Project ID: 337

Competitive Research Grant

Sub-Project Completion Report

On

Integrated Pest Management (IPM) approaches to major pests of tea for sustainable tea production

Project Duration
May 2017 to September 2018

Bangladesh Tea Research Institute (BTRI)
Srimangal-3210, Moulvibazar
&
Bangladesh Tea Research Institute
Panchagarh Sub Station

Submitted to
Project Implementation Unit-BARC, NATP 2
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

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Project Implementation Unit
National Agricultural Technology Program-Phase II Project (NATP-2)
Bangladesh Agricultural Research Council (BARC)
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Bangladesh

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Published in: September 2018

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Acronyms

BARC	=	Bangladesh Agricultural Research Council
BTB	=	Bangladesh Tea Board
BTRI	=	Bangladesh Tea Research Institute
Co-PI	=	Co-Principal Investigator
CRD	=	Completely Randomized Design
CRG	=	Competitive Research Grant
DMRT	=	Duncan's Multiple Range Test
DSK	=	Deep Skiff
ETL	=	Economic Threshold Level
FAO	=	Food and Agriculture Organization
GDP	=	Gross Domestic Product
GoB	=	Government of Bangladesh
HAT	=	Hours After Treatment
IPM	=	Integrated Pest Management
LoA	=	Letter of Agreement
LP	=	Light Pruning
LSK	=	Light Skiff
MSK	=	Medium Skiff
N/A	=	Not Applicable
NATP	=	National Agricultural Technology Program
PCR	=	Project Completion Report
PI	=	Principal Investigator
PIU	=	Project Implementation Unit
RCBD	=	Randomized Completely Block Design
UPASI	=	United Planters' Association in South India
USAID	=	United States Agency for International Development

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Executive Summary

Tea is a major cash crop as well as an export commodity of Bangladesh meeting almost the entire domestic demand of this cheapest health beverage. Tea plants are subjected to the attack of several insect, mites, nematodes, fungal pathogens and weeds. Thus, tea production is greatly hindered due to different arthropod and non-arthropod pests. Management of pests, diseases and weeds is an important operation for sustainable tea cultivation. To combat these problems different groups of chemical pesticides like organochlorine, organophosphate, pyrethroids, carbamates and some unclassified group have been using in the tea fields since 1960. Chemical pesticides have been using for a long time, but have serious drawbacks, such as direct toxicity to beneficial insects, fishes and human being; pesticide induced resistance, health hazard and increased environmental, social costs and undesirable pesticide residue in made tea. Therefore, managing these pest populations within economic threshold level is important for which application of pesticides becomes imperative in Integrated Pest Management (IPM) system. Unfortunately, little research work has been done on the cultural control, bio-control, resistant agro-types, bio-pesticides or any other IPM approaches against major insect pests of tea within the frame work of pest management. So, attempts were made to evaluate different components of integrated pest management (IPM) strategy for the four major pests of tea i.e. tea mosquito bug, red spider mite, thrips and looper caterpillar in tea in Bangladesh. A sub-project entitled "Integrated Pest Management (IPM) Approaches to Major Pests of Tea for Sustainable Tea Production" under Competitive Research Grant (CRG) of NATP-2 of PIU, BARC was initiated by Bangladesh Tea Research Institute to minimize the load of synthetic pesticides through a sustainable management practice along with consumers' safety by adopting IPM practices during May 2017 to September 2018. A pest management laboratory with modern scientific equipments and an IPM field laboratory have been established at BTRI Substation, Panchagarh. A series of experiments were carried out to develop integrated pest management (IPM) strategy for the major four insect pests of tea in Bangladesh during May 2017 to September 2018 at Bangladesh Tea Research Institute (BTRI) Sub Station, Panchagarh and BTRI Main Farm, Srimangal, Moulvibazar for multi-location trial. Data were collected regularly following respective method and analyzed by means using DMRT in MSTAT programme. Results revealed that light pruning (LP) significantly reduced the infestation of pests of tea other than skiff pruning. Seven days plucking round reduced the incidence of *Helopeltis*. Weeding significantly reduced the infestation of red spider mite in tea. Solar power light trap & yellow sticky trap captured greater number of thrips, *S. dorsalis* and moths of looper caterpillar. BT1, BT2 & BT15 clones were found less attacked by *Helopeltis*. BT5, BT6 & BT17 clones were found less attacked by Red spider mite. BT3, BT4, BT8, BT9, BT12, BT13, BT14, BT15, BT18, BT19, BT20 were found less infested by thrips. Fresh leaves, succulent stems, seeds of Akonda *(Calotropis procera),* Basok (*Adhatoda vasica*), Bishkatali (*Polygonum hydropiper*), Bhat (*Clerodendron infortunatum*), Burweed (*Xanthium strumarium*), Castor bean (*Ricinus communis*), Datura (*Datura metel*), Garlic (*Alium sativum),* Lantana (*Lantana camara*), Mahogani (*Swietenia mahagoni*), Nishinda (*Vitex negundo*) and Tobacco (*Nicotiana tabacum*) have strong insecticidal properties and can be used as an alternative to chemical pesticides. Bio-control agents *Bracon hebetor* as a larval parasitoid @ 5 adults/30 larvae is effective against Looper caterpillar infesting tea. Two microbial pesticides (entomopathogens) viz., *Metarhizium anisopliae* and *Pseudomonas fluorescens* @ 1.0 ml/L showed the toxic effect on red spider mite, *Oligonychus coffeae* infesting tea and significantly reduced mite population. Bacterial formulation of *Bacillus thuringiensis* showed the toxic effect on looper caterpillar in tea and significantly reduced the pest population. Therefore, strong based IPM techniques in tea such as Cultural (Plucking, Pruning & Weeding), Resistant clones, Mechanical (Solar power light traps, yellow & blue sticky traps), Botanicals (Indigenous plant extracts), Bio-control agent *Bracon hebetor* as larval parasitoid, entomopathogens against major pests of tea have been developed. This will eventually minimize pesticide use, thus reduce cost of production, and enhance environmental safety. Finally, an expert system of IPM as a valuable tool for the management of major pests of tea will be developed. Thus, the developed strong based IPM strategies of major pests of tea will be easily adopted by the planters in large scale for their high return of the production of pesticide free, high value commodities for domestic as well as export markets.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. **Title of the CRG sub-project:**

