DIVERSITY OF INSECT, MITE AND NEMATODE SPECIES IN TEA ECOSYSTEM OF BANGLADESH

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Abstract

The study was undertaken on insect, mite and nematode species diversity in Bangladesh Tea Research Institute (BTRI) main farm, Baraoora and Phulcherra tea estates in Sreemangal, Bangladesh from the period of 2014 to 2015. The study was done through direct field observations, sweeping net, food trap, sticky trap, light trap and Baermann Funnel method. A total of 71 insect, mite and nematode species was recorded belonging to 45 families under 14 orders. Among these, 25.35% species were foliar insects and mites, 26.76% soil insects and nematodes, 21.13% beneficial insects and 26.76% butterflies. All the foliar and soil insects, mites and nematodes were found as recognized pests of tea. The highest number of individuals among foliar pest was the red spider mite (*Oligonychus coffeae*) and the lowest number was the coffee red borer (*Zeuzera coffeae*). Of the soil pests, 77.47% species were termites, 14.33% nematodes, 4.86% field cricket, 2.63% mole cricket and 0.72% cockchafer grub. Regarding the soil pests, live wood termite (*Microtermes obesi*) was the highest and dagger nematode (*Xiphinema* sp.) was the lowest in number. One species of foliar insect, looper caterpillar (*Hyposidra infixaria*) and three species of nematodes, *viz*. reniform nematode (*Rotylenchulus* sp.), ring nematode (*Criconemoides* sp.) and dagger nematode (*Xiphinema* sp.) were recorded for the first time as tea pest in Bangladesh. In case of beneficial insects, 81.49% species were predators, 16.73% parasitoids and 1.78% parasites. Lady bird beetle (*Micraspis discolor*) was the highest in number and anthocorids (*Anthocoris* sp.) were the lowest. Nineteen species of butterflies were found. Of the observed butterflies, lemon emigrant (*Catopsilia pomona*) was the highest and large oakblue (*Arhopala amantes*) was the lowest in number. According to pest status, tea mosquito bug, red spider mite, thrips, looper caterpillar, live wood termites, root knot nematode and root lesion nematode were major, and the rest of those were occasionally regarded as minor pest. The population of most of the pest species was higher in peak cropping season (April-November), whereas the lowest population was recorded in off season (December-February). According to diversity indices, the diversity of foliar pest was higher than the other groups and the foliar pest was more evenly distributed in comparison to soil, beneficial insects and butterflies.

Key words: Biodiversity, insects, mites, nematodes, tea ecosystem.

INTRODUCTION

Tea is an important non-alcoholic health beverage and cash crop of Bangladesh. It is a long established plantation crop of enormous economic importance to Bangladesh meeting the entire domestic demand as well as export. Now it is one of the largest agro-based industries in the country. There are 162 tea estates producing 66.35 million kg of made tea (Anonymous 2016). There are 15 small holders and 498 small growers in Panchagarh district. Tea is also grown at Bandarban, Khagrachari and Rangamati in Chittagong Hill Tracts as small holders (34) producing 6592 kg of made tea (Anonymous 2015).

Bangladesh tea is grown in the three fairly divergent ecological zones of category, namely (i) Surma valley in greater Sylhet, (ii) Halda valley in Chittagong and (iii) Korotoa Valley in Panchagarh districts. The Surma valley is again subdivided into six valley circles, *viz*. North Sylhet, Juri, Lungla, Balisera, Monu-Doloi and Luskerpore (Sana 1989, Alam 1999, Ahmed 2005).

Tea ecosystem has a great influence on the biodiversity of various flora and fauna. This ecosystem is a complex agro-ecosystem comprising different types of biotic flora and fauna like tea plant, shade tree, other ancillary crops, insects, mites, diseases, soil microorganisms, birds, reptiles, amphibians etc. along with various abiotic elements including soil nutrients, sunshine, light, day length, rainfall pattern,

cloudiness, wind velocity, temperature, relative humidity etc. (Sana 1989, Ahmed 2005). An extensive monoculture of a perennial crop like tea over an extensive and continuous area in an apparently isolated ecological zone in Bangladesh has virtually formed a stable ecosystem for widely divergent organisms. Besides the architecture of tea plantation, variability of plant types and the systematic interaction of various agro techniques like weekly tea plucking rounds, presence of shade and ancillary crops, intercultural operations etc. impose a significant impact on subsequent colonizing, stabilizing and distribution of different pests.

Tea plants are subjected to the attack of insects, mites and nematode pests. All parts of the plant, leaf, stem, root, flower and seed are fed upon by at least one pest species. Of the production, about 15% of its crop could be lost per year by various pests particularly insects, mites and nematodes if adequate control measures are not taken. Moreover crop losses to the extent of 50% or more may be inflicted by the advent of an epidemic or outbreak of specific pests in a particular season or tea estate. So far 25 insect, four mites and 10 nematode species have been recorded in Bangladesh tea (Sana 1989, Ahmed 2005). Due to climate change, pest infestation is increasing as well as pest status is changing. On the other hand, deforestation is resulting in the migration of forest pest to tea ecosystem (Antony *et al.* 2012). The indiscriminate use of synthetic pesticides has significant effect on the reduction of beneficial insect population resulting in pest resurgence and resurrection of minor pest to major one (Ahmed 2005). Natural biocontrol agents play an important role to regulate the pest population in tea ecosystem. Existence of more than one hundred species of indigenous natural biocontrol agents of tea pests including predators, parasites, parasitoids were recorded from the tea ecosystem (Borthakur *et al.* 2010).

