Asian Journal of Conservation Biology, December 2020. Vol. 9 No. 2, pp. 183-187 AJCB: EN0018
ISSN 2278-7666 ©TCRP Foundation 2020 https://doi.org/10.53562/ajcb.EN00018

EDITORIAL

Conservation of the tea (*Camellia sinensis* (L.) O. Kuntze) ecosystem through enhancement of natural enemies of pests

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Tea (*Camellia sinensis* (L.) O. Kuntze), being its perennial and monoculture nature, provides a stable microclimate for various insect pests, which cause substantial loss of crop (Li *et al*., 2019). With the escalating cost of insect pest management and increasing concern about the adverse effects of the pesticide residues in manufactured tea, there is an urgent need to explore other avenues of alternate pest management strategies (Babu, 2011). In general, the tea plantations provide a stable microclimate and food supply for several notorious pests, such as insects, mites, and nematodes, etc. They also support an array of natural enemies in the ecosystem. Although there are numerous non-conventional methods available, pest control in the tea ecosystem was mainly achieved by the use of synthetic pesticides until today. Biological pest control methods are adopted globally in major crops to avoid the negative impact of synthetic pesticides (Gillespie *et al*., 2000). Several tea pests may be controlled by using natural enemies as biological control agents in an integrated pest management approach (Babu *et al*., 2011).

The natural enemy guild is dominated by predators in several ecosystems. Muraleedharan and Roy (2016) reported a total of 200 predatory arthropod species were recorded in the tea ecosystem. The overall species composition reflects the richness of arthropod natural enemies, *i.e.,* predators and parasitoids of tea pests, where the natural enemy to pest ratio is 1.7:1. The tea plantations in Northeast India harbour several species of coccinellids, such as *Cryptogonus bimaculatus, Juravia quandrinotata, J. opaca, Menochilus sexmaculatus,* and *Stethorus gilvifrons*, which feed on eriophyid mites, spider mites, aphids, and scale insects (Somchoudhury *et al*. 1995). The parasitoids, *Apanteles coedicius*, *Trioxys indicus,* and *Aphidus colemani*, have several hosts, like *Toxoptera aurantii* feeding on tea, and *Aphis gossipii* and *Aphis craccivora* on weeds in tea fields. The tea mosquito bug *H. theivora are* being preyed upon by *Chrysoperla carnea*, *Oxyopes* sp., *Plexippus* sp., *Phidippus* sp., and *Scymnus* sp. and *mantids*. Eggs of *H. theivora* were found parasitized by *Erythmelus helopeltidis* Gahan in South India (Sudhakaran and Muraleedharan, 2006). The activities of predators and parasitoids have been found to be high in Northeast India. In the areas of North Bengal, Roy *et al*. (2005) found 35 species of spiders and 25 species of coccinellids as natural enemies in the tea ecosystem, while 94 species of predators and 33 species of parasitoids were reported from the sub-Himalayan tea plantations of North Bengal, among which the predators, spiders and ladybird beetles, and among the parasitoid groups, Braconidae and Ichneumonidae, were dominant (Das *et al*. 2010).

Sycanus collaris (Fabricius):

Reduviidae a large family that belongs to the order Hemiptera, are found to be efficient predators of different insect pests, preferably lepidopteran larvae (Ambrose *et al*., 2009). *Sycanus collaris, (*Fabricius), known as the assassin bug, all of its life stages efficiently feed on the target insect. The sequential predatory behaviour of the genus *Sycanus* on its prey is very active (Ambrose *et al*., 2009). *S. collaris is* found to feed on different hosts, like the tea red slug caterpillar, *Eterusia magnifica* (Butler) as well as the pupal stage of the tea looper, *Hyposidra talaca Walker*. During the winter period (December to February), when the tea plants are subjected to pruning, *S. collaris* forages for food and shelter in the un-pruned plots and shade trees. They preferred to shelter in small jungle trees associated with tea fields. The voracious predatory behaviour of *S. collaris* effectively prevented the increasing population density of *H. talaca* under field conditions. Sarkar *et al*., (2019). Sarkar *et al*., (2019) reported the predatory efficiency of *S. collaris* on the larvae of *H. talaca* and reconfirmed that the larger size of life stage *S. collaris* preferred by the later stages (IV and V instar larvae) to fulfill the nutritional requirements. Predatory behaviour of feeding preference highlights the vital role of this predator as an efficient biological control agent in the tea ecosystem. Conservation of this predator in the plantation belt would be useful in developing a bio-control-based looper pest management strategy in the tea ecosystem.

