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RESEARCH ARTICLE

Seasonal Abundance and Predatory Potential of *Stethorus aptus* Kapur (Coleoptera: Coccinellidae): A Biocontrol Agent of Tea Red Spider Mite *Oligonychus coffeae* Nietner (Acarina: Tetranychidae)

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Abstract The tea red spider mite, *Oligonychus coffeae* Nietner is one of the major pests of tea plants in North-east India. The ladybird beetle, *Stethorus aptus* Kapur, is a newly reported predator of *O. coffeae*. Predatory efficiency study of *S. aptus* under laboratory conditions revealed that adult of *S. aptus* consumed significantly more mites than larvae. In free choice condition, the predator consumed within a range of 48–56 adults and 82–90 larvae of *O. coffeae* whereas the 3rd and 4th instar larvae of *S. aptus* consumed 20–26 adults and 50–60 larvae of *O. coffeae* per day respectively. Population dynamics of *S. aptus* was observed for 1 year under field conditions. The maximum density of the predator was recorded during January to March and it gradually declined from September onwards. Population of *S. aptus* showed positive correlation with its prey *O. coffeae* and relative humidity while effect of other factors was insignificant.

Keywords Tea plantation · Red spider mite · Beetle *Stethorus aptus* · Predation · Population dynamics

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Introduction

Oligonychus coffeae Nietner (Acari: Tetranychidae), the red spider mite (RSM) is one of the most serious and persistent pest of tea in almost all tea producing countries. In North East India, Assam, its occurrence in tea has been known to be associated from the very early days of tea cultivation (Peal 1986). Severe infestation of this pest causes about 17–46% crop loss (Das 1959; Sudoi 1997; Muraleedharan et al. 2005; Sudoi et al. 2011). Several pest control strategies are mainly based on chemical application. A wide range of acaricides belonging to different chemical groups are being recommended worldwide to control this mite pest. However, extensive and repeated use of these synthetic pesticides over a long period of time could lead to many undesirable effects like pollution of the environment, possible development of resistance apart from the residue problem in manufactured tea. Due to growing environmental and economic concerns involved in the use of synthetic chemicals, there is a dire need to develop alternate measures for the sustainable management of *O. coffeae*.

Biological control is one of the oldest pest management strategies that play a vital role in the control of many tea pests below economic injury level (Roy et al. 2014a). Many studies have recognized the potential of natural enemies on the natural control of red spider mites (Perumalsamy et al. 2009, 2010). Coccinellid beetles of the genus *Stethorus* are acarophagous in nature and control mite pests significantly in different agricultural crops (James et al. 2001; Roy et al. 2003; Gotoh et al. 2004; Ragkou et al. 2004; Roy et al. 2005; Latifian 2012). *Stethorus aptus* (Kapur) which was earlier reported on the citrus mites in China (Li et al. 1990) has been newly recorded in the tea growing areas of North Eastern region

(Babu 2012). Preliminary studies on the bionomics of *S. aptus* have been conducted (Barua et al. 2013). However, there is no detailed work on its seasonal abundance and feeding preference on various stages of *O. coffeae* in tea. Determining the feeding ability of a predator is an important parameter in assessing its potential as a biological control agent (Huang and Enkegaard 2009). Keeping this in view, the present investigation was carried out to study the population dynamics and its predatory potential against tea RSM.

Materials and Method

Study Area and Sampling

The study area was selected in the experimental plot of Tocklai Tea Research Institute, Assam (26°47′, 94°12′) to record the seasonal incidence of *S. aptus* in tea plantation for a period of one year from January 2013 to December 2013 following the method of Perumalsamy et al. (2010). The experimental plot consisted of 300 tea bushes which were further divided into three subplots (A, B and C), each consisting of 100 bushes. The said plot was kept free from application of insecticide during the study period. To assess the occurrence and abundance of populations of *S. aptus* and *O. coffeae,* sampling was conducted fortnightly for a period of one year by collecting 25 leaves at random from each plot. Leaves were placed in plastic bags separately and brought to the laboratory. Different developmental stages of *S. aptus* and *O. coffeae* were counted under a stereomicroscope (LEICA EZ4D) using ×8 magnification. Environmental parameters during experimental period were obtained from the meteorological division of Tocklai Tea Research Institute for statistical analysis.

