatory mite, 10 prey eggs/ larvae/ nymphs/ adults were provided for the first four treatments and 3 individuals of each stage together for the fifth treatment. To the adult predatory mite, 25 prey eggs/ larvae/ nymphs/ adults were provided in the first four treatments and 5 individuals of each stage together in the fifth treatment. The experiment consisted of 10 replications for each treatment. Observations were recorded on the number of each prey stages consumed by the predatory mite in its larval, protonymphal, deutonymphal and adult stage at 24 h interval still its natural death. At each observation, the remains of the dead prey mites were removed and replaced with the fresh ones to maintain their number and to ensure sufficient prey availability.

Data analysis. The Data obtained from prey preference and feeding potential study of the predatory mite were subjected to statistical analysis by SPSS software version 23.0. Minimum and maximum consumption, mean total consumption were calculated and prey preference was compared by using one-way ANOVA followed by Tukey's HSD test (P<0.01). Data of the number of prey stages consumed by the predatory mite in a day (24 h) and total prey consumption till its death, when offered separately or together was subjected to one-way ANOVA followed by Tukey's Honestly Significant Difference (HSD) test (P<0.01).

RESULTS AND DISCUSSION

A. Preference of life stages of predatory mite Neoseiulus longispinosus for life stages of prey mite Tetranychus urticae

The data on the number of *T. urticae* prey stages consumed by four different life stages of predatory mite, *N. longispinosus* are presented in Table 1 and depicted in Fig. 1. The larva was found to be a non-feeding stage and did not consume any prey mites during its mean life span of 15.7h. Hegde and Patil (1994), Ibrahim and Palacio (1994), Kadu (2007) and Rao *et al.* (2017) also observed the non-feeding behavior of the larval stage of the predatory mite *N. longispinosus*. This non-feeding behavior is not confined only to *N. longispinosus*, larvae of other phytoseiid mites *Phytoseiulus longipes* (Badii *et al*., 1999), *Typhlodromus pyri* (Croft & Croft 1993) and *Euseiusovalis* (Liyaudheen *et al*., 2014) were also reported to be non-feeding.

Table 1: Feeding preference of life stages of predatory mite, *Neoseiulus longispinosus* for life stages of prey mite, *Tetranychus urticae.*

Feeding stages of predatory mite	Prey mite stages offered together	Number consumed			N_e/N_o
		Mean±S.E.	Min.	Max.	
Larva (Lived for 12.35 h)	**Did not consume any prey stage**				
Protonymph (Lived for 23.28 h)	Egg	$0.73 \pm 0.13^{b*}$	0	2	0.24 ± 0.04^{b}
	Larva	1.83 ± 0.11^{c}	1	3	0.61 ± 0.03^{c}
	Protonymph	0.73 ± 0.11^{b}	0	2	0.24 ± 0.03^{b}
	Deutonymph	0.20 ± 0.07^{a}	0	1	0.06 ± 0.02^{a}
	Adult	0.00 ± 0.00^{a}	0	0	0.00 ± 0.00^{a}
Deutonymph (Lived for 27.26 h)	Egg	1.23 ± 0.20^{bc}	0	4	0.24 ± 0.04^{bc}
	Larva	1.43 ± 0.16^{c}	0	3	0.28 ± 0.03^{c}
	Protonymph	0.70 ± 0.12^{ab}	0	2	0.14 ± 0.02^{ab}
	Deutonymph	0.96 ± 0.13^{bc}	0	2	0.19 ± 0.02^{bc}
	Adult	0.10 ± 0.05^{a}	0	1	0.02 ± 0.01^{a}
Adult (In 24 h)	Egg	4.00 ± 0.24^{d}	2.5	5	0.80 ± 0.04^{d}
	Larva	1.85 ± 0.16^{c}	1	3	0.37 ± 0.33^{c}
	Protonymph	1.45 ± 0.21^{bc}	0	2.5	0.29 ± 0.04^{bc}
	Deutonymph	0.90 ± 0.16^{ab}	0	1.5	0.18 ± 0.03^{ab}
	Adult	0.10 ± 0.06^{a}	0	0.5	0.02 ± 0.01^{a}

*****For each feeding stage of the predator, values within the column with a same alphabetical superscript are not statistically significant (@ P=0.01)

