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Stage-Specific Feeding Potential and Preference of Predatory Mite *Neoseiulus longispinosus* (Evans) (Acari: Phytoseiidae) on Spider Mite *Tetranychus truncatus* Ehara

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Abstract: *Tetranychus truncatus* Ehara is an important pest of a number of important agricultural and horticultural crops and is mainly prevalent in the southern Indian states of Karnataka, Tamil Nadu and Kerala. The pest is very often associated with predatory phytoseiid mite, *Neoseiulus longispinosus* (Evans), on almost all crops. Its ability to feed and preferred prey stage were determined under laboratory conditions of 23°C to 28°C and 75–80% RH. The larva was the non-feeding stage of the predator but protonymphs and deutonymphs showed comparable preferences for prey mite eggs and larvae, adult predators preferred more prey mite eggs. The predatory mite protonymph ingested 2.30 eggs, 2.70 larvae, 2.00 nymphs of prey mite and did not consume the adult stage. Deutonymph of the predator, consumed 6.60 eggs, 6.80 larvae, 4.70 nymphs and did not feed on the adult stage of the predatory mite. Adult female predator unlike its immature stages consumed 121.20 eggs, 144.30larvae, 94.70 nymphs and 36.20 adults of *T. truncatus* in the entire life span.

Keywords: *Tetranychus truncatus*, *Neoseiulus longispinosus*, Feeding preference, Feeding potential, Phytoseiids

The most significant phytophagous family, the Tetranychidae, is thought to cause significant harm to cultivated crops by directly feeding on them thus reducing photosynthetic activity, causing defoliation, and lowering the economic yield (Gorman et al 2002). *Tetranychus truncatus* Ehara was first described from mulberry in Japan. It is well distributed in the Asiatic region attacking major crops like cotton, brinjal, peach, papaya and cassava *etc*. (Sakunwarin et al 2003). In India Spider mite *Tetranychus truncatus* was recorded from the northwestern Himalayan region of Jammu, Kashmir and Himachal Pradesh in 1983 on *Dahlia* sp. From Karnataka, it was described as a developing pest on domesticated and wild species of mulberry (Srinivasa et al 2012) and was reported as a serious pest of vegetable crops in Kerala (Binisha and Bhaskar 2013, Bennur et al 2015). The use of various acaricides to control spider mites has a number of unfavorable effects, including pesticide resistance, pesticide residues on crops, environmental risks, health risks, *etc*. (Roy et al 2011). Field populations of *T. truncatus* have reportedly become resistant to relatively new acaricides such as spiromesifen and fenazaquin (Bachhar et al 2019). It is challenging to control this phytophagous pest with common acaricides, so finding alternatives such as biological control to adequately manage this pest has become essential.

Phytoseiid mites are well known natural enemies of phytophagous mites on cultivated and wild plants in a variety of habitats. They have high reproductive potential, rapid rate of development and equivalent to their prey number allowing them to respond numerically to increased prey density, and can easily be mass-reared (Hoy 2011). Phytoseiid mites are effectively utilized as biocontrol agents in IPM programs in a variety of agricultural systems due to their great predatory potential. *Neoseiulus longispinosus*(Evans) a type II phytoseiid predatory mite has drawn significant interest in Asian nations as a possible biocontrol agent of spider mites of *Tetranychus* spp. There are 189 phytoseiid mite species reported from India (Gowda 2009) and over 2700 species worldwide (Demite et al 2017). As they are widely distributed in India and proved to be an effective predator of tetranychid mites since 2010, *N. longispinosus* has received more attention in the management of spider mites in the Asian continent. It can develop on many tetranychid species belonging to the genus Tetranychus, Eutetranychus, and Oligonychus (Nusartlert et al 2011). The preference and feeding potential of *N. longispinosus* on *T. truncatus* has not been systematically studied across the world including the Indian subcontinent. The present study was aimed at investigating the stage preference and feeding potential of the predatory mite *N. longispinosus* on its prey mite *T. truncatus.*

MATERIAL AND METHODS

Maintenance of prey mite culture *T. truncatus*: The culture of prey mite, *T. truncatus* was maintained on excised mulberry leaves placed abaxial side up over wet foam sheets in plastic trays under laboratory conditions of temperature 23±1°C-28±1°C and 75-80% RH. The foam sheets were kept moist by regular watering to maintain the freshness of mulberry leaves or succulence. The dried or exhausted mulberry leaves were replaced with fresh leaves in every 5-6 days.

Maintenance of predatory mite culture *Neoseiulus longispinosus*: Stock culture of the predatory mite *N. longispinosus* was maintained on spider mite infested French bean plants in the polycarbonate house. The predatory mite nucleus culture was subsequently maintained in the lab using French bean leaves that had been infested with spider mites. Over damp foam sheets, predator-infested leaves were arranged in plastic trays and to stop the predatory mites from escaping, the foam sheet was maintained wet by watering the trays regularly.