Maintenance of *Stethorus aptus* and *Oligonychus coffeae*

To maintain the stock culture of *S. aptus*, different stages of the predator were collected from the tea fields of Tocklai Tea Research Institute. The culture was maintained at 25 ± 2 °C, 75 ± 5% RH and 16L: 8D photoperiod in the laboratory by following the method of Perumalsamy et al. (2010). To have the mass culture of the predatory beetle, various stages of field collected *S. aptus* were reared in small containers and provided with red spider mite (larvae and nymphs). The pupae were collected from the container and kept for adult emergence.

A culture of red spider mite was maintained in the laboratory following the detached leaf culture method of Roy et al. (2014a, b). Matured tea leaves (6 cm^2) were placed on water soaked cotton pads (ca 1.5 cm thick) in plastic trays (42 × 30 × 6.5 cm) and red spider mite laden leaves were cut into small pieces and placed on to the new leaves arranged in trays. Rearing trays were kept under the same controlled conditions. Water was added to the rearing trays when necessary to keep the cotton moist and thereby prevent the leaves from withering. Withered leaves were replaced with new ones at regular interval.

Predatory Efficiency of *Stethorus aptus*

1. No-choice feeding

In no choice condition, feeding efficiency of *S. aptus* was studied by offering different life stages of *O. coffeae* (eggs, larvae, nymphs and adults) separately. Matured tea leaflets of 4 cm^2 cut from the whole leaf were used for the experiment. To determine the prey consumption of *S. aptus*, fixed numbers of each life stages of red spider mite were transferred from the stock culture to the leaflets with a fine brush. First instar grub, adult male and female beetle were released onto each leaflet and placed on moist cotton in a Plexiglas box (breadth 3.5 cm, length 2 cm) and the lid was covered with a fine muslin cloth for proper aeration. The experiment was conducted at 25 ± 2 °C, 75 ± 5% RH and 16L: 8D photoperiod in the laboratory. Daily consumption by each instar and adults of *S. aptus* was recorded at 24 h interval. Presence of exuviae of *S. aptus* grub was examined to confirm the developmental stages and the number of prey consumed during each larval instar was recorded. To maintain the original prey density, fresh sets of RSM were provided on a daily basis to the predator. Each experiment was replicated five times.

2. Free-choice feeding

To assess the predatory potential of *S. aptus* in a choice condition, different life stages of red spider mite were offered together onto tea leaflet of 4 cm^2. Predetermined numbers of eggs, larvae, nymphs and adults of red spider mite were transferred to the leaflets as described above. The leaflets were placed in a plexiglas box on moist cotton pads. Thereafter a single first instar grub of *S. aptus* and adult beetle was released in the boxes separately and the lid was covered with a fine muslin cloth. The daily consumption of different instars of *S. aptus* on a variety of prey stages was noted at every 24 h interval under stereomicroscope by subtracting the number of *O. coffeae* individuals left in the cage. The experiment was replicated five times.

Correlation coefficients were worked out between meteorological data (temperature, rainfall and relative humidity) and population of predator and also between predator and their prey population to forecast the population dynamics of *S. aptus*. Data on the predatory potential of *S. aptus* was determined by analysis of variance (ANOVA) and means were separated by Tukey's multiple comparison test.

Results and Discussion

The seasonal abundance of *S. aptus* varied with the population densities of RSM during the study period. The population of *S. aptus* increased consistently from January onward and attained a maximum level between February and March (Fig. 1). From July, the population of RSM showed a decreasing trend till November (Fig. 2) and simultaneously the population of *S. aptus* also declined and again increased after a few weeks. The population of predator showed a significant positive correlation (r = 0.822) with the biotic factor (RSM). Highest number of predator was recorded in the month of March. The abundance of *S. aptus* was also influenced by various abiotic factors. The predator showed a positive correlation with maximum temperature (r = 0.585) and relative humidity (r = 0.591) while positive but not significant correlation between minimum temperature (r = 0.336) and rainfall (r = 0.417) (Table 1).