   Integrated Pest Management (IPM) Approaches to Major Pests of Tea for Sustainable Tea Production

2. **Implementing organization:**

   Bangladesh Tea Research Institute (An organ of Bangladesh Tea Board)

3. **Name and full address with phone, cell and E-mail of PI/Co-PI (s):**

   Principal Investigator: Dr. Mohammad Shameem Al Mamun, Senior Scientific Officer (Entomology), Bangladesh Tea Research Institute Sub Station, Bangladesh Tea Board, Dhakkamara, Panchagarh. Cell No: 01712119843, Email: kbdshameem@gmail.com

   Co-Principal Investigator: Md. Jahangir Alam, Scientific Officer, Entomology Division, Bangladesh Tea Research Institute, Srimangal, Moulvibazar. Cell No: 01723316421, Email: anikbau52@gmail.com

4. **Sub-project budget (Tk):**

   4.1. Total: Tk. 21,31,600.00 (Twenty One Lakh Thirty One Thousand Six Hundred Only)

   4.2. Revised (if any): N/A

5. **Duration of the sub-project:**

   5.1. Start date (based on LoA signed): 11 May 2017

   5.2. End date: 30 September 2018

6. **Justification of undertaking the sub-project:**

   Tea is a major cash crop as well as an export item of Bangladesh. Tea is a long established plantation crop of enormous importance to Bangladesh meeting almost the entire domestic demand of this cheapest health beverage. Now, there are 166 tea estates having about 61,605 hectare of tea plantation producing about 85.05 million kg of finished tea per annum with an average yield of about 1,530 kg per hectare in Bangladesh (BTB, 2017). Bangladesh tea sector contributes 0.11% of GDP.