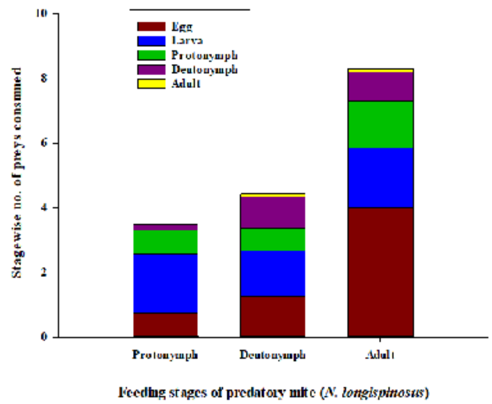

Fig. 1. Feeding preference of life stages of predatory mite, *Neoseiulus longispinosus* for life stages of prey mite, *Tetranychus urticae.*

Each protonymph of *N. longispinosus* consumed 0.73±0.13 eggs, 1.83±0.11l arvae, 0.73±0.11 protonymphs and 0.20±0.07 deutonymphs of *T. urticae* in its mean life span of 23.28 h indicating its preference for the larval stage of the prey mite with a mean consumption of 61%, followed by egg & protonymphal stages (24% each) and the deutonymphal stage (6%). And interestingly the predatory protonymph did not feed on the adult prey mite. The deutonymph consumed 1.23±0.20 eggs, 1.43±0.16 larvae, 0.70±0.12 protonymphs, 0.96±0.13deutonymphs and 0.10±0.05 *T. urticae* adults of in its life span of 27.26 h, which indicated its preference forlarva, egg & the deutonymphal stages of the prey mite with the mean corresponding consumption rate of 28%, 24% & 19%, the protonymph and adult prey mites were least preferred (14% & 2%, respectively). The adult female consumed a mean of 4.00±0.24 prey eggs, 1.85±0.16 larvae, 1.45±0.21 protonymphs, 0.90±0.16 deutonymphs & 0.10±0.00 adults in 24h time, indicating its most preference for egg stage of *T. urticae* (80%), followed by larvae (37%), protonymphs (29%) & deutonymphs (18%) and it showed least preference for the adult prey mite (2%).

The preference of adult *N. longispinosus* for the egg and larval stages of *T. urticae* is supported by earlier studies. Jayasinghe and Mallik (2015) reported that the adult predatory mite consumed more of eggs than the other stages of *T. urticae*. Kadu (2007) found that the adult *N. longispinosus* showed more preference for eggs (59.67±6.42) than the adults (16.06±1.88) of its prey mite, *T. urticae*. Mandape *et al*. (2018) reported that *N. longispinosus* female consumed a mean of 56.27±3.37 eggs, 31.54±1.16 mixed stages and 19.93±1.75 adults of prey, *T. urticae* showing its preference for eggs than the other stages. Rao *et al*. (2017) reported that *N. longispinosus* adult female preferred more of larval stages its prey, *T. urticae* followed by the nymphal stages, consuming 20.04±0.75 larvae and 17.87±0.16 protonymphs per day and the adult prey was least preferred (5.12±0.39 per day). Ibrahim and Palacio (1994) found that *N. longispinosus* preferred more of larval and nymphal stages of prey, *T. urticae* and the adult prey was least preferred. The results of the above studies support the present findings as the adult predatory mite consumed more number of prey eggs followed by larvae and nymphs.