Eocanthecona furcellata (Wolff):

The stink bug, *Eocanthecona furcellata* (Wolff) is one of the important predator that has recently included in the field of biological control due to its potential to prey different orders of insect pests such as, lepidoptera,

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coleoptera and heteroptera (De Clercq, 2000). Das *et al*. (2010) reported the presence of this predatory stink bug in tea ecosystem. Chakravarty *et al*. (2017) observed that higher temperatures and cloudy conditions favored the population dynamics of this stink bug. Earlier studies on seasonal abundance of *E. furcellata* showed that its occurrence was coinciding with the cyclic oscillations of the looper (*H. talaca*) population. Statistically significant correlation and regression values with all the abiotic factors indicated that, the populations of *E. furcellata* can easily build-up in tea ecosystem. The survival fitness of this stink bug and fecundity rate confirmed the possibility of maintaining and mass rearing of this predator under laboratory conditions.

***Stethorus aptus* (Kapur):**

The ladybird beetles have gained considerable significance in biological control in several agro-ecosystems. The predatory nature of most coccinellid beetles makes them economically important. They have the capacity to search and feed ravenously on larval and adult stages of aphids, mites and other soft-bodied arthropods (Kim-Kyuchin *et al*. 2000). In recent years, the introduction of indigenous natural enemies has been more favored than exotic predators for efficient biocontrol and to reduce undesirable ecological problems (Brader, 1980). In this regard, the predacious ladybird beetles are widely used in biocontrol as the majority of them feed on different tea pests (Muraleedharan *et al*., 2001). This coccinellid beetle, *Stethorus aptus (*Kapur), has been recorded for the first time in the tea growing areas of the north east region (Barua *et al*., (2013). Barua *et al*., (2013) while studying the *S aptus* in the tea ecosystem in order to evaluate their potential against the tea red spider mite, reported that the predatory efficiency of this Coccinellidae beetle was found to increase with advancement of larval instars. The fourth larval instar of the beetle was found to be more voracious than the other larval instars. (Barua *et al*., 2013). In general, it is well established that most *Stethorus* species are considered to be 'high density predators', since they require abundant prey (McMurtry and Johnson 1966). Barua *et al*., (2016) reported that all the stages of the red spider mite were predated by *S. aptus*. However, prey preference varied among the larval stages of *S. aptus*. The high rate of consumption by *S. aptus* adults suggests that this species has certain advantages as a potential biocontrol agent due to its high longevity, dispersal characteristics, and ability to locate host density areas.

***Cotesia ruficrus* (Haliday):**

Braconid wasps as promising parasitoids are being considered as potential natural enemies in several agro-ecosystems (Rahman and Bhola 2011). Endoparasitoid belonging to the family Braconidae lay eggs and complete their larval period inside a suitable host insect (Jung *et al*. 2006). They usually prefer healthy larvae of lepidopteran pests. This kind of parasitism affects the fitness of the host larvae and ultimately leads to mortality. Generally, the growth of the larvae of the parasitoid and developmental duration depend on the host's fitness, stage, and physiological condition (Kim *et al*. 2006). Parasitizatism by the braconid wasp alters the host's normal feeding and movement. *Cotesia ruficrus* Haliday is found to be one of the effective parasitoid wasps which attack the tea looper complex (Das *et al*., 2010). Several innovative research works have been done on the host-parasite interaction between *C. ruficrus* and *Cnaphalocrocis medinalis* (Chen *et al*., 2016). The parasitoid, *Cotesia* spp, was reported to be an efficient parasitoid on its selected host, *H. talaca*, consequently leading to the death of the host (Das *et al*., 2010). Just after emerging from the host, the larvae of the parasitic wasp construct pupal cocoons and, after a few days, the adults emerge (Potting *et al*., 1997). Sarkar *et al*., (2020) while studying the stage specificity for successful parasitism by *C. ruficrus* by providing different host larval instars of *H. talaca*. The highest percentage of parasitisms of almost 74% with the maximum number of pupal cocoons was recorded from the fourth instar host larvae. The female wasps show more preference towards the fourth instar host larvae of *H. talaca*. More successful parasitization may be attributed to the large body size, which could be more suitable for the developing larvae inside the host. Similar parasitic activities were also reported earlier by Chen *et al*. (2016) on the host selection of *C. ruficrus and* reported more than 60% successful parasitism by *C. ruficrus* on fourth instar host larvae, which indicated their ability to regulate the population of this major tea pest in the tea ecosystem. The host-parasitic interaction between *C. ruficrus* and *H. talaca* might be helpful in developing an IPM component for eco-friendly management.