   Tea plants are subjected to the attack of several insect, mites, nematodes, fungal pathogens and weeds. Tea plants are damaged by a number of pests causing important economic losses. Thus, tea production is greatly hindered due to different arthropod and non-arthropod pests. As a long-lived woody perennial and monoculture, tea provides a stable microclimate and a continuous supply of food for rapid buildup of phytophagous species that includes insects, mites and eelworms. Obviously the intensive monoculture of a perennial crop like tea over an intensive cultivated area during last 160 years had formed a stable tea ecosystem for widely divergent endemic or introduced pests. Moreover, a characteristic feature viz. the performance of shade trees, ancillary crops forests, an uniformity of cultural practices such as sequential pruning cycles, weekly plucking rounds, weeding, mulching etc. have a greater impact on the subsequent colonization, stabilization and distribution of pests. Each tea growing country has its own distinctive pests, diseases and weeds.

In Bangladesh tea, so far 25 insects, 4 mites and 10 species of nematodes have been recorded (Ahmed, 2005). Among them, Tea mosquito bug, Red spider mites and Termites are the major pests in mature tea plantation; while Thrips, Aphids, Jassids, Flushworms and Nematodes are the major pests in nursery and young tea plantation. About 10-15% of its crop could be lost by various pests particularly insects, mites and nematodes. It may be extended to as high as 50% when pest attack/ disease incidence is very severe.

Tea pests may be classified into three categories on the basis of the site of attack/infestation viz. *root pests* like nematode, termites, cockchafer grub; *stem pests* like red coffee borer, stem borer and *leaf pests* like tea mosquito bug, thrips, jassid, aphid, flushworm, looper caterpillar, leaf roller and all mite species (Mamun and Iyengar, 2010). Major insect pests of tea recorded in Bangladesh and their niches in the plant are shown in Fig. 1 & 2, respectively.