The tea flowers are pollinated by insects. Tea is virtually self-sterile and almost entirely cross-pollinated. Supplementary pollination produces more, larger, and heavier capsules, better viability, and higher grades of seeds. Butterflies are considered to be an important bio-resource and pollinating agent for the conservation of natural gene-flow in plant kingdom. A butterfly acts as a strong indicator of any pollution or of any change in an ecosystem.

Considering the above fact, the present study was undertaken to know the biodiversity of insect, mite and nematode species in the tea ecosystem of Bangladesh. This knowledge can help to provide information regarding their status, feeding habit, habitat, seasonal abundance and plant-insect interaction, and to predict where and when infestation will occur, what extend they will become, and how long they will last. Ultimately, this information tends to take decision making in an integrated pest management programme in tea.

MATERIAL AND METHODS

Study area

The study was conducted in the Bangladesh Tea Research Institute (BTRI) main farm, Baraoora and Phulcherra tea estates of Balisera valley circle at Sreemangal upazila of Moulvibazar district located in the North-East of Bangladesh (Fig. 1). Sreemangal is located in between 24°08' and 24°28' north latitudes and in between 91°36' and 91°48' east longitudes with an area of 450.74 sq km. The climate of this area is considered to be sub-tropical monsoon with three distinct seasons: warm season (mid February to mid may), monsoon season (mid May to mid October) and cold season (mid October to mid February). The tea zones of Sreemangal experience dry season from November to April while the rainy season continues from May to October and above 80% of annual rainfall is obtained during June-September. Under Bangladesh condition it is observed that about 1400 mm of annual rainfall is a critical limit and the monthly mean temperature < 18.33^0 and > 29.44^0C seem unfavourable for tea (Ahmed 2005, Sana 1989).

