Diversity of arthropod natural enemies in the tea plantations of North Bengal with emphasis on their association with tea pests

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A study was undertaken to explore the diversity of arthropod natural enemies in sub-Himalayan tea plantations of North Bengal, India. The study revealed the presence of 94 species of predators and 33 of parasitoids in the region. New records on tea pest–natural enemy associations were made on the basis of field observations as well as laboratory rearing. Among the predators, spider and lady-bird fauna, and among the parasitoid groups, Braconidae and Ichneumonidae were dominant during the survey period.

Keywords: Natural enemies, parasitoids, pests, predators, tea.

TEA, *Camellia sinensis* (L.) O. Kuntze is grown as a key plantation crop in North East India. The tea industry is one of the oldest organized industries in India. Sub-Himalayan tea-growing areas of West Bengal (North Bengal) are spread over Darjeeling hill slopes and the adjoining plains of Terai and the Dooars. Moreover, Darjeeling District has been declared as an Agri Export Zone for producing export-quality tea to the world market (*The Statesman*, 5 June 2003) and tea from this region has also gained the 'geographical indicator' status, as many of the tea estates produce 'flavour leaves' bio-rationally or organically. Total absorption of Indian tea in 2004 was estimated to be 900 million kg, out of which approximately 23% is harvested from North Bengal[1]. Tea is grown as a perennial monoculture crop over large contiguous areas. Such cropping condition provides a comparatively stable microclimate, continuous supply of food and suitable sites of reproduction for about 300 species of phytophagous insects and mites almost throughout the year in India[2,3], resulting in 11–55% loss in yield in general. Among these tea attackers, the dominant arthropod pests causing substantial damage to the crop in this foothill and its Terai region were the different species of looper caterpillars (*Buzura suppressaria* Guen., *Hyposidra talaca* (Walker), and *Hyposidra infixaria* Walker), red slug caterpillar (*Eterusia magnifica* Butl.), tea mosquito bug (*Helopeltis theivora* Waterh.), flush worm (*Cydia leucostoma* Meyrick), leaf roller (*Caloptelia theivora* Walsingham), tea tortrix (*Homona coffearia* Nietner), aphid (*Toxoptera aurantii* Boyer), jassid (*Empoasca flavescens* Fabr.), thrips (*Mycterothrips setiventris* (Bagnall) and *Scirtothrips dorsalis* Hood) and the red spider mite (*Oligonychus coffeae* Nietner). Pest control in tea is mainly achieved by the use of synthetic pesticides. But different international organizations like the Environmental Protection Agency, Codex Alimentarius Commission, Commission of European Communities, and Food and Agricultural Organization have established low and stringent 'maximum residue limits' for different pesticides on tea[1,4]. Thus, from the export point of view, international regulations of pesticide residues need to be complied with, which in turn would help in ameliorating environmental pollution and health-hazard issues due to overuse of synthetic pesticides.

Under such a warranting situation the importance of insect natural enemies (predators and parasitoids) as biocontrol agents is largely realized as they play a remarkable role in the management of many crop pests and keep their population low. Conservation and application of naturally occurring biocontrol agents are more preferred than introduction of exotic predators and parasitoids for better efficacy and to avoid ecological problems[5]. The knowledge gained from a study of natural enemies may be of immense practical value in insect pest management[6]. Reviews on predators and parasitoids of tea pests are available from southern India[4,7], but not from tea plantations of North East India. Moreover, it is well known that the pest and natural enemy complex within a region/crop might undergo dynamic changes over space and time[8]. Therefore, periodic surveillance of pests and their natural enemies is needed.

In the present study, a survey was undertaken during 2006–2008 to document the arthropods natural enemies in the tea ecosystems of sub-Himalayan West Bengal. A good number of (i.e. 127) natural enemies are listed in this communication, of which at least 33 species were found to be intimately associated with tea pests or occurred as their hosts.