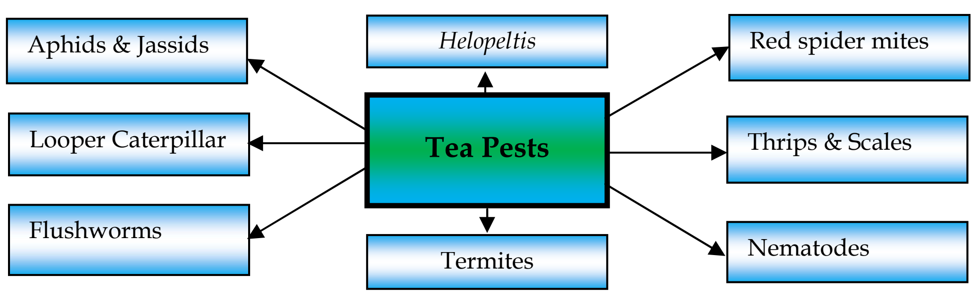


Fig. 1. Major insect pests of tea in Bangladesh

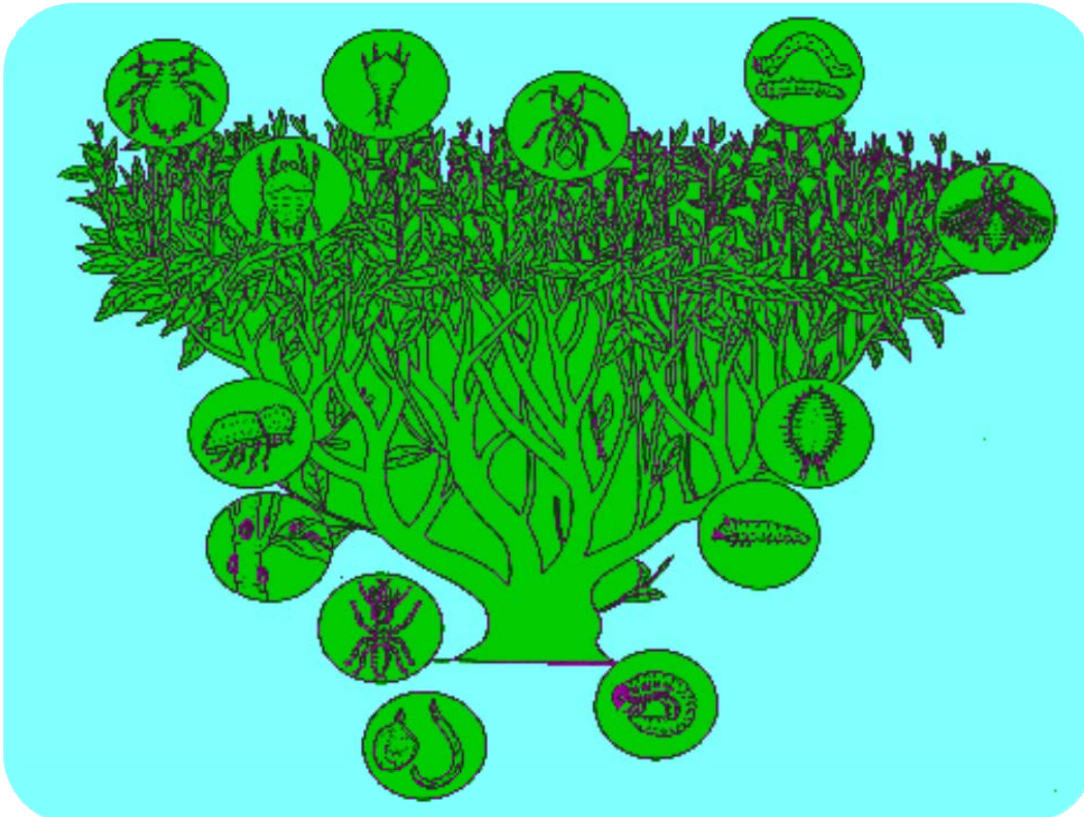


Fig. 2. The pests of tea, occupying different niches in the plant

Among them, the four major pests of tea, which are economically importance based on nature of damage and crop loss, are enumerated below:

Tea mosquito bug (*Helopeltis theivora* Waterhouse) (Hemiptera: Miridae) is the most serious pest of tea in Bangladesh and India. From the economic point of view, the pest is considered to be the major one causing damage to tea both in respect of quantity and quality. Both nymphs and adult cause damage by sucking the cell sap from succulent stems, buds and young leaves by inserting the proboscis (Plate 1).

Plate 1. Tea mosquito bug and their damage symptom

Red spider mite, *Oligonychus coffeae* Nietner (Acarina: Tetranychidae) is one of the major and serious pests of tea in Bangladesh. Hundreds of spider mites are found on the upper and undersurface of every tea leaf, together with thousands of eggs. Red spider mites are responsible for depredation of yield and debilitation of tea plants causing considerable crop loss (Plate 2).

Plate 2. Red spider mite and their damage symptom

Thrips, *Scirtothrips dorsalis* Hood. (Thysanoptera: Thripidae) is one of the major pests of tea causing appreciable loss in nursery, young tea and tea recovering after pruning. Thrips prefer unopened or partly opened young leaves and buds. Both adults and nymphs generally feed on them and cause lacerations of the tissues, which appear as large number of streaks. The leaf surface becomes uneven, curled and matty as feeding marks on the leaves. As a result, the growth of the affected leaves becomes stunted and immature leaves may look burnt (Plate 3).

Plate 3. Thrips and their damage symptom

Looper caterpillar, *Biston suppressaria* Guen. (Lepidoptera: Geometridae) is one of the defoliating pests of tea in Bangladesh especially in North Bengal region. It is the larval stage of moths. Young caterpillars feed on tender leaves, making punctures along the margin. With the increase in larval age, feeding rate also increases and the loopers consume the entire leaves, leaving only the mid ribs. The mature larva prefers older leaves and the bushes are completely stripped of leaves in severe attack (Plate 4).