Feeding preference of predator active stages on life stages of *Tetranychus truncatus*: In order to estimate predatory mite preference for individual life stages of the prey mite, a known number of each of the life stages of the prey mite (egg, larva, protonymph, deutonymph and adult) were offered together on fresh mulberry leaf bits of 2 cm^2 placed abaxial side up on wet foam sheets in plastic trays of 12″X10″ dimension. To each leaf bit known number of each life stage of prey mite was transferred. Later one freshly hatched neonate larva of the predatory mite was introduced onto each leaf bit and the number of prey stages consumed by the predatory mite was recorded. Accordingly, two each of the egg, larva, protonymph, deutonymph and adult prey stages were offered to the larval stages of the predatory mite, likewise three each of the above prey stages were offered to the predatory protonymph stages, five each to the predatory deutonymph and ten each to a female adult stage predatory mite. Thirty replications for the predatory immature stages and ten replications for the adult predatory mite were maintained. Observations were recorded at 3 h intervals for the number of prey stages consumed by the immature predator and at 12 h intervals for the number of prey stages consumed by the adult predator.

Feeding potential of predator active stages on life stages of *T. truncatus*: The experiment was conducted to know the maximum number of prey mites a predatory mite can consume. To achieve this, the predatory mite was given distinct prey life stages, including eggs, larvae, nymphs (protonymph + deutonymph), and adults, from the beginning of its larval stage to the end of its adult stage. The number of prey life stages consumed was recorded. For comparison, a treatment was also run combining all four stages of the prey mite. On each mulberry leaf bit, one neonate larva of the predatory mite was transferred. The predatory mite stages were allowed to feed on prey mites during their developmental stages and at adulthood till their natural death. For the protonymphal stages of the predatory mite, six prey eggs/larvae/nymphs/adults were offered in the first four treatments and two individuals of each prey stage were offered together in the fifth treatment. Likewise, for the deutonymphal stage of the predatory mite, ten prey eggs/larvae/nymphs/adult prey mites were offered in the first four treatments and three individuals of each stage were offered together in the fifth treatment. For the female adult predatory mite, twenty-five prey eggs/larvae/nymphs/adults were offered separately in the first four treatments and five individuals of each stage were offered together in the fifth treatment. The experiment was designed in CRD with ten replications. Observations on the number of each of the prey stages consumed by the predatory mite in its protonymphal, deutonymphal and adult stages were recorded at 24h intervals till its natural death. At each observation, the dead preys were removed and replaced by the fresh prey to make up the number as in the first instance (from the stock culture) to ensure the continuous availability of prey for feeding by the predator.

Statistical analysis: Prey consumption data by predatory mite active stages was subjected to analysis using IBM SPSS Statistics 23 software followed by Tukey's HSD test. With the data obtained for each stage of the predator, the per cent consumption was calculated using the (Jyothis and Ramani 2019)

$N_e/N_0 X 100$

Where, N_e = Number of prey stages consumed, N_0 = Number of prey stages offered

RESULTS AND DISCUSSION

Feeding preference of predator active stages on life stages of *T. truncatus*: The predatory mite larva in the present study did not consume any prey till it moulted into the protonymphal stage. Similar predator larval non-feeding behaviour was observed by Kadu (2007) and Rao et al (2017). Protonymph of *N. longispinosus* consumed a mean number of 1 prey egg, 1.12 larvae, 0.58 protonymphs and 0.29 deutonymphs. No adult mites were consumed during its life period of 17.28 h. An equal feeding preference for egg and larval stages of prey mite with a mean consumption rate of 33 and 37%, followed by protonymphal stage (19%) and deutonymphal stage (9%) of the prey mite was observed. The predator deutonymph consumed 1.70 prey eggs, 1.58 larvae, 0.83 protonymphs, 0.48 deutonymphs and 0.12 adults of prey mite in its life span of 22.08 h, which indicated its preference equally for egg and larval stage of the prey mite accounting for a mean corresponding consumption of 34 and 31%, followed by 16% protonymph, 9% deutonymph and 2% adult prey consumption. Each adult female predatory mite consumed 3.55 prey eggs, 1.85 larvae, 1.80 protonymphs, 1.35 deutonymphs and 0.10 adults, exhibiting a preference for the egg stage of prey, *T. truncatus* with a consumption pattern of 71% eggs, followed by 37% larvae, 36% protonymph and 27% deutonymph stage and showed least preference for the adult stage of the prey mite (2%) (Table 1). Ahn et al (2009) and Farazmand et al (2012), observed that adult predatory mite, *N. californicus* on *T. urticae* consumed more eggs than other prey stages, which is consistent with the current findings. Jyothis and Ramani (2019), also reported that predator *N. longispinosus* preferred *T. neocaledonicus* eggs to larvae, nymphs, and adults, respectively. Kasap and Atlihan (2010) examined the consumption rate and functional response of the predatory mite *Kampimodromus aberrans* with *T. urticae* and reported that the predatory mite consumed a relatively higher number of larvae followed by eggs, protonymphs, and deutonymphs with the consumption of 3.27 eggs, 3.78 larvae, 1.86 protonymphs, and 0.60 deutonymphs, respectively which is in contrast to the present findings where predator consumed more number of egg stages of prey mite of *T. truncatus* followed by larval and nymphal stages.