***Mallada boninensis* (Okamoto):**

The green lacewing, *Mallada boninensis* (Okamoto), is also an important predator of a variety of soft-bodied arthropods, including red spider mites found in tea. Green lacewings have been frequently suggested for biological control efforts in recent years (Singh and Jalali, 1991). The larvae feed on spider mites, early caterpillars, scales, and aphids, etc., infesting a variety of plants. Adults eat mostly nectar, pollen, and honeydew, but a few are predatory (McEven *et al*. 2001). The green lacewing has been described as an efficient predator of red spider mites infesting tea, and its biology and predatory capabilities on red spider mites have been examined (Babu *et al*., 2011; Vasanthakumar *et al*., 2012).

***Chrysoperla carnea*(Stephens):**

Chrysoperla carnea (Stephens), the common green lacewing is an important generalist predator (Sarwar, 2014) and is best known as a biocontrol agent (Menon *et al*., 2015). The larval stage is a more voracious feeder of soft-bodied insects such as tea mosquito bugs, aphids, whiteflies, mealy bugs, thrips, mites, leaf hoppers, jassids, caterpillars, and insect eggs (Sarwar and Salman, 2016). However, aphids are the more preferred hosts (Solangi *et al*., 2013). The adults are free living and they only feed on honey, pollen and water (Nadeem *et al*., 2014). The ability of *C. carnea* to be exploited as a biocontrol agent in the IPM program (Memon *et al*., 2015).

Natural enemies are subjected to continuous deterioration in populations, especially in modern agricultural systems characterized by complete removal of plants after harvesting as well as by frequent application insecticides. The practice of complete removal of plants gives rise to the elimination of natural enemies after each crop season. Conservation biological control is the protection of natural enemies against adverse effects of pesticides and incompatible cultural practices, and improving their efficiency by providing food sources.

The maximum of natural control is an essential concept of integrated pest management. Thus, temporal variations in arthropod abundance, variety, species richness, and community structures are key factors to consider when developing different pest management methods. Arthropod species invade tea plantations once they are planted, and their variety grows over time. The environment, cultivars, cropping patterns, and production techniques all influence their communities. *In situ* protection and preservation of natural enemies in the tea ecosystem, as well as a decrease in the use of pesticides, are desirable in order to accomplish the goal of producing export-quality tea: a biorational approach to tea production. As seen by comparing research on natural enemy diversity between organic (high diversity index) and pesticide-treated conventional tea gardens, large-scale and indiscriminate applications of broad-spectrum organo-synthetic insecticides for pest control destroy natural enemies (Das *et al*. 2005). The basic aim of conservation biological control (CBC) would be to protect, maintain, and improve the efficacy of the current population of natural enemies by using environmentally benign methods and reducing pesticide use (Jonsson *et al*. 2008). Plant diversification programmes assist inhabitant manipulation by inter-cropping with shade trees and cover planting un-occupied areas in tea plantations, which may aid the CBC process by providing shelter, nectar, pollen (Wackers *et al*. 2007), and alternate host/prey for natural enemies (Zehnder *et al*. 2007). Conservation of the tea ecosystem through preserving and enhancing natural enemies provides alternatives to chemical pesticides.

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