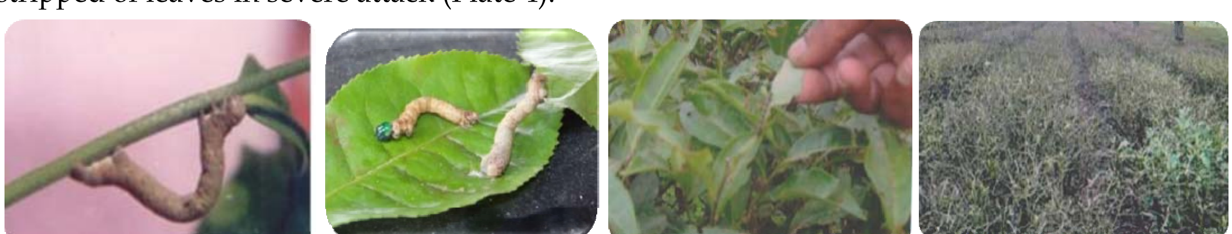


Plate 4. Looper caterpillar and their damage symptom

Management of pests, diseases and weeds is an important operation in sustainable tea cultivation. To combat these problems different groups of chemical pesticides like organochlorine, organophosphate, pyrethroids, carbamates and some unclassified group have been used in the tea fields since 1960. In this perspective, chemical control of pests is a dominating feature in Bangladesh tea (Alam, 1999). Different group of pesticides of different formulations are for the control of major pest pests of tea in Bangladesh (Mamun *et al.,* 2014). Chemical pesticides have been used for a long time, but have serious drawbacks, such as direct toxicity to beneficial insects, fishes and human being; pesticide induced resistance, health hazard and increased environmental, social costs and undesirable pesticide residue in made tea.

Therefore, managing these pest populations within economic threshold level is important for which application of pesticides becomes imperative in Integrated Pest Management (IPM) system. According to Food and Agricultural Organization (FAO, 1967) IPM is defined as "a pest management system, that, in the context of associated environment and population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury". As an alternative to these techniques, IPM has been encouraged. The following important components of IPM strategy may be considered in tea gardens (Fig. 3).

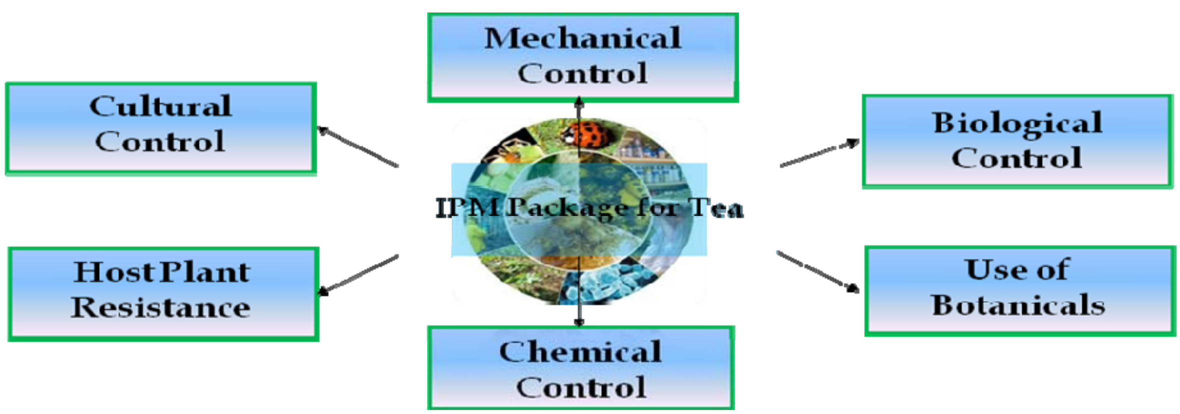


Fig. 3. Components of IPM package for major pests of tea

The important components of IPM strategy for major pests of tea are described below:

Cultural control

Cultural control apparently is the most economical and widely applicable method of pest control. In agricultural crops, selection of crop plant varieties, timing of planting and harvesting, irrigation management, crop rotation, and use of trap crops helps to reduce populations of weeds, microorganisms, insects, mites, and other pests. In tea culture, certain routine cultural practices such as plucking rounds, adjustment of pruning cycles, the modification of shade trees and timely weed control, proper irrigation and drainage, trap crop and use of balanced fertilizers may be effectively employed as pre-emptive measures of pest control (Sasidhar and Sanjay, 2000; Mamun and Iyengar, 2010). In this context, some important agronomic practices i.e. Plucking, pruning, weeding are being considered as cultural control options as environmentally safe, economical and renewable alternatives of chemicals for use in IPM programme in tea. This approach of pest control is cheap, risk free and often effective for long period without adverse effect on the environment.