The preference for *T. urticae* prey eggs and larval stages by other phytoseiid predatory mites have been reported in several studies. Furuichi *et al*. (2005), while studying the prey stage preference of the predatory mite, *Neoseiulus womersleyi* on *T. urticae* reported that the adult female predatory mites preferred eggs to the prey adults consuming 12.18±2.64 eggs as against 0.18±0.095 adult stages every day. Reichert *et al*. (2016), while studying the feeding preference of phytoseiid predatory mite, *Neoseiulus idaeus* reported that, the predatory mite preferred *T. urticae* eggs compared to other stages, as the larva of the predatory mite consumed 0.36 eggs per day and no other stages; proton mph consumed 4.00 eggs, 0.72 larvae, 1.06 nymphs and no adult stages; the deutonymph consumed 4.91 eggs, 1.38 larvae, 1.34 nymphs and no adult stages, whereas, the adult predatory mite consumed 16.09 eggs, 4.95 larvae, 8.47 nymphs and 2.77 adult prey stages per day. Canlas *et al*. (2006) reported that the predatory mite, *Neoseiulus californicus* preferred the larvae and eggs of prey mite, *T. urticae* followed by nymphs, consuming 22.46 larvae, 20.91 eggs and 12.57 nymphs per day. Ahn *et al*. (2009) also showed that the predatory mite, *N. californicus* female consumed a greater number of *T. urticae* eggs and larvae than the nymphs (on strawberry) with the consumption of 17.14 eggs, 15.14 larvae and 11.81 nymphs in 24 h period. Farazmand *et al*. (2012) found that *N. californicus* consumed more of eggs than the nymphs of *T. urticae,* given a choice between the two stages. Rezaie *et al*. (2017) reported that all the life stages of *N. californicus* preferred eggs of *T. urticae* (on strawberry) consuming 2.6, 3.8, and 9.5 eggs by the protonymph, deutonymph and adult predatory mite, respectively. Croft and Croft (1993) reported that the immature stages of the predatory mite, *Metaseiulus occidentalis* consumed more of eggs and larvae of *T. urticae*. Badii *et al*. (2004), while determining the prey stage preference of the predatory mite, *Euseius hibisci* showed that at constant densities of different stages of *T. urticae*, the predatory mite consumed more number of eggs (4.1), followed by larvae (3.4), protonymphs (2.3), deutonymphs (0.03) and adults (0.01) every day. Moghadasi *et al.* (2013), while studying the prey stage preference of the predatory mite, *Typhlodromus bagdasarjani* to *T. urticae* prey (on rose) found that the predatory mite significantly preferred the eggs, followed by larvae and protonymphs of its prey. Akyazi *et al*. (2019), while studying the prey-stage preferences of phytoseiid predatory mites, *Amblyseius swirskii* and *N. californicus* between egg and nymphal stages of *T. urticae* indicated that *N. californicus* had no preference between eggs and nymphs of *T. urticae* (mean egg: nymph predation rate was 34.92%:38.82%) whereas, *A. swirskii* preferred nymphs to eggs of *T. urticae* (mean egg: nymph predation rate was 40.68%:63.37%).

B. Feeding potential of the predatory mite Neoseiulus longispinosus on life stages of prey mite Tetranychus urticae

Daily prey consumption of different life stages (egg, larva, nymph and adult) of *T. urticae* by the adult female predatory mite, *N. longispinosus* during its entire life span is presented in Table 2 and the total prey consumption by different life stages of predatory mite on life stages of prey mite, when prey mites offered @ one prey stage at a time or together, is presented in Table 3. Data on the daily consumption on life stages of the prey mite by the predatory mite indicated that, in a single day one female predatory mite consumed a maximum of 17.6 eggs or 15.1 larvae or 10.5 nymphs or 4.5 prey adults when offered separately or 12.5 prey individuals, when offered together (Table 2 & Fig. 2). The longevity of the female predatory mite when offered prey eggs or larvae or nymphs or adults separately, or together, ranged from 20-25 days, 22-29 days, 21-26 days, 18-27 days and 21-29 days, respectively. The mean prey consumption by the predatory mite female was low at the initial age, which increased gradually and declined further as the predator age advanced.

Table 2: Daily feeding potential of adult predatory mite, *Neoseiulus longispinosus* on life stages of the prey mite, *Tetranychus urticae.*