Feeding potential of predator active stages on life stages of *T. truncatus*: The daily feeding potential of female adult predator on the four life stages of *T. truncatus* prey mites (egg, larva, nymph, and adult) when provided separately or collectively was examined (Table 2). On the first day, the predator consumed 7.2% of eggs with a mean consumption of 1.8 individual eggs, 20.4% of larvae with a mean consumption of 5.1 individuals, 10 % of nymphs with a mean consumption of 2.5 individuals, 1.2% of adults with a mean consumption of 1.4 individuals. On day 8th the predator consumed 22.8% eggs, 24% larvae, 14.8% nymphs, 6% adults and 20% of mixed stages with a mean consumption of 5.7, 6.0, 3.7, 1.5 and 5.0 individuals, respectively. On day 15th predator consumed 32.5% eggs, 26.8% larvae, 14.8% nymphs, 8% adults and 24.4% of mixed stages with a mean consumption of 8.1, 6.7, 3.7, 2.0 and 5.6 individuals, respectively. On day 22nd predator consumed 25% of larvae, 17.2% of nymph, 6.2% of adults and 21.2% of mixed stages with mean consumption rates of 6.3, 4.3, 1.6 and 5.3 individuals, respectively. The predator ceased feeding entirely on the 29th day. Ahn et al (2009) and Canlas et al (2006) recorded greater *T. urticae* prey consumption of per day, by predatory mite, *Neoseiulus californicus*, much higher than the present study. The difference in predator and prey species in these studies may be attributed to the variations in prey consumption. Singh and Singh (2018) reported that *Amblyseius indicus* consumed 6.13, 2.57 and 1.41 eggs, larvae and adults of the prey mite, *Tetranychus neocaledonicus* in 24 h, respectively, while, *Amblyseius tetranychivorus* correspondingly consumed 5.82, 2.24 & 1.18 eggs, larvae and adults of the prey mite. Eggs and larval consumption by the adult female predators of *A. indicus* and

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

Feeding stages of predatory mite	Prey mite stages offered together	Mean±S.E.	N_e/N_o
Protonymph (lived for 17.28 h)	Egg	1.00±0.16^{cd}	0.33±0.05^{cd}
	Larva	1.12±0.12^{d}	0.37±0.04^{d}
	Protonymph	0.58±0.13^{bc}	0.19±0.04^{bc}
	Deutonymph	0.29±0.08^{ab}	0.09±0.02^{ab}
Deutonymph (lived for 22.08 h)	Egg	1.70±0.18^{c}	0.34±0.03^{c}
	Larva	1.58±0.17^{c}	0.31±0.03^{c}
	Protonymph	0.83±0.16^{b}	0.16±0.03^{b}
	Deutonymph	0.48±0.12^{ab}	0.09±0.02^{ab}
	Adult	0.12±0.07^{a}	0.02±0.01^{a}
Adult (in 24 h)	Egg	3.55±0.26^{c}	0.71±0.05^{c}
	Larva	1.85±0.21^{b}	0.37±0.04^{b}
	Protonymph	1.80±0.18^{b}	0.36±0.03^{b}
	Deutonymph	1.35±0.22^{b}	0.27±0.04^{b}
	Adult	0.10±0.06^{a}	0.02±0.01^{a}

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

Table 2. Daily feeding potential of predatory adult *Neoseiulus longispinosus* on life stages of prey *Tetranychus truncatus*