Pruning: Pruning is one of the important cultural operations in tea husbandry. The influence of pruning cycle is mainly to provide suitable and favorable micro-climate for many tea pests. Pruning removes a large part of the pest populations present on the foliage and stems. Most foliar pests like Tea mosquito bug, Flushworm, Aphid, Jassid, Red spider mite, Scarlet mite and Purple mite are removed during pruning operation. When an attack by *Helopeltis* becomes unmanageable the affected bushes may be skiffed to reduce the damage. Generally, four year pruning cycle is adopted in tea culture in Bangladesh. In tea culture, the pruning is started from December to January.

Plucking: Plucking is one of the common phenomena in tea culture. This process has a significant impact on the removal or reduction of many foliar pests, viz. Tea mosquito bug, Thrips, Aphid and leaf folding caterpillars such as flushworms, leaf rollers and tea tortrix. The shorter the plucking rounds, the more removal of eggs, larvae and juvenile stages of pests from the bush will take place. Severely infested areas by tea mosquito bug could be earmarked and black plucked to retard the growth of its population.

Weeding: Field hygiene often has a pest control purpose. Field sanitation assumes significance in the management of several pests. Weeds offer excellent hiding places and serve as alternate hosts for *Helopeltis*. Growth of weeds and wild host plants in and around tea fields may be controlled which will help to reduce the incidence of this pest. Weeds like *Micania cordata, Bidens bitrnata, Emillia* sp., *Polygonum Chinese, Oxalis acetocella, Malastoma malabethricum* and *Lantana camara* offer excellent hiding places and serve as alternate hosts for the Tea mosquito bug. *Malastoma malabethricum* and *Urena lohata* weeds act as alternate host of Red spider mite. *Clerodendron infortunatum, Borreria hispida, Pouzolzia indica, Commelina bengalensis* and *Malastoma malabethricum* are the alternate host of Scarlet mite. *Ageratum conizoides, Borreria hispida, Commelina bengalensis, Pouzolzia indica* and *Oxalis corymbosa* are alternate host of Root knot nematode. So, growth of host plants in and around tea fields should be controlled and this will help to reduce the growth of pest population.

Mechanical control

Mechanical control is one of the important approaches to the integrated pest management programme. Mechanical control means controlling pests and diseases with the help of mechanical measures. This includes light traps, sticky traps and pheromone traps etc. The behavior of certain species of insects being attracted to light could be advantageously used in their management. Light trap is a cost effective and environment-friendly monitoring tool of Lepidopetran pests in tea plantations (Ahmed *et al.*, 2010). Fluorescent light traps and yellow pan traps are useful in attracting the moths of caterpillars and other insects. They can be set up the seasons of moths' emergence. These traps are useful for monitoring the activity of the pests and as a means of control.

Host plant resistance

Host plant resistance is perhaps one of the least expensive, safest and most practical ways of integrated pest management in tea plantation. Painter (1951) developed a classification of plant resistance phenomena which is still extremely useful and widely used. *Antixenosis* (non-preference) refers to plant properties which cause avoidance or reduced colonization by pests seeking food or oviposition site. *Antibiosis* directly or indirectly affects the pests in terms of survival, growth, development rate, fecundity etc. The final category, *tolerance,* refers to a reduced plant response (usually in terms of yield loss) to a given pest burden. The aim of plant resistance is to reduce the losses in yield caused by pests. Hairiness, waxiness, gummosis, color, palatability, necrosis, tissue hardness, toxins and nutritional factors are the mechanism of plant resistance to pests. Tea being a perennial crop, research on clonal selection and breeding is primarily aimed at the resistance to pests. China varieties are more susceptible to the attack of red spider mites while Assam cultivars are apparently more susceptible to the attack of pink mites. UPASI-3 and UPASI-12 are more susceptible to mite attack, whereas the leaves of UPASI-6 and UPASI-10 harbored few mites. China jats and TV1 clone are highly susceptible to *Helopeltis*. UPASI-17 is more susceptible to flushworms while UPASI-1 is the least infested. Soft wooded tea plants are known to be easily attacked by termites. Certain Sri Lankan clones like TRI 2024 and TRI 2025 should avoided in shot hole borer prone areas. Screening of tea clones for susceptibility or tolerance to major pests must become a prerequisite for the release of new clones. The quality and taste of tea is sensitive to chemical pesticides and so there is an increased interest in the use of eco-friendly methods as well as exploiting the inherent resistance present in the different cultivars to devise suitable IPM strategies.