The collection of natural arthropod enemies was mainly done in tea ecosystems of the sub-Himalayan North Bengal region. For this purpose, five tea estates were selected each from the Darjeeling hill slope (c. 1000 m), Dooars and Terai regions. The survey was conducted two times in a month. Blocks of size 50 × 50 ft in three replications were sampled in all the selected tea estates.

The natural enemies were sampled using a vacuum sampler for 10 min duration in each block. The advantage of vacuum sampling is the more complete extraction of the tiny species and the immature forms of even the larger insects. The vacuum sampling method is useful in studies of arthropod communities[9,10] and in pest management programmes to assess the balance of predators and parasites as well as pests.

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Table 1. Predator fauna of tea ecosystem in North Bengal

Order	Family	Predators
Class: Arachnida		
Acarina	Oxyopidae	*Oxyopes shweta* Tikader
		Oxyopes ratnae Tikader
		Oxyopes birmanicus Thorell
		Oxyopes sp.
	Salticidae	*Marpissa bengalensis* Tikader
		Marpissa sp.
		Marpissa tigrina Tikader
		Plexippus paykulli Aud.
		Euophrys sp.
		Phidippus sp.
		Euophrys chiriatapuensis Tikader
		Plexippus sp.
		Rhene sp.
		Telamonia dimidiate Simon
	Sparassidae	*Sparassus* sp.
	Clubionidae	*Cheiracanthium melanostoma* Thorell
		Cheiracanthium sp.
		Cheiracanthium sadanai Tikader
		Clubiona drassodes Cambridge
	Araneidae	*Leaucage* sp.
		Leaucage decorate Black wall
		Zygeilla sp.
		Cyclosa hexatuberculata Tikader
		Gasteracantha kuhli Koch
		Neoscona sp.
		Neoscona mukerjei Tikader
	Thomisidae	*Philodromus* sp.
		Runcinia affinis Simon
	Heteropodidae	*Heteropoda* sp.
		Heteropoda venatoria L.
	Homalonychidae	*Homalonychus* sp.
	Gnaphosidae	*Gnaphosa* sp.
	Tetragnathidae	*Tetragnatha* sp.
	Lycocidae	*Lycosa* sp.
		Pardosa minutus Tikader & Malhotra
		Pardosa birmanica Simon
	Thomisidae	*Dieta* sp.
		Philodromida bhagirathai Tikader
	Lyssomantidae	*Lyssomanes* sp.
	Pisauridae	*Pisaura* sp.
Class: Insecta		
Coleoptera	Coccinellidae	*Afidentula mandertiernae* Muls
		Aspidimerus circumflexa Muls
		Caelphora sp.
		Callineda decemnotata Fab.
		Chilocorus circumdatus Gyllenhal
		Coccinella repanda Thumb
		Coccinella septempunctata L
		Coccinella transversalis Fab.
		Coclophora sexareata Muls
		Coclophora unicolor Muls
		Crytogonus bimaculatus Kapur
		Crytogonus quardriguttatus Weise
		Harmonia sp.
		Henospilachna septima Dieke
		Jauravia opace Weise
		Jauravia quadrinotata Kapur
		Jauravia soror Weise
		Les dimidiate Muls

(*Contd.*)

Table 1. (*Contd.*)