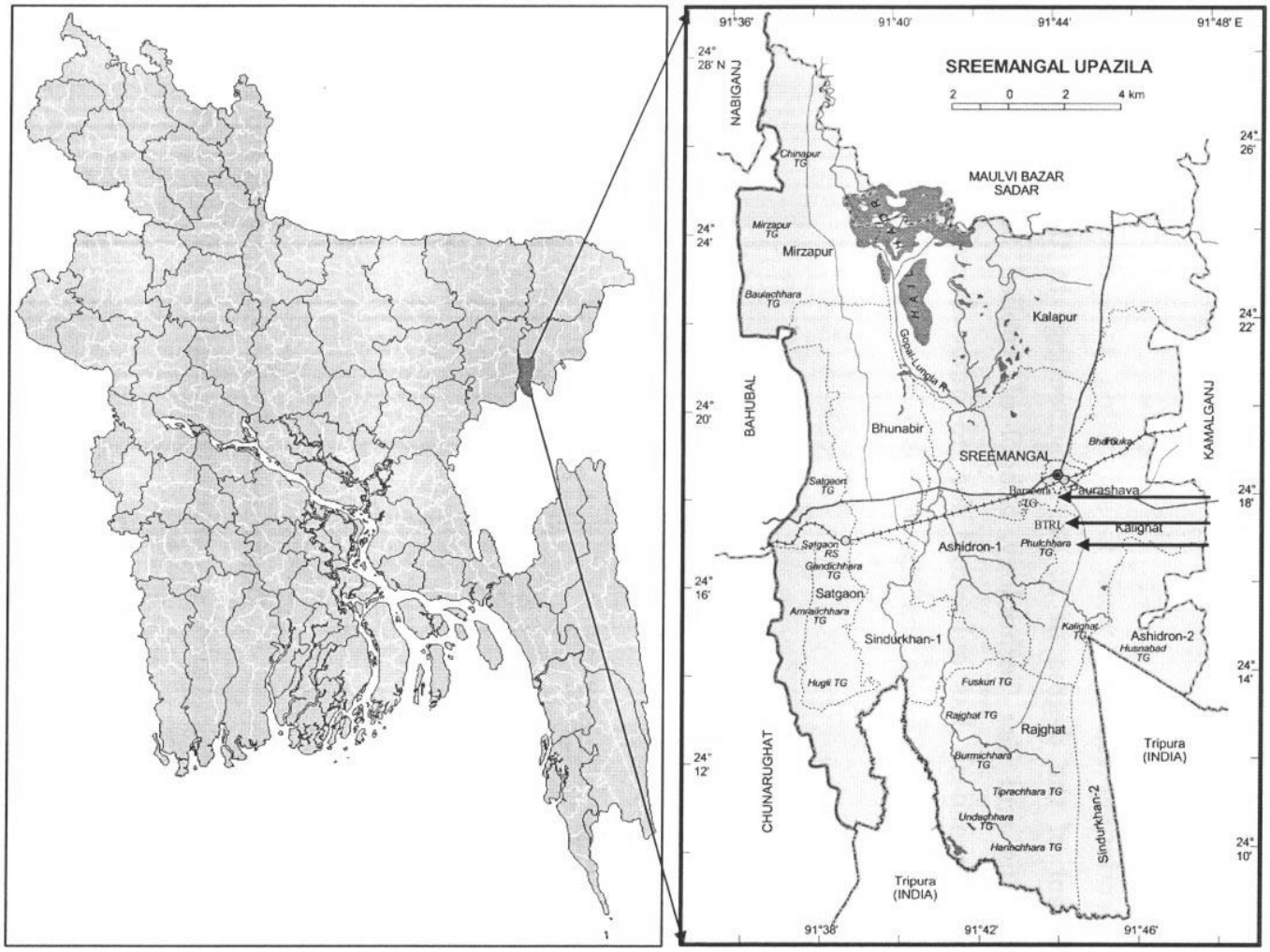

Fig. 1. The locations of the study area (source: Banglapedia 2003): *arrow marks indicating the three study locations at Sreemangal upazila.

Soil is highly weathered and extremely acidic with low fertility. Texturally the soil is predominantly loamy. Topography may be divided into three units, (i) Tillah or low hills-upto 90 m in height, about 32% of tea land is Tillah which is suitable for tea, but subjected to water stress and erosion; (ii) High flat- which are the higher valleys constitute about 45% of the land, 6-9 m above the plain and dissected by narrow valleys created by water erosion, soils are suitable for tea cultivation; and (iii) Low flat- which are the valley floor and constitute about 23% of tea land, top soil may be relatively rich in organic matter but subjected to water logging (Alam 1999, Sana 1989).

Observation technique

Data were collected through direct field observations during the period between January 2014 and December 2015. Field observations were made at monthly intervals. Data were collected at early morning, mid-day, late afternoon and night in a day. Collected insect species were immediately kept in a jar with chloroform and carried to the Entomology laboratory of BTRI. Morphological characteristics of the collected insect species were studied under a stereomicroscope (40x) for taxonomic identification. For the identification of plant parasitic nematodes, their morphological characteristics were studied under a trinocular compound microscope (1000x) with camera facilities. Photographs were taken with a

digital semi-SLR camera (canon SX 40HS) in order to confirm the identification. To identify insect, mite and nematode species, Ahmed (1997, 2005), Bashar (2013, 2014), Bingham (1907), Chen and Chen (1989), Evans (1992), Imms (1957), Mai and Lyon (1975), Mian (1998), Ross (1956) and Sana (1989) were followed. Already identified species placed in Entomology Laboratory, Bangladesh Tea Research Institute (BTRI) helped a lot in the process. The study period was divided into four seasons, viz. off season (December-February), early cropping season (March-May), peak cropping season (June-September) and late cropping season (October-November). Sampling was done in nursery, young tea (≤5 years) and mature tea (>5 years) areas. The relative abundance of some pest species was estimated on the basis of Economic Threshold Level (ETL) described by Mamun *et al.* (2014).

The Shannon-Wiener (1949) index and Simpson (1949) index of diversity and Evenness (quantifies how numerically equal the community is) of species in the study area were also calculated. The using formulas are:

$$\text{Simpson's Index of diversity, } D = 1 - \text{sum } (P_i^2)$$

$$\text{The Shannon-Wiener Index, } H = - \text{sum } (P_i \ln[P_i]) \text{ (natural log)}$$

$$\text{Evenness, } E = \frac{H}{\ln(S)} \text{ (natural log)}$$

Where,

$$P_i = \frac{\text{No. of individuals of a species}}{\text{Total no. of individuals of all species from the same group}}$$

S = No. of species from the same group observed

Systematic index with order, family, scientific name, common name, population status, feeding habit etc. were provided. Status of the pest was categorized as major and minor according to Ahmed (2005) and Sana (1989).

Plot counting

Plot counting method was followed for estimating sessile and non-sessile insects. A total of 15 plots was selected during the study period. Each plot size was 10×10 m^2. For non-sessile insect, direct observation was made for individual counting in each plot. In case of sessile insect, 100 mature leaves and 100 shoots (two leaves and one bud) were selected randomly. Both mature leaves and shoots were observed under a stereomicroscope (40x) in the Entomology Laboratory of BTRI.

Sweeping net

For capturing flying insect and butterflies, a sweeping net was used. The sweeping net was 0.30 m diameter fitted with a cone size bag of fine mesh nylon mosquito net and a wooden handle of 0.90 m long. Randomly sweeping was made in different locations of the study area.

Food trap

Food traps were used for determining termite population. Five types of food traps, such as saw dust, tissue paper, dried tender bamboo sleeves; jute sticks and susceptible soft timber were used as food traps (Ahmed, 2014). These food traps were scatteredly placed over the soil surface in the plot of 10×10 m^2.