Use of botanicals

Botanicals are natural plant products, which are environmentally safe, less hazardous, economic and easily available. Certain products derived from indigenous plants may be used for tea pest control. The pool of plants possessing insecticidal substances is enormous (Kabaru and Gichia 2001). Biopesticides belong to the so-called secondary metabolites, which include alkaloids, terpenoids, phenolics, and minor secondary chemicals. It is estimated that the plants may contain as many as 4,000,000 secondary metabolites. Over the past 50 years, more than 2,000 plant species belonging to different families and genera have been reported to contain toxic principles, which are effective against insects (Isman, 1997). Twenty-five of these plants species posses the characteristics required for an ideal botanical insecticide and are therefore more promising for use in tea pest control programmes (Radhakrishnan, 2005). Recently, Mamun and Ahmed (2011) reviewed some works on botanicals and their usage in tea pest management. They reported that botanicals like Basaka (*Adhatoda vasica*), Bazna *(Zanthoxylum rhetsa)*, Bhat (*Clerodendron infortunatum*), Bonkalmi (*Ipomoea maxima*), Bishkatali (*Polygonum hydropiper*), Burweed (*Xanthium strumarium*), Datura (*Datura metel*), Durba (*Cynodon dactylon*), Eucalyptus (*Eucalyptus globulus*), Ghora-neem *(Melia sempervirens)*, Hijal *(Barringtonia acutangula)*, Karanja *(Pongamia pinnata)*, Lantana (*Lantana camara*), Mahogoni *(Swietenia mahagoni)*, Marigold (*Tagetes erecta*), Neem *(Azadirachta indica)*, Nishinda (*Vitex negundo*), Pithraj (*Aphanamixis polystachya*), Sweet flag (*Acorus calamus*), and Tobacco (*Nicotiana tabacum*) have strong insecticidal properties and may be grown by the planters with minimum expense and extracted by indigenous methods. These botanical materials can be used as an alternative to chemical pesticides. This will be very helpful in minimizing the undesirable side effects of synthetic pesticides.

Biological control

Biological control is one of the important components of IPM in many crops. It involves the conservation, preservation and introduction of natural enemies like predators, parasitoids and pathogens for suppression of pests within tolerable levels. Among all the prospective tactics used in integrated control of insect pests, biological control has excelled all others. 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. More than 170 species parasites and predators have been recorded from the tea estates of India. The minor status of several pests such as aphids, scale insects, flushworms, leaf rollers and tea tortrix is due to the action of these natural enemies. Efforts towards the conservation and augmentation of natural enemies in the tea ecosystem, could offer significant advances in biological control programme in tea. Among them, ladybird beetles gain considerable significance in biological control in several agro ecosystems. The predatory nature of most of the 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; Babu and Ananthakrishnan 1993; Ara Begum *et al*., 2002). The predacious ladybird beetles are widely used in biocontrol as majority of them feed on different tea pests (Muraleedharan *et al.* 2001). The coccinellid beetle, *Stethorus aptus* (Kapur) has been newly recorded in the tea growing areas of north east region of India (Babu, 2012) which was earlier reported as a predator of *Panonychus citri* of citrus plant in China (Li *et al*., 1990). Ladybird beetles belonging to the genus *Stethorus* (Coleoptera: Coccinellidae) are obligate predators of tetranychid mites (Putman, 1955).