Order	Family	Predators
		Menochilus sexmaculatus Fab.
		Micraspis discolor Fab.
		Oenopia kirbyi Muls
		Oenopia luteopustulata Muls
		Oenopia sexareata Muls
		Ola sp.
		Scymnus sp.
		Stethorus gilviforn Muls
		Vernia vincta Gorh
	Carabidae	*Ophinea indica* Thumb
		Calleida sp.
	Staphylinidae	*Paederus fuscipes* Curtis
	Cicindelidae	*Cicindela sexgutta* Fab.
		Cicindela collicia Acciavatti & Pearson
Hemiptera	Pentatomidae	*Canthecona furcellata* Wolff
		Eocanthecona furcellata Wolff
	Reduviidae	*Acanthaspis quinquespinosa* Fab.
		Allaeocranum quadrisignatum Reuter
		Rhynocoris marginatus F.
		Epidaus sp.
		Opistoplatys sp.
		Sycanus croceovittatus Dohrn.
	Lygaeidae	*Geocoris ochropterus* Fieber
Neuroptera	Chrysopidae	*Chrysopa* sp.
		Chrysoperla carnea Stephens
	Hemerobiidae	*Micromus timidus* Hagen
Mantodea	Mantidae	*Amantis* sp.
		Elmantis sp.
		Hierodula sp.
		Humbertiella indica Saus
	Amorphoscelidae	*Amorphoscelis* sp.
Odonata	Coenagrionidae	*Ceriagrion* sp.
		Pseudagrion sp.
	Gomphidae	*Ictinogomphus* sp.
	Aeshnidae	*Anax* sp.
Diptera	Syrphidae	*Ishindon scutellaris* F.

The natural enemies collected were preserved dry or wet according to the procedure used for soft and hard-bodied insects. Some hosts (tea pests) were reared in the laboratory for emergence of the parasitoides. The collected specimens were identified with the help of available taxonomic literature[11,12] and if needed, expert systematists. New records on the predators of tea pests or their association were based on field observations.

To study tea pest–parasitoid relationship, the immature stages of the pests (mostly lepidopteran larvae) were reared in the laboratory until the emergence of the parasitoids. In the tea ecosystems of sub-Himalayan West Bengal, 94 species of predators and 33 species of parasitoids were recorded (Tables 1 and 2). Among the predatory arthropods, spiders outnumbered the other predatory groups and were widely distributed throughout the study area during the survey period. Spiders representing 14 families, 29 genera and 40 species were recorded during the study (Table 1). Among them, species of genera *Oxyopes*, *Plexippus*, *Phidippus* and *Marpissa* were dominant. The insect predators included 32 species of Coleoptera under four families, eight species of Hemiptera under three families, four species of Odonata and one species of Diptera. Among the families of Coleoptera, Coccinellidae was dominant with 27 species.

Of the predatory arthropods, the spider occupied 43%, Coleoptera 31%, Hemiptera 8%, Neuroptera 5%, Mantodea 7%, Odonata 4% and the rest of the predatory insects 2% (Figure 1). The dominance of coccinellids and spiders confirms the earlier report of Roy *et al.*[13].

The survey indicated that the number of species of predators was more than that of parasitoids in tea plantations. The relative abundance of predator species was highest in Terai (86.46%), followed by Darjeeling (79.37%) and Dooars (77.19%). With regard to parasitoids, the Terai region exhibited lowest percentage of occurrence of

Table 2. Parasitoid fauna of tea ecosystem in North Bengal

Order	Family	Parasitoids
Class: Insecta		
Hymenoptera	Braconidae	*Cotesia* sp.
		Cotesia ruficrus Haliday
		Dolichogenidea sp.
		Pambolus sp.
		Meteoridinae sp.
		Spathius critolaus Nixon
		Chelonus indicus Cameron
		Agathidinae sp.
	Ichneumonidae	*Astomaspis* sp.
		Charops sp.
		Apophua sp.
	Mymaridae	*Polynema* spp. (2 spp.)
		Anagurus sp.
		Alaptus spp. (2 spp.)
	Encyrtidae	*Ooencyrtus ferriere* Shafi Alam & Agarwal
	Eulophidae	*Pediobius elasmi* Ashmead
		Pediobius foveolatus Crawford
		Elasmus sp.
		Elasmus anamalaianus Mani & Saraswat
		Aprostocetus nowsherensis Kurian
		Tetrastichus epilachnae Kurian
		Nesolynx sp.
	Scelionidae	*Telenomus* spp. (2 spp.)
		Trissolcus sp.
		Gryon spp. (2 spp.)
		Sparasion sp.
	Platygastridae	*Synopeas* sp.
		Leptacis indicus Mukerjee
	Ceraphronidae	*Aphanogmus* spp. (6 spp.)
	Pteromalidae	*Dipara* sp.
	Diapriidae	*Trichopria* sp.
	Blatygastridae	*Fidiobia* sp.
	Chalcididae	*Brachymeria lasus* Walker