Sticky traps

For non-sessile insects, sticky traps (adhesive traps) were also used. Commercially available two types of sticky traps, such as yellow and blue sticky card traps were placed in the tea field at 10 m distance from each other. The traps were hanged at the canopy level of the tea plants with a bamboo stick. The traps were checked once a week.

Light trap

For collecting nocturnal insects, light trap was used. At night the collections were done by operating light trap (fluorescent tubes run from rechargeable 12V batteries) between 6.00 PM and 9.00 PM. The light was horizontally fixed on a bamboo pole and placed one m from ground. An engine oil coated polythene sheet was placed 15 cm below the light to stick insects. In order to prevent water entering in the traps, they were kept under permanent shade of a thatch.

Baermann Funnel method

For counting plant parasitic nematodes, soil samples were collected from rhizosphere of tea seedlings grown in poly tube from secondary nursery bed as well as young tea field using a soil-sampling auger at a depth of 23 cm and about 5 cm from the base of the plants. Baermann funnel method with some modifications (Mian, 1998) was followed to extract nematodes from the soil samples.

RESULTS AND DISCUSSION

A total of 71 species of insects belonging to 45 families under 14 orders (viz. five foliar insects, five soil insects, seven beneficial insects and one butterfly order) was observed. Of them, 86.82% species were foliar pests, 8.21% soil pests, 1.84% beneficial insects and 3.13% species butterflies (Tables 2-5).

Faunal composition

The foliar pests were grouped into two types: insects and mites. Three species represented mites and the rest of them belonged to insects. Among the foliar insects, the frequently observed species (n= 1541) was the thrips (*Scirtothrips dorsalis*) and the less frequent was the coffee red borer (*Zeuzera coffeae*). On the other hand, the frequently observed foliar mite species (n=5312) was the red spider mite (*Oligonychus coffeae*) and the less frequent was the pink mite (*Acaphylla theae*) (Table 2). In case of soil pests species, insects and nematodes were found. Of them, 77.47% species were termites, 14.33% nematodes, 4.86% field crickets, 2.63% mole crickets and 0.72% cockchafer grubs. The individual of live wood termite (*Microtermes obesi*) was the highest whereas dagger nematode (*Xiphinema* sp) was the lowest in number (Table 3). In the study area, 15 species of beneficial insects were recorded. 81.49% species were being predator, 16.73% parasitoid and 1.78% parasite. The highest number of beneficial insects belonged to the lady bird beetle (*Hippodamia convergens*) and the lowest number to the anthocorids (*Anthocoris* sp.). Among the beneficial insects, the beetles (Coleoptera: Coccinellidae) were dominant (Table 4). A total of 19 species of butterflies belonging to five families under Lepidoptera order was observed. The butterflies of Pieridae family were predominant. Among them, the highest number of butterfly species was lemon emigrant (*Catopsilia pomona*) and the lowest was large oakblue (*Arhopala amantes*) (Table 5).

Seasonal abundance of insect species

Seasonal abundance of tea pests varied to a greater extent. The populations of major pests were present throughout the year. *Helopeltis* sp. invasion was found between April and August and again from October to the end of November, while the occurrence of red spider mite was observed between March and June and again from September and November. Thrips was prevalent during the end of February to July and again from the middle of September to the end of November. On the other hand, looper caterpillar was found during February-March and June-September. In case of termite, population started to increase from the months of November to April. It was found that nematode population was higher during April-September. Occurrence of major pests was also found overlapping in the next generation under prevailing climatic conditions

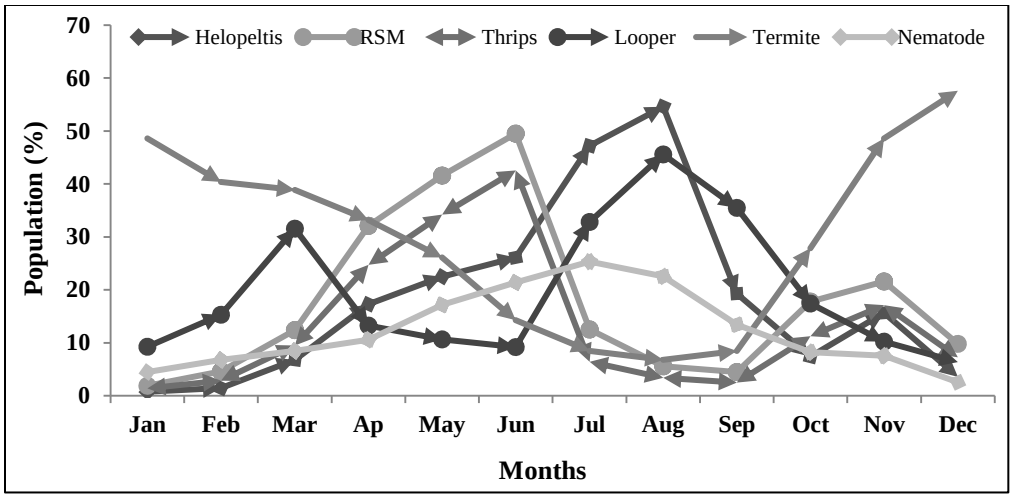

Fig. 2. Seasonal abundance of major insect, mite and nematode species in tea ecosystem.