Days	Single prey stage offered				All prey stages offered together				
	Egg	Larva	Nymph	Adult	Egg	Larva	Nymph	Adult	Total
Day 1	1.8 (10) (7.2 %)	5.1 (10) (20.4 %)	2.5 (10) (10%)	0.3 (10) (1.2 %)	0.5 (2%)	0.8 (3.2%)	0.1 (0.4%)	0	1.4 (10) (5.6%)
Day 8	5.7 (10) (22.8 %)	6.0 (10) (24 %)	3.7 (10) (14.8 %)	1.5 (10) (6%)	1.3 (5.2%)	1.8 (7.2%)	1.2 (4.8%)	0.7 (2.8%)	5.0 (10) (20%)
Day 15	8.1 (8) (32.5%)	6.7 (10) (26.8%)	3.7 (10) (14.8%)	2.0 (10) (8%)	1.4 (5.6%)	2.1 (8.4%)	1.2 (4.8%)	0.9 (3.6%)	5.6 (10) (24.4%)
Day 22	0 (4)	6.3 (8) (25%)	4.3 (10) (17.2%)	1.6 (7) (6.2%)	1.0 (4%)	1.9 (7.6%)	1.6 (6.4%)	0.9 (3.6%)	5.3 (8) (21.2%)
Day 29	0	0 (1)	0 (1)	0 (2)	0	0	0	0	0 (1)

*Figures in the parenthesis indicate the total number of female predatory mites alive out of 10 replicates over time and the per cent consumption

Table 3. Feeding potential of different life stages of the predatory mite, *Neoseiulus longispinosus* on life stages of prey mite, *Tetranychus truncates* (Mean±S.E.)

Feeding stages of predatory mite	Single prey stage offered				Prey stages offered together			
	Egg	Larva	Nymph	Adult	Egg	Larva	Nymph	Adult
Protonymph	2.30±0.39^{b*}	2.70±0.33^{b}	2.00±0.21^{b}	0	0.90±0.23^{a}	1.00±0.25^{a}	0.40±0.22^{a}	0
Deutonymph	6.60±0.97^{b}	6.80±0.67^{b}	4.70±0.36^{b}	0	1.30±0.39^{a}	2.20±0.41^{a}	0.78±0.24^{a}	0
Adult (Life period)	121.20±9.88^{b}	144.30±21.82^{b}	94.70±5.18^{ab}	36.20±4.67^{a}	28.30±3.94^{ab}	41.00±4.06^{b}	24.50±3.37^{ab}	13.40±2.53^{a}
Total	130.10±10.15^{b}	153.80±21.56^{b}	101.40±5.45^{b}	36.20±4.67^{a}	30.50±4.07^{ab}	44.20±4.18^{b}	25.68±3.28^{ab}	13.40±2.53^{a}

Mean values superscripted by the same letter within the row are not significantly different @ p=0.01

A. tetranychivorus was comparable to the number consumed in the present study.

Protonymph of predator had the potential to consume, on average 2.30 eggs, 2.70 larvae, 2.00 nymphs, when offered them separately and 0.90 eggs, 1.00 larvae and 0.40 nymphs, when offered all the prey stages together. The deutonymph consumed, on average 6.60 eggs, 6.80 larvae, 4.70 nymphs & no adult stage, when offered them separately and 1.30 eggs, 2.20 larvae, 0.78 nymphs when offered together in its life period. The, adult female predator during its living period consumed 121.20 eggs, 144.30 larvae, 94.70 nymphs, 36.20 adults of the prey when offered separately and 28.30 eggs, 41.00 larvae, 24.50 nymphs and 13.40 adults when offered as mixed stages. The predatory mite female from its protonymphal stage to the end of its adult stage had the potential of consuming 130.10 eggs, 153.80 larvae, 101.40 nymphs, and 36.20 adults of prey mite when offered separately (no-choice), and 30.50 eggs, 44.20 larvae, 26.10 nymphs, and 13.40 adults when all prey stages were offered as mixed (with choice) (Table 3). Facundo and Raros (2005) observed that *N. longispinosus* consumed 292 eggs of *T. truncatus* in its life span of 29 days. It is possible that the different survival periods of predators may be the cause for variation in the number of eggs consumed in these studies. Sanchit and Shukla (2016) recorded that *N. longispinosus* consumed substantially less *T. urticae* eggs , adults , and mixed-stages , than reported in the current study. Negm et al. (2014) reported that the predators, *Cydnoseius negevi* and *Neoseiulus barkeri* consumed 270 and 205 *Oligonychus afrasiaticus* preys in their lifetime which was significantly more than what was seen in the current study, may be because of change in the predator and prey species. Sathish et al. (2019) reported the predator *Neoseiulus baraki* consumed 553 *Aceria guerreronis* prey overall during its whole life span, the higher number may be because of the smaller size of eriophyid mites.

CONCLUSION

Protonymph and deutonymph of predator equally preferred the egg and larval stages while adult predators only preferred the egg stage of prey mite. The adult female predator had the potential of consuming 121.20 eggs or 144.30 larvae or 94.70 nymphs or 36.20 adults of *T. truncatus* during the course of its whole life. The data generated from the present study will be helpful to plan the biocontrol program against *T. truncatus*.

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