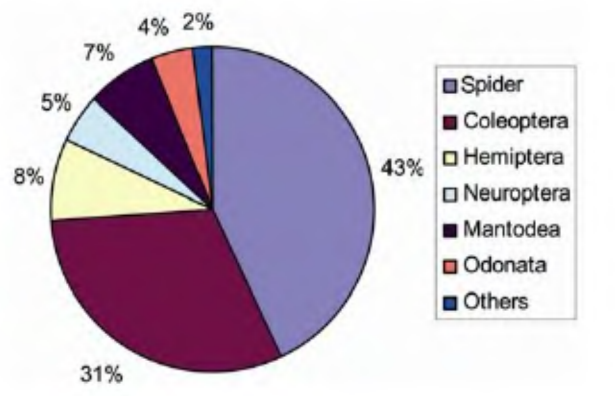

Figure 1. Relative abundance (%) of different groups of predators in tea plantations of the sub-Himalayan regions of North Bengal.

parasitoids (13.54%), whereas the Dooars and Darjeeling regions registered 20.63–22.80% abundance (Figure 2).

Eleven families of Hymenoptera consisting of at least 33 parasitoid species were known to be distributed in tea plantations of North Bengal. Of these, Braconidae comprised 40%, Ichneumonidae 20%, Eulophidae 15%, Scelionidae 7%, Platygastridae 4% and the rest of the six families represented 14% of the relative abundance of parasitoids in North Bengal tea plantations (Figure 3). The highest number of species of natural enemies was collected from Darjeeling hill slopes (45%), followed by Dooars (30%) and Terai (25%) regions (Figure 4). Many of the listed predators and parasitoids were found associated with the common tea pests occurring in this region, implying that a natural control of the pests was also taking place besides other methods applied (Table 3).

Biodiversity plays a major role in sustainability and healthy functioning of an ecosystem[14]. The ecosystem of tea fields is complex and stable. The tea plant is perennial and evergreen with leaves stratified in two layers. The bush below the plucking surface is important as a refuge for natural enemies[4].

Table 3. Association of natural enemies with their hosts (tea pests)

Natural enemies	Hosts
Parasitoids	
Cotesia sp.	*Eterusia magnifica* Butler (red slug caterpillar)
	Buzura suppressaria Guen. (looper caterpillar)
	Hyposidra talaca (Walker) (looper caterpillar)*
	Hyposidra infixaria Walker (looper caterpillar)*
Argyrophylax sp.	*E. magnifica* Butler
	H. talaca Walker*
Exorista sp.	*E. magnifica* Butler
Aphanogmus sp.	*Buzura suppressaria* Guen.
Dolichogenidea sp.	*Cydia leucostoma* Meyr. (flush worm)*
Pediobius sp.	*C. leucostoma* Meyr.
Tetrastichus sp.	*C. leucostoma* Meyr.
Nesolynx sp.	*C. leucostoma* Meyr.*
Elasmus sp.	*C. leucostoma* Meyr.
	Caloptilia theivora (Walsingham) (leaf roller)
Brachymeria lasus	*Homona coffearia* Nietner (tea tortrix)
Telenomus sp.	*H. coffearia* Nietner
Apophua sp.	*H. coffearia* Nietner
Predators	
Sycanus croceovittatus	*E. magnifica* Butler
	Helopeltis theivora Waterhouse (tea mosquito bug)
Canthecona furcellata	*E. magnifica* Butler
Dalpada oculata	*E. magnifica* Butler
Coccinella septempunctata	*Toxoptera aurantii* (Boyer de Fonscolombe) (tea aphid)
	Mycterothrips sentiventris (tea thrips)
	Lefroyothrips lefroyi (tea thrips)
Coccinella transversalis	*T. aurantii*
Scymnus sp.	*T. aurantii*
	Oligonychus coffeae (Nietner) (red spider mite)
	Empoasca flavescens Fabr. (tea jassid)
	Scirtothrips dorsalis (tea thrips)
Aspidimerus circumflexa	*T. aurantii* (tea aphid)*
	E. flavescens Fabr. (tea jassid)*
	Mycterothrips setiventris (Tea thrips)*
Oenopea sexareata	*T. aurantii**
Ola sp.	*T. aurantii**
Jauravia quadrinotata	*O. coffeae* (Nietner)
Micraspis discolor	*O. coffeae* (Nietner)*
	*T. aurantii**
Stethorus gilviforn Mulsant	*O. coffeae* (Nietner)
Micromus timidus	*O. coffeae* (Nietner)
	T. aurantii
	Brevipalpus australis Tucker (Scarlet mite)
Chrysoperla carnea	*H. theivora*
	O. coffeae (Nietner)
Oxyopes sp.	*H. theivora*
Plexippus sp.	*H. theivora*
Phidippus sp.	*H. theivora*
Marpissa sp.	*H. theivora*
Geocoris ochropterus	*T. aurantii*
	Tea thrips
Praying mantis	*H. theivora*
Syrphid larvae	*T. aurantii*