Status and relative abundance of insect species

All the foliar and soil insects, mites and nematodes were found as recognized pests of tea among the identified species. Overall relative abundance showed that 86.82% species were foliar pests, 8.21% soil pests, 1.84% beneficial insects and 3.13% species were butterflies (Fig. 3).

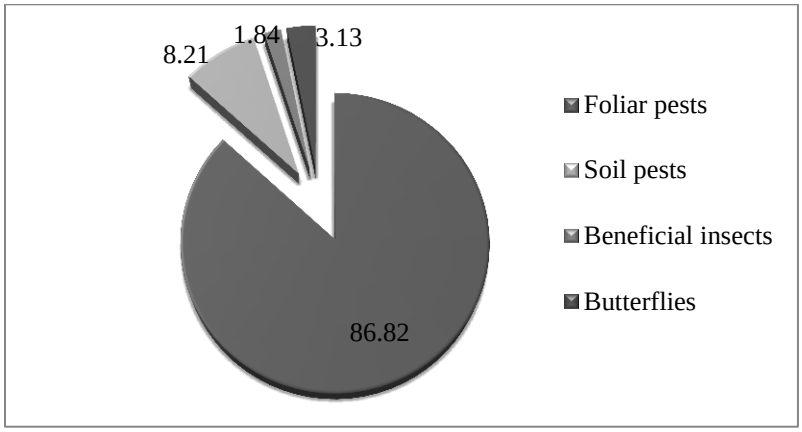

Fig. 3. Relative abundance of insect, mite and nematode species in the study area.

The relative abundance of individual pest population, i.e. low, medium and high depends on their degree of infestation and feeding capacity (Table 1). According to pest status, tea mosquito bug, red spider mite, thrips, looper caterpillar, live wood termites, root knot nematode and root lesion nematode were major pests and rest of those were occasional regarded as minor pests. Pest populations were found high in peak cropping season and the beneficial insects also increased during that time. Whereas, butterflies abundant in the months of March-July and October-December.

Species diversity indices

The calculated values indicate that the diversity of foliar insects (Simpson's Index of diversity = 0.846 and Shannon-Wiener's Index = 2.335) was higher than the other groups observed (viz. soil insects, butterflies and beneficial insects). However, the foliar and soil insects were more evenly distributed (foliar insects = 0.808 and soil insects = 0.759) in comparison to butterflies and beneficial insects (Table 6).

Table 1. Relative abundance of individual pest species.

Name of the Pest	EIL	Relative abundance of individual pest species/plant		
		Low	Medium	High
Tea Mosquito Bug	5% shoot infestation	<5	5-10	>10
Aphids	20% shoot infestation	<25	25-90	>90
Thrips	3 thrips per shoot	<60	60-200	>200
Jassids	50 nymphs per 100 leaves	<30	30-100	>100
Looper caterpillar	4-5 looper per plant	<5	5-10	>10
Flush worm	5 infested rolls per plant	<5	5-10	>10
Leaf rollers	5 infested rolls per plant	<5	5-10	>10
Red spider mite	5 mites per leaf	<200	200-1000	>1000
Termites	10% bush infestation	<30	30-50	>50
Nematodes	7 nematodes per 10g soil	<7	7-15	>15

EIL= Economic Injury Level

Tea, a perennial and monoculture crop grown in apparently isolated ecological zone in Bangladesh has formed virtual and stable ecosystem for widely divergent organisms. In this study, 23 insects, three mites, eleven nematodes were identified as tea pests. Previously, 25 insects, four mites and 10 nematodes were identified by Ahmed (2005) and Sana (1989) in Bangladesh tea. In the present investigation, one species of foliar insect, looper caterpillar (*Hyposidra infixaria*) and three species of nematodes, *viz*. reniform nematode (*Rotylenchulus* sp.), ring nematode (*Criconemoides* sp.) and dagger nematode (*Xiphinema* sp.) were recorded first time as tea pest in Bangladesh. Climate change and habitat loss due to deforestation might have promoted migration of new pest species in tea. Indiscriminate use of synthetic pesticides has also negative impact on natural enemies resulting pest resurgence and resurrection of minor pest to major one (Ahmed, 2005). Thrips and Looper caterpillar were also found as major pests.

According to feeding habit, the identified species were found as sucking, defoliating, feeding, leaf rolling, cutting, boring and bark feeding with the highest percentage of foliar insect's species. These species are similar to the other tea growing regions of the world (Chen and Chen 1989, Das 1965, Hamasaki *et al.* 2008, Muraleedharan 2005).

Most of the pest species identified in the present study are under Lepidoptera and Hemiptera orders. Ahmed (2005) and Chen and Chen (1989) found that among the Arthropod pests, Lepidoptera is the largest order in tea garden containing 32% of the pest species followed by Hemiptera with 27%. The adaptations of insects, mites and nematodes have enabled them to attack every part of the tea plant and the maximum number of pests occur on foliage.