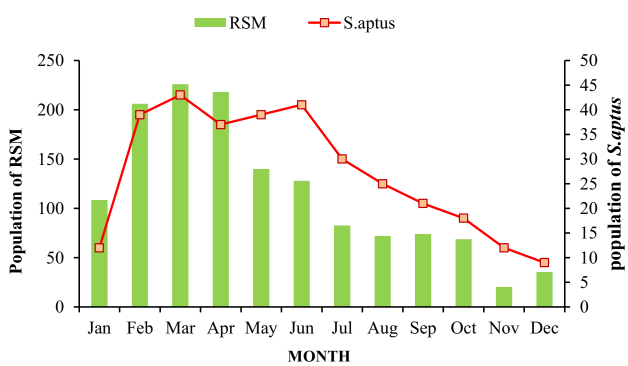

Fig. 1 Population dynamics (in number) of *S. aptus* in respect to densities of red spider mite

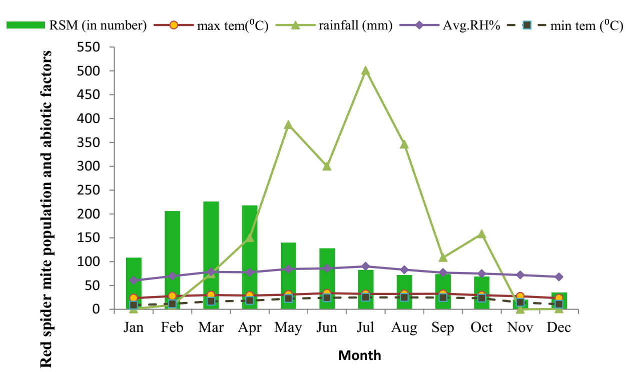

Fig. 2 Population dynamics of red spider mite in respect to abiotic factors (temperature, relative humidity, rainfall)

Table 1 Correlation between population of *Stethorus aptus* with biotic and abiotic factors

Parameter	Correlation co-efficient (r)
O. coffeae	0.822*
Maximum temperature	0.585*
Average relative humidity	0.591*
Minimum temperature	0.336
Total rainfall	0.417

* Significant at 5% ($p = 0.05$) level of significant, $df = 10$

The predatory efficiency of the grub and adult was determined by counting total number of RSM consumed by each developmental stage. All the instars and adults of *S. aptus* were fed on eggs, larvae, nymphs and adults of RSM. Data presented in the Tables 2 and 3 indicate that the rate of feeding increased gradually with the successive developmental stages of the predator. Consumption of first and second instar grubs was more towards eggs when compared to the adults. Third instar grub showed enhanced predatory activity than first two instars. Fourth instar grubs were very much voracious until pupal transformation which was evident from the maximum consumption (Table 2). They required more food than the previous instars due to bigger size and to accumulate nutrient for metamorphosis. In 24 h, an adult beetle consumed 57.26 adult mites, 96.83 larvae and 178 eggs of RSM in no choice feeding experiment, while in free choice feeding, the predator consumed comparatively less number of prey (Table 3).

The population density of *S. aptus* closely synchronized with the cyclic oscillation of the prey population. It almost disappeared from the tea fields when prey mass was very low. Perumalsamy et al. (2009) reported that in South India the populations of a related species *S. gilvifrons* Mulsant coincided with the abundance of *O. coffeae*. Kishimoto (2002) reported the seasonal occurrence of spider mites and their predators in three Japanese pear orchards where *Stethorus japonicus* Kamiya (Coccinellidae) and *Oligota* spp. (Staphylinidae) and predatory thrips, *Scolothrips takahashii* Priesner (Thripidae) were abundant and their population trend was closely associated with that of the prey. Roy et al. (2005) reported that seasonal activity of the predators *Stethorus punctillum* Weise (Coccinellidae) and the predatory mite *Neoseiulus fallacis* (Garman) also coincided with that of their prey, *Tetranychus mcdanieli* McGregor in raspberry. Raros and Haramoto (1974) reported the same in Hawaii, with *S. siphonulus* Kapur with the population of three mite species, *Tetranychus cinnabarinus* Boisduval, *Tetranychus tumidus* Banks and *Eutetranychus banksi* McGregor. The incidence of *S. siphonulus* was very scarce during December to February as the population of *T. cinnabarinus* Boisduval and *T.*