Feeding period	Number consumed								
	When single prey stage offered				When all prey stages offered together				
	Egg	larva	Nymph	Adult	Egg	Larva	Nymph	Adult	Total
Day 1	4.7 (9)	3.3 (10)	2.1(10)	0.0 (10)	0.0	0.1	0.3	0.0	0.4 (10)
Day 2	17.1 (9)	8.3 (10)	4.6 (10)	1.2 (10)	1.6	3.6	1.2	0.4	6.8 (10)
Day 3	13.9 (9)	10.3 (10)	4.6 (10)	2.7 (10)	2.2	3.5	1.9	0.6	8.2 (10)
Day 4	10.3 (9)	11.3 (10)	7.6 (10)	1.9 (10)	2.7	4.3	2.6	1.2	10.8 (10)
Day 5	9.4 (9)	11.9 (10)	10.5 (10)	3.1 (10)	0.7	4.1	3.9	1.5	10.2 (10)
Day 6	14.2 (9)	15.1 (10)	9.5 (10)	3.3 (10)	2.2	3.8	2.4	1.3	9.7(10)
Day 7	14.3 (9)	14.8 (10)	10.4 (10)	2.9 (10)	2.0	4.1	3.9	1.2	11.2 (10)
Day 8	15.3 (9)	15.1 (10)	10.1 (10)	3.1 (10)	2.5	4.6	3.1	1.9	12.1 (10)
Day 9	17.6 (9)	13.3 (10)	9.9 (10)	3.0 (10)	2.6	4.0	4.2	1.7	12.5 (10)
Day 10	16.6 (9)	13.6 (10)	8.3 (10)	4.5 (10)	0.5	4.0	3.2	0.9	8.6 (10)
Day 11	13.0 (9)	10.6 (10)	6.8 (10)	3.5 (10)	1.6	4.2	2.3	1.1	9.2(10)
Day 12	12.8 (9)	11.9 (10)	5.1 (10)	3.7 (10)	1.1	4.6	1.9	1.1	8.7 (10)
Day 13	10.8 (9)	11.9 (10)	5.3 (10)	3.6 (10)	1.4	3.5	1.7	0.7	7.3 (10)
Day 14	9.8 (9)	11.7 (10)	5.3 (10)	3.4 (10)	0.7	2.9	1.0	0.8	5.4 (10)
Day 15	6.6 (9)	11.3 (10)	5.6 (10)	3.2 (10)	0.7	3.3	1.2	0.7	5.9 (10)
Day 16	3.0 (9)	11.2 (10)	5.2 (10)	2.5 (10)	0.4	3.9	1.3	0.4	6.0 (10)
Day 17	2.4 (9)	11.0 (10)	4.5 (10)	1.9 (10)	0.6	3.5	1.0	0.1	5.2 (10)
Day 18	6.2 (9)	10.0 (10)	3.7 (10)	1.4 (9)	0.5	2.1	0.6	0.8	4.0 (10)
Day 19	8.0 (9)	7.7 (10)	2.4 (10)	1.4 (9)	0.3	1.9	0.9	0.9	4.0(10)
Day 20	6.1 (8)	5.4 (10)	1.6 (10)	1.8 (9)	0.6	1.1	0.6	0.6	2.9 (10)
Day 21	3.3 (7)	3.4 (10)	0.9 (9)	1.2 (9)	0.7	1.9	1.0	0.2	3.8 (9)
Day 22	0.0 (5)	1.3 (9)	1.0 (9)	1.1 (8)	0.6	1.6	0.7	0.7	3.4 (9)
Day 23	0.0 (4)	1.4(8)	0.0 (7)	0.7 (7)	0.6	1.6	0.9	0.6	3.8 (8)
Day 24	0.0 (3)	0.0 (5)	0.0 (4)	0.0 (4)	1.1	1.4	1.1	0.1	3.9 (7)
Day 25	0.0 (1)	0.0 (2)	0.0 (2)	0.0 (4)	0.2	1.5	1.0	0.3	3.0 (6)
Day 26	-	0.0 (2)	0.0 (2)	0.0 (1)	0.4	0.8	0.0	0.0	1.2(5)
Day 27	-	0.0 (1)	-	0.0 (1)	0.0	0.8	0.0	0.0	0.8 (4)
Day 28	-	0.0 (1)	-	-	0.0	1.0	0.5	0.0	1.5 (2)
Day 29	-	0.0 (1)	-	-	0.0	0.0	0.0	0.0	0.0 (1)

*Figures in the parentheses indicate the total number of female predatory mites alive out of 10 replicates over time

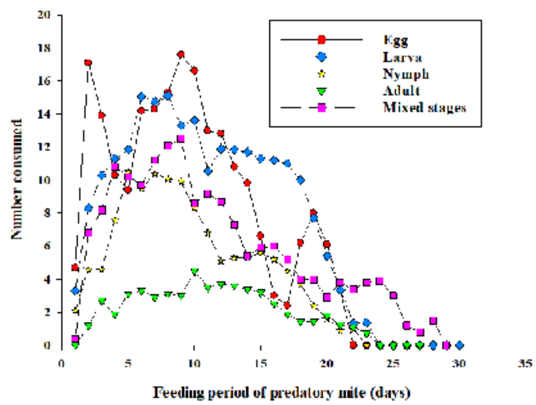

Fig. 2. Feeding potential of adult predatory mite, *Neoseiulus longispinosus* on life stages of preyite, *Tetranychus urticae.*