It was observed that seasonal abundance of tea pest varied to a greater extent. Availability of food, variety, age of plants and climate play an important role on population build up (Muraleedharan 2005). In peak cropping season, number of foliar pests and population were found high as well as the beneficial insects were also increased in that time. During this season climatic condition is suitable and food is relatively more available. Similarly, butterflies were found more in the flowering time of tea plant, shade trees and other forest plants in tea ecosystem. Insect populations were found low during off season. Because pruning operation was done in that time and food supply was limited. Among the 37 pest species, only tea mosquito bug, red spider mite, thrips, looper caterpillar, live wood termites, root knot nematode and root lesion nematode were found in all the study locations and caused a substantial crop loss in most of the time during the study period. In some cases, the individual population size was found more in minor pests. Whereas potential yield loss not only depends on population size but also on degree of infestation, feeding capacity, distributional pattern and seasonal abundance of individual pest species (Ahmed 1996).

Table 2. List of foliar pest species observed in three study locations at Sreemangal from January 2014 to December 2015.

Category	Order	Family	Scientific Name	Common Name	Individuals observed	Habitat	Feeding habit	Status
Insects	Hemiptera	Miridae	*Helopeltis theivora*	Tea mosquito bug	416	Young leaves, shoots	Sucking	Major
		Jassidae	*Empoasca flavescens*	Jassid	680	Young leaves, shoots	Sucking	Minor
		Aphididae	*Toxoptera aurantii*	Aphid	712	Young leaves, shoots	Sucking	Minor
		Pentatomidae	*Poecilocoris latus*	Tea seed bug	105	Flowers, seed, bud	Sucking	Minor
		Coccidae	*Coccus viridis*	Green scale	680	Leaves, shoots, stem	Sucking	Minor
			Chrysomphalus aonidum	Florida red scale	517	Leaves, shoots, stem	Sucking	Minor
	Thysanoptera	Thripidae	*Scirtothrips dorsalis*	Thrips	1541	Unopened & partly opened bud	Sucking	Major
	Lepidoptera	Geometridae	*Hyposidra infixaria*	Looper caterpillar	368	Young & mature leaves	Defoliating	Major
		Eucosmidae	*Lespeyresia leucotoma*	Flush worm	190	Two leaves & a bud	Feeding	Minor
		Gracilaridae	*Gracilaria theivora*	Leaf roller	104	Young leaves	Leaf rolling	Minor
		Psychidae	*Clania cramerii*	Bag worm	78	Leaves, shoots, buds	Cutting	Minor
			Clania sikkima	Faggot worm	39	Leaves, shoots, buds	Cutting	Minor
		Cossidae	*Zeuzera coffeae*	Coffee red borer	19	Stem	Boring	Minor
		Inderbelidae	*Inderbela theivora*	Bark eating borer	39	Stem	Bark feeding	Minor
	Hymenoptera	Formicidae	*Oecophylla amaragdina*	Nest building ants	855	Older leaves	Tier	Minor
Mites	Acarina	Tetranychidae	*Oligonychus coffeae*	Red spider mite	5312	Upper surface of the mature leaves	Sucking	Major
		Tenuipalpidae	*Brevipalpus phoenicis*	Scarlet mite	948	Under surface of the mature leaves	Sucking	Minor
		Triophyidae	*Acaphylla theae*	Pink mite	685	Surface of young & mature leaves	Sucking	Minor

Table 3. List of soil pest species observed in three study locations at Sreemangal from January 2014 to December 2015.

Category	Order	Family	Scientific Name	Common Name	Individuals observed	Habitat	Feeding habit	Status
Insects	Orthoptera	Gryllidae	*Brachypterypes portensus*	Field cricket	61	Stems, root, young plants	Cutting	Minor
		Gryllotalpidae	*Gryllotalpa Africana*	Mole cricket	33	Stems, root of young plants	Cutting	Minor
	Isoptera	Termitidae	*Microtermes obesi*	Live wood termite	293	Root, stem, stump	Feeding	Major
			Microcerotermes championi	Live wood termite	165	Root, stem, stump	Feeding	Major
			Odontotermes feae	Scavenger termite	71	Root, stem, stump	Feeding	Minor
			Odontotermes homi	Scavenger termite	119	Root, stem, stump	Feeding	Minor
		Rhinotermitidae	*Coptotermes heimi*	Live wood termite	325	Root, stem, stump	Feeding	Major
	Coleoptera	Scarabaeidae	*Melolontha melolontha*	Cockchafer grub	9	Root	Feeding	Minor
Nematodes	Tylenchida	Pratylenchidae	*Pratylenchus loosi*	Root lesion nematode	53	Root	Sucking	Major
		Hoplolaimidae	*Helicotylenchus* sp.	Spiral nematode	11	Root	Sucking	Minor
			Hoplolaimus sp.	Lance nematode	7	Root	Sucking	Minor
			Rotylenchulus sp.	Reniform nematode	9	Root	Sucking	Minor
		Heteroderidae	*Meloidogyne* sp.	Root-knot nematode	67	Root	Sucking	Major
		Tylenchidae	*Tylenchus* sp.	Citrus nematode	6	Root	Sucking	Minor
		Aphelenchoididae	*Aphelenchoides* sp.	Dwarf nematode	5	Root	Sucking	Minor
		Criconematidae	*Criconemoides* sp.	Ring nematode	7	Root	Sucking	Minor
		Tylenchulidae	*Paratylenchus* sp.	Pin nematode	6	Root	Sucking	Minor
		Belonolaimidae	*Tylenchorhynchus* sp.	Stunt nematode	5	Root	Sucking	Minor
	Dorylaimida	Longidoridae	*Xiphinema* sp.	Dagger nematode	4	Root	Sucking	Minor