Table 2 Predatory efficiency of *Stethorus aptus* on immature and adult red spider mite in no choice test

Instars of *S. aptus*	Instar of RSM (mean ± SD)			
	Eggs	Larvae	Nymphs	Adults
I[st] instar	16.00 ± 1.00[a]	9.80 ± 1.48[a]	8.2 ± 0.84[a]	8.80 ± 1.48[a]
II[nd] instar	31.8 ± 1.79[b]	15.60 ± 1.52[a]	14.80 ± 1.92[b]	12.80 ± 1.30[a]
III[rd] instar	68.8 ± 1.64[c]	53.20 ± 1.30[b]	32.20 ± 2.68[c]	22.80 ± 3.35[b]
IV[th] instar	98.21 ± 2.68[d]	75.63 ± 4.34[c]	55.60 ± 2.30[d]	24.83 ± 3.11[b]
Adult (male)	165.20 ± 4.44[e]	93.20 ± 4.32[d]	81.60 ± 2.88[e]	54.60 ± 3.13[c]
Adult (female)	178.60 ± 5.46[f]	96.80 ± 4.44[d]	84.60 ± 1.52[e]	57.60 ± 1.82[c]

Means followed by the same letter in a column do not differ significantly at $p = 0.05$ according to Tukey's multiple comparison test

Table 3 Predatory efficiency of *Stethorus aptus* on immature and adult red spider mite in free choice test

Instars of *S. aptus*	Instar of RSM (mean ± SD)			
	Eggs	Larvae	Nymphs	Adults
I[st] instar	14.2 ± 1.22[a]	8.3 ± 1.41[a]	8.6 ± 0.69[a]	6.8 ± 1.22[a]
II[nd] instar	23.6 ± 3.37[a]	14.2 ± 1.31[a]	12.3 ± 2.16[a]	9.2 ± 1.47[a]
III[rd] instar	58.4 ± 1.34[b]	54.6 ± 3.09[b]	30.4 ± 4.59[b]	20.3 ± 2.36[b]
IV[th] instar	77.8 ± 4.70[c]	62.5 ± 4.71[c]	58.6 ± 6.10[c]	22.6 ± 4.80[b]
Adult (male)	152.2 ± 14.05[d]	82.2 ± 3.39[d]	74.5 ± 5.71[d]	48.3 ± 2.26[c]
Adult (female)	172.4 ± 10.47[e]	85.3 ± 3.16[d]	76.4 ± 4.35[d]	52.2 ± 5.88[c]

Means followed by the same letter in a column do not differ significantly at $p = 0.05$ according to Tukey's multiple comparison test

tumidus Banks was low and when the mite population reached its peak during June- July, the abundance of the beetle simultaneously increased.

In general, it is well established that most *Stethorus* species are considered to be 'high density predators', since they require abundant prey (Putman 1955; McMurtry and Johnson 1966). Findings of the present study also showed that all the stages of RSM was predated by *S. aptus*. Similar results were explained by Ahmed and Ahmed (1989), Afshari (1999), Fiaboe et al. (2007) and Perumalsamy et al. (2009). However prey preference varied among the larval stages of *S. aptus*. The first instar larva generally preferred the eggs and smaller nymphs of RSM. Adults and late larval instars of *S. aptus* showed more preference for RSM eggs both in free choice and no choice condition. Finally it is assumed that, as *S. aptus* develops from the third larval instar to the adult stage, they establish a greater preference for the egg stage. The high rate of consumption by *S. aptus* adults suggests that this species has certain advantages as a potential biocontrol agent, due to their high longevity, dispersal characteristics and ability to locate host density area. Conservation of this predator in plantation belt would be useful in developing a biocontrol-based mite pest management in tea ecosystem.

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