*Indicates new record on natural enemy – tea pest association from tea plantations of sub-Himalayan regions of North Bengal.

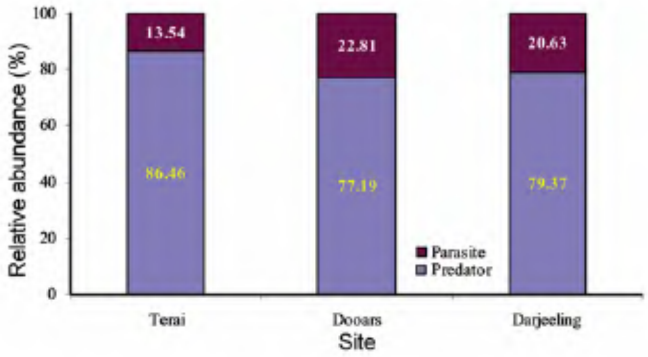

Figure 2. Relative abundance of natural enemies collected from different tea ecosystems at three locations of sub-Himalayan regions of North Bengal.

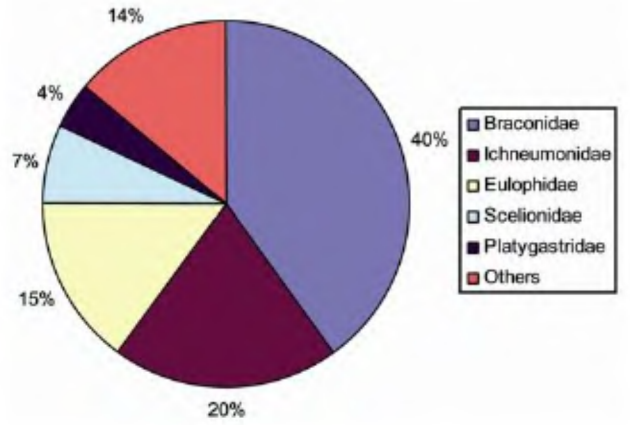

Figure 3. Relative abundance (%) of different families of parasitic Hymenoptera in tea plantations of the sub-Himalayan regions of North Bengal.

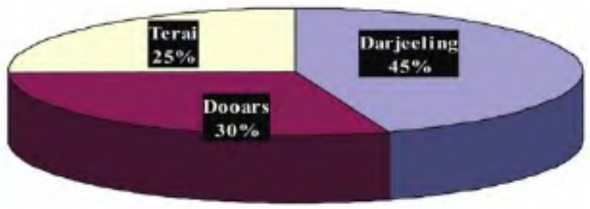

Figure 4. Species richness of natural enemies from three tea-growing sub-Himalayan regions of North Bengal.

The present study revealed the presence of a good number of natural enemies in the tea ecosystems of Darjeeling slopes and its adjoining plains of Terai and the Dooars. A large area of tea plantations in hill slopes is organically managed, which possibly results into a higher species richness in this region in comparison to the adjoining plains of Terai and Dooars, where only a few gardens are organic. An earlier study on hymenopteran parasitoids also revealed higher species diversity in organically managed tea plantations[15].

The effect of natural enemies on the population of tea pests appears to be significant. Tachinid fly, *Argyrophylax* sp. was reported to parasitize up to 80% red slug caterpillar (*Eterusia magnifica*) population in organic plantations[16] during early summer. Up to 47% control of looper caterpillars (*Buzura suppressaria, Hyposidra* spp.) by *Cotesia* was witnessed (Hymenoptera: Braconidae) during March–May[16]. In controlling tea aphids, larva and adult of predatory lady beetles, larvae of syrphid fly *Syrphus* sp., nymphs and adults of green lace wing *Chrysoperla carnea* (Stephens) and larva and adult of the bug *Geocoris ochropterus* Fabr. play a significant role[17]. An adult lady bird beetle may eat as many as 50 aphids per day. Larvae of lady bird beetles, *Syrphus* sp. and *C. carnea* may feed up to 300, 400 and 600 aphids respectively during their development[18]. Adult *G. ochropterus* on an average consumes 13 aphids per day for a period of about 22 days[12]. *C. carnea* nymphs also feed on red spider mite eggs and adults[19]. The larvae of *G. ochropterus* effectively feed on tea thrips too[20]. Rahman *et al.*[21] reported that *C. carnea*, *Oxyopes* sp., *Plexippus* sp., *Phidippus* sp., *Marpissa* sp., praying mantids and reduviid bug are predatory on tea mosquito bug (*Helopeltis theivora*). Being a slow feeder, an adult assassin bug (*Sycanus croceovittatus* Dohrn.) on an average consumes 3.5 caterpillars of red slug per day[22]. The grubs of *Micraspis discolor* consumed on an average 280.30 red spider mites and 188.66 tea aphids during its larval period of development[23]. Larvae and adults of *Stethorus gilvifrons*, *Verania vincta*, *Jauravia quadrinotata*, and *Scymnus* sp. are important natural enemies of tea mites[24].

Such prey–predator/parasitoid coactions prevailing in the tea ecosystems should be optimized by minimizing chemical control of tea pests and adopting integrated pest management (IPM) strategies in order to produce residue-free healthy tea.

Reports on culture methods of the natural enemies of tea pests are scanty. However, *G. ochropterus*, a good predator of aphids and thrips could be reared successfully in the laboratory[25]. Rearing of the reduviid predator, *S. croceovittatus* was also possible in the laboratory on termite diet[22].

In order to achieve the objective of production of export-quality tea, *in situ* conservation and maintenance of natural enemies in the tea ecosystems is desirable along with reduction in the use of insecticides: a biorational method of tea production. IPM in tea cultivation is already in practice in Vietnam[26]. Large-scale and indiscriminate application of broad-spectrum organosynthetic insecticides for control of pests eliminates natural enemies, as is evident from comparative studies on diversity of natural enemies between organic (with high diversity index) and pesticide-treated conventional tea gardens[15,18,27]. Protection, maintenance and enhancing efficacy of the existing population of natural enemies by practising ecofriendly operations and modification of pesticide use constitute the main objectives of conservation biological control (CBC)[28]. Plant diversification programmes help in habitat manipulation by means of intercropping with

shade trees and cover-cropping of vacant land in tea plantations, which may contribute to the process of CBC, by providing shelter, nectar, pollen[29], and alternative host/prey to the natural enemies[30].

As tea is a widely accepted beverage and as the demand for contaminant-free made tea is increasing, a key responsibility of tea growers shall be to increase the production of toxicant-free made tea devoid of harmful molecules. Such production of tea would largely owe its pest management to the silent but relentlessly working biocontrol agents (i.e. the natural enemies) active in regulation of tea pests.

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