Table 4. List of beneficial insect species observed in three study location at Sreemangal from January 2014 to December 2015.

Order	Family	Scientific Name	Common Name	Nature of action on target pest	Individuals observed	Host Plants	Target pests
Dictyoptera	Mantidae	*Mantis* sp.	Preying mantid	Predator	23	Tea	*Helopeltis*
Hemiptera	Reduviidae	*Euagoras plagiatus*	Reduviid bug	Predator	7	Tea	*Helopeltis*
	Anthocoridae	*Anthocoris* sp.	Anthocorids	Predator	5	Tea	Thrips
Neuroptera	Chrysopidae	*Chrysoperla carnea*	Chrysoperla	Predator	23	Tea	*Helopeltis,* Aphid, Mites, Thrips
		Mallada boninensis	Green lacewing	Predator	19	Tea	Red spider mite, *Helopeltis*
Coleoptera	Coccinellidae	*Micraspis discolor*	Lady bird beetle	Predator	49	Tea	Aphid, Mites
		Verania vincta	Verania beetle	Predator	17	Tea	Red spider mite
		Stethorus gilviforns	Stethorus beetle	Predator	12	Tea	Red spider mite
	Staphylinidae	*Oligota pygmaea*	Staphylinid beetle	Predator	19	Tea	Red spider mite
Hymenoptera	Braconidae	*Bracon hebetor*	Braconid wasp	Parasitoid	39	Tea	Flush worm
		Apanteles aristaeus	Apanteles	Parasitoid	8	Tea	Flush worm, Looper Caterpillar
	Eulophidae	*Sympiesis dolichogaster*	Eulophid wasp	Parasite	5	Tea	Leaf roller
Araneae	Oxyopidae	*Oxyopes* sp.	Spider	Predator	35	Tea	*Helopeltis,* Mites
Mesostigmata	Phytoseiidae	*Amblysieus herbicolus*	Phytoseiid	Predator	9	Tea	Mites
		Amblyseius longispinosus	Predatory mite	Predator	12	Tea	Red spider mite

Table 5. List of butterfly species observed in three study location at Sreemangal from January 2014 to December 2015.

Order	Family	Scientific Name	Common Name	Individuals observed	Individual (%)
Lepidoptera	Nymphalidae	*Euthalia lepidea*	Grey count	18	3.76
		Neptis soma	Sullied sailor	16	3.34
		Junonia atlites	Gray pansy	22	4.59
		Junonia lemonias	Lemon pansy	43	8.98
		Athyma perius	Common sergeant	18	3.76
	Danaidae	*Euploea core*	Common crow	41	8.56
		Danaus genutia	Common tiger	10	2.09
	Papilionidae	*Papilio polymnester*	Blue mormon	26	5.43
		Papilio polytes	Common mormon	46	9.60
		Graphium sarpedon	Common blue bottle	12	2.51
	Lycaenidae	*Chilades pandava*	Plains cupid	15	3.13
		Arhopala amantes	Large oakblue	9	1.88
		Remelana jangala	Chocolate royal	10	2.09
	Pieridae	*Eurima hecabe*	Common grass yellow	16	3.34
		Catopsilia pomona	Lemon emigrant	51	10.65
		Catopsilia crocale	Common emigrant	35	7.31
		Pieris brassicae	Large cabbage white	27	5.64
		Appias olferana	Striped albatross	43	8.98
		Hebomoia glaucippe	Great orange	21	4.38

Table 6. Species diversity indices according to insect groups.

Parameter	Foliar insects	Soil insects	Beneficial insects	Butterflies
Simpson's Index of diversity (D)	0.846	0.813	0.769	0.795
Shannon-Wiener Index (H)	2.335	2.236	1.776	2.072
Evenness (E)	0.808	0.759	0.656	0.704

Fifteen beneficial insects and nineteen butterfly species were found during the study period. In North-East India more than 100 species of beneficial insects were recorded (Borthakur *et al.* 2010). Bashar (2014) reported that 300 species of butterflies were found in Lawacherra national forest in 2002. The forest is nearby to the study area. Though the survey was done only in three tea estates, it is a matter of concern that their population is decreasing. Frequent use of pesticides and lack of adequate conservation technique might be the main reasons of population reduction of beneficial insects and butterflies in tea ecosystem. Human activities are more in tea ecosystem than forest areas which is also an important reason for low population of butterflies in tea ecosystem.