Microbial control

Use of entomopathogen is a new arena of research for integrated pest control in tea. Several microbes are pathogenic to tea pests. Fungi are the predominant pathogens found in RSM populations, and are unique in their ability to infect their hosts through the external cuticle. Formulations of the bacterial insecticides, *Bacillus thuringiensis* have been effectively used for the control of looper caterpillars, cutworms, flushworms and other lepidopterous pests. A local strain of *Beauveria bassiana* has been found effective against shot hole borer. Certain entomopathogenic fungi, *Verticillium lecani, Paecilomyces fumosoroseus* and *Hirsutella thompsonii* were evaluated and found effective against pink, purple and red spider mites. The microbial biocides as *Beauveria bassiana* (Gurusubramanian *et al*., 1999), *Verticillium leucanii* (Ghosh Hajra, 2002), *Paecilomyces fumoroseus* (Barua, 1983), *P. lilacinus* (Gurusubramanian, 2005), *Metarhizium anisopliae* (Debnath, 2004) are very effective and have been used widely against for the management of tea mosquito bug, tea mites, tea thrips. *Paecilomyces fumoroseus* formulation (Mycomite) developed by UPASI gave good control of the red spider mites when applied @ 2.0 kg/ha along with 2.0 kg crude sugar. Certain entomopathogenic fungi, *Verticillium lecanii, Paecilomyces fumosoroseus* and *Hirsutella thompsonii* were evaluated and found effective against pink, purple and red spider mites (Babu *et al*., 2008). *Metarhizium anisopliae* is the commonest entomopathogenic fungi that reduced the population of red spider mites, thrips and live wood termites in tea (Ahmed and Mamun, 2013).

Unfortunately, little research work has been done on the cultural control, bio-control, resistant agrotypes, bio-pesticides or any other IPM approaches against major insect pests of tea within the frame work of pest management. So, attempts were made to evaluate different components of integrated pest management (IPM) strategy for the major insect pests i.e. tea mosquito bug, red spider mite, thrips and looper caterpillar in tea in Bangladesh.

7. **Sub-project goal:** Minimizing the load of synthetic pesticides through a sustainable management practice along with consumers' safety
8. **Sub-project objective (s):**
    a. To develop integrated pest management (IPM) strategy by incorporating all the suitable methods in a compatible manner for the management of major pests of tea for sustainable tea production in Bangladesh.
    b. To introduce a permanent control measures with safety of natural enemies and reducing comparative use of synthetic pesticides to keep the surroundings healthy.
    c. To minimize the risk of pesticide residue in made tea through utilization of IPM practices and ensure consumers safety.
9. **Implementing location (s):** Srimangal, Moulvibazar & Panchagarh
10. **Methodology in brief:**

A series of experiments were carried out to develop integrated pest management (IPM) strategy for the major four insect pests of tea in Bangladesh during May 2017 to September 2018 at Bangladesh Tea Research Institute (BTRI) Sub Station, Panchagarh and BTRI main farm, Srimangal, Moulvibazar. Four major foliar pests of tea i.e. Tea mosquito bug, *Helopeltis theivora;* Red spider mite, *Oligonychus coffeae;* Thrips, *Scirtothrips dorsalis;* and Looper caterpillar, *Biston suppressaria* were selected for the study.

The following experiments were conducted under IPM strategies to achieve the objectives of the study under CRG sub project:

- Evaluation of some cultural control measures such as Plucking, Pruning & Weeding against *Helopeltis*, Red spider mite, Thrips and Looper Caterpillar in tea
- Evaluation of different traps such as solar light traps, yellow and blue sticky traps against Looper caterpillar, Thrips and *Helopeltis* in tea
- Screening of tea clones against *Helopeltis*, Red spider mite and Thrips in tea
- Evaluation of some indigenous plant extracts against *Helopeltis*, Red spider mite and Thrips in tea
- Predation capacity of biocontrol agents i.e. predators and parasitoids against Red spider mite and Looper Caterpillar in tea
- Evaluation of some commercial entomopathogens against Red spider mite and Looper Caterpillar in tea

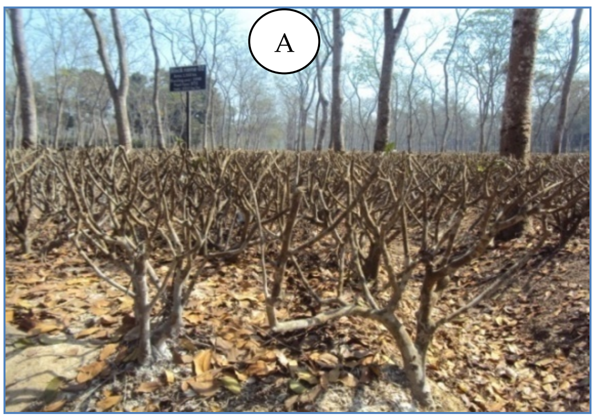
Work plan of the project:

Sl. No	Major activities	Year-1**													Y-2**
		Month													
		M	