It was observed from Table 3 that the larva of the predatory mite did not feed on any of the prey stages when offered either separately or together. The predator protonymph consumed, mean of 1.70±0.30 eggs or 2.60±0.30 larvae or 2.10±0.17 nymphs & zero adults, when offered separately or 2.30±0.14 mixed prey stages, when offered together. The deutonymph consumed mean of 3.70±0.65 eggs or 4.20±0.41 larvae or 3.50±0.50 nymphs or 0.40±0.16 adults, when offered separately or 3.70±0.24 prey individuals, when offered together. Whereas, the adult female predatory mite in its entire life span consumed a mean of 214.80±22.11 eggs or 225.10±22.64 larvae or 124.80±4.07 nymphs or 54.20±5.24 adult prey mites, when offered separately or 164.30±9.70 prey individuals as mixed stages. The overall prey consumption by the female predatory mite during its entire life span including immature active stages was found to be 220.5±6.93 eggs or 231.90±22.59 larvae or 130.40±3.83 nymphs or 54.60±5.26 adults of *T. urticae* when offered separately or 170.30±9.71 prey individuals, when offered together (Table 3 & Fig. 3).

Studies by earlier workers on the feeding potential of the predatory mite, *N. longispinosus* on the prey mite *T. urticae* have shown varying results.Ibrahim and Palacio (1994) reported that the protonymph and deutonymph of the predatory mite, *Amblyseius longispinosus* (=*Neoseiulus longispinosus*) consumed 3.94±0.16 and 3.99±0.22 eggs of the prey mite, *T. urticae*. The present findings are in little deviation to this study, wherein, the predatory protonymph consumed a smaller number of prey eggs (1.7±0.30) than reported by them, while the deutonymph consumed more or less the same number of prey eggs (3.7±0.65). Kadu (2007), while studying the feeding potential of the predatory mite, *A. longispinosus* on *T. urticae* infesting apple reported that the protonymph and deutonymph of the predatory mite consumed 3.57±0.15, 1.58±0.15 & 0.73±0.13; 3.79±0.20, 2.04±0.14 & 1.08±0.13 eggs, nymphs and adults of the prey mite, respectively, the adult predatory mite consumed a mean of 59.67±6.42, 22.94±2.51 & 16.06±1.88 eggs, nymphs and adults of the prey mite, respectively. The findings of the present study are almost similar with respect to the prey consumption by the predatory nymphs (Table 3), but the prey consumption by the adult predatory mite reported by them is much lower than that recorded in the present study, may be due to difference in prey densities used.

Chandrasekharappa *et al*. (1995) reported that the maximum per day consumption of *T. urticae* eggs by the adult *N. longispinosus* (at 25°) was 16.29±1.91, whereas, the adult prey consumption was 7.8±1.91. In the present study the per day mean prey consumption by the predatory mite was 9.14±0.26 eggs and 2.17±0.18 adults, respectively, lower than they recorded, the reason may be variation in temperature in their studies. Ibrahim and Rahman (1997) reported that the gravid females of predatory mite, *N. longispinosus* were more voracious compared to younger females with a mean consumption of 17 larvae by the young females and 27.8 for the gravid females in 24 h. Whereas, in the present study, *N. longispinosus* female consumed 9.01±0.92 larvae per day, much lower than they recorded, may be due to difference in prey densities used and the study temperature.

Sanchit and Shukla (2016), reported that *N. longispinosus* female predatory mite consumed a mean of 56.27±3.37 eggs, 31.54±1.16 mixed stages and 19.93±1.75 adults of prey mite, *T. urticae* during its entire life span. The mean prey consumption recorded in the present study was 220.00±6.93 eggs, 54.60±5.26 adults and170.30±9.71 mixed stages, much higher than their report. The reason may be differences in temperature and the host plant. Rao *et al*. (2017) reported that the adult female *N. longispinosus* consumed 13.12±0.54 eggs, 20.04±0.75 larvae, 17.87±0.16 protonymphs, 12.25±0.45 deutonymphs and 5.12±0.39 adults of *T. urticae* per day. In the present study the number of eggs, larvae, nymphs and adults consumed by *N. longispinosus* was 9.14±0.26 eggs, 9.01±0.92 larvae, 5.19±0.17 nymphs & 2.17±0.18 adults. The difference in daily prey consumption between two studies may be may be due to difference in prey densities used and the study temperature.

Studies pertaining to feeding potential of other phytoseiid predatory mites on *T. urticae* prey was available for comparison. Gorji *et al*. (2009), while studying the prey consumption of the predatory mite, *Phytoseius plumifer* on *T. urticae* found that the total prey consumption by female predatory mite was 426.98 at 25ºC. Kasap and Atlihan (2010), while investigating the consumption rate and functional response of the predaceous mite, *Kampi modromusaberrans* on *T. urticae* found that the predatory mite consumed a higher number of larvae followed by eggs, protonymphs and deutonymphs with a per day consumption of 3.27±0.22, 3.78±0.27, 1.86±0.26 and 0.60±0.13, respectively. Rasmy *et al*. (2013), while studying the functional response of the phytoseiid predatory mite, *Typhlodromus negevi* on nymphal stage of prey mite, *T. urticae* reported that the protonymph, deutonymph and female predatory mite consumed a maximum of 10.43, 13.4 and 22.42 *T. urticae* nymphs per day, respectively. The consumption of *T. urticae* prey by the respective predatory mites are higher or lower than those recorded in the present study for the predatory mite, *N. longispinosus*. This evidently indicates that each predatory mite species has its own prey potentiality against the common prey mite, *T. urticae*.

Table 3: Feeding potential of different life stages of predatory mite, *Neoseiulus longispinosus* on life stages of prey mite, *Tetranychus urticae.*

Feeding stages of predatory mite	Number of prey consumed (Mean±S.E.)				
	Single prey stage offered				Mixed prey stages offered together
	Egg	Larva	Nymph	Adult	
Larva	Non- feeding stage				
Protonymph	$1.70\pm0.30^{b*}$	2.60 ± 0.30^{b}	2.10 ± 0.17^{b}	0.00	2.30 ± 0.14^{b}
Deutonymph	3.70 ± 0.65^{b}	4.20 ± 0.41^{b}	3.50 ± 0.50^{b}	0.40 ± 0.16^{a}	3.70 ± 0.24^{b}
Adult	214.80 ± 22.11^{cd}	225.10 ± 22.64^{d}	124.80 ± 4.07^{b}	54.20 ± 5.24^{a}	164.30 ± 9.70^{bc}
Total	220.0 ± 6.93^{cd}	231.90 ± 22.59^{d}	130.40 ± 3.83^{b}	54.60 ± 5.26^{a}	170.30 ± 9.71^{bc}
Per day consumption of *N. longispinosus* on *T. urticae* (adult)					
Consumption	9.14 ± 0.26^{c}	9.01 ± 0.92^{c}	5.19 ± 0.17^{b}	2.17 ± 0.18^{a}	6.26 ± 0.18^{b}

*****Values within the row with a same alphabetical superscript are not statistically significant (@ P=0.01)

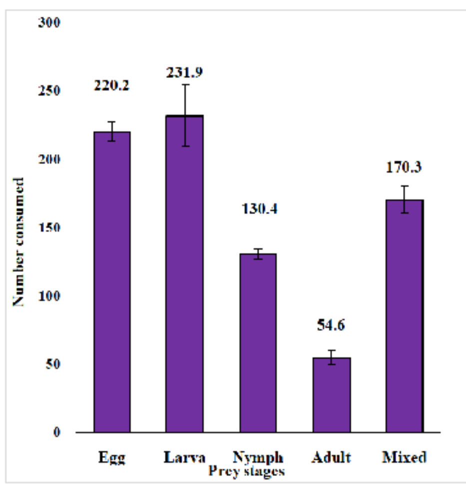

Fig. 3. Feeding potential of predatory mite, *Neoseiulus longispinosus* on life stages of prey mite, *Tetranychus urticae* in its life time.

CONCLUSION

Present study generated comprehensive information on feeding preference and feeding potential of life stages of indigenous predator *Neoseiulus longispinosus* on life stages of highly destructive pest of agricultural crops, *Tetranychus urticae*. All the developmental stages of *N. longispinosus* except larval stage when offered prey mite stages all together consumed all the stages of *T. urticae* with no distinct preference for feeding under laboratory conditions. The information generated in the present study will be thus helpful in planning the bio-control programme against *T. urticae*.

FUTURE SCOPE

Using indigenous predator, *Neoseiulus longispinosus* for more effective suppression of *Tetranychus urticae* on variety of crops under protected cultivation and on limited scale under open field conditions

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Conflict of Interest. None.

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