Tea cultivation in Bangladesh experiences diverse and complex insect species situation because it is being cultivated as mono crop adjacent to forest ecosystem. Different types of insects, mites and nematodes species are found in this study. Their interaction with ecology, seasonal abundance, distributional pattern, food habit is also understood which is very important to maintain stable biodiversity. Pesticides are integral part of pest management in tea. But, their indiscriminate use has detrimental effects on beneficial insects thereby disturbing the biodiversity and the balance in natural ecosystem. Non chemical methods of integrated pest management should be augmented. In case of chemical control, less toxic, selective pesticides should be preferred as much as possible, to maintain a stable biodiversity in tea ecosystem.

REFERENCES

Ahmed, M. 1996. Relationship between infestation intensity and crop loss by *Helopeltis* in Tea. *Tea. J. Bangladesh.* **32**(1 and 2): 20-30.

Ahmed, M. 1997. Tea termites of Sylhet and their distinctive morphological characteristics. *Tea J. Bangladesh.* **33**(1 and 2): 19-27.

Ahmed, M. 2005. *Tea Pest Management*. Evergreen Printing and Packaging. Dhaka. 101 pp.

Ahmed, M. 2014. Use of food traps for monitoring termite population in tea. *Tea. J. Bangladesh*. **43**: 10-14.

Alam, A. F. M. B. 1999. Profile of tea industry in Bangladesh. In: N. K. Jain (ed.). *Global Advances in Tea Science.* Aravali Books, New Delhi, India., pp. 1-22.

Anonymous. 2015. *Statistics on Bangladesh tea industry*. Project Development Unit (PDU), Bangladesh Tea Board, Sreemangal-3210, Moulvibazar, Bangladesh., pp. 26-30.

Anonymous. 2016. *Annual Bulletin of Statistics*. International Tea Committee (ITC). London, UK., pp. 48-54.

Antony, B., P. A. Sinu and A. Rahman. 2012. Looper caterpillar invasion in North-East Indian tea agro-ecosystem: Change of weather and habitat loss may be possible causes? *J. Tea Sci. Res.* **2**(1): 1-5.

Bashar, M. A. 2013. *Acharon-bichorone amader projapoti* (Bangla version). A pictorial view of different butterflies in Bangladesh., pp. 2-31.

Bashar, M. A. 2014. *Butterflies of Bangladesh: A broad approach for nature lovers*. Vol. 1. 1st ed. BCTF publications, Dhaka-1000. 514 pp.

Bingham, L. C. T. 1907. *The fauna of British India*. Taylor and Francis, London. **2**: 282-471.

Borthakur, M., A. Rahman and S. Sarmah. 2010. Pest management in tea in North East India. *Bul. UPASI Tea Res. Found.* **55**: 10-18.

Chen, Z and X. Chen. 1989. An analysis of the world tea fauna. *J. Tea Sci.* **9**: 13–22.

Das, G. M. 1965. Pests of tea in North East India and their control. *Memorandum No. 27*. Tocklai Tea Research Institute, Tea Research Association, Jorhat, Assam, India., pp. 169-73.

Evans, G. O. 1992. *Principles of Acarology*. CAB International, Willingford: Cambridge, UK. 563 pp.

Hamasaki, R. T., R. Shimabuku and S. T. Nakamoto. 2008. *Guide to insect and mite pests of tea (Camellia sinensis) in Hawaii.* Cooperative Extension Services/CTAHR, University of Hawai, manoa, Honolulu, Hawaii., pp. 1-15.

Imms, A. D. (Revised by Richards, O.W. and Davies, R.G.). 1957. *A General Textbook of Entomology*. Methuen, London., pp. 1-1354.

Mai, W. F. and H. H. Lyon. 1975. *Pictorial Key to Genera of Plant Parasitic Nematodes*. Cornel University Press, Ithaca, NY. 219 pp.

Mamun, M. S. A., M. Ahmed and S. K. Paul. 2014. Integrated approaches in tea pest management for sustainable tea production. *Proc. Workshop on Tea Production Technology Updated.* Bangladesh Tea Research Institute, Sreemangal, Moulvibazar and Krishi Gobeshona Foundation, BARC Campus, Dhaka., pp. 18-32.

Mian, I. H. 1998. *Introduction to Nematology*. IPSA, Gazipur, Bangladesh., pp. 29-66.

Muraleedharan, N. 2005. Tea insects, ecology and control. In: D. Pimental (ed.). *Encyclopledia of pest management*. CRC press, India., pp. 672-674.

Ross, H. H. 1956. *A Textbook of Entomology*. John Wiley and Sons, Inc., New York., pp. 203-403.

Sana, D. L. 1989. *Tea Science*. Ashrafia Boi Ghar, 36, Bangla Bazar, Dhaka, Bangladesh., pp. 120-197.

Shannon, C. E. and W. Wiener. 1949. *The mathematical theory*. University of Illinois press, Urbana, USA. 117 pp.

Simpson, E. H. 1949. *Measurement of diversity*. *Nature*. **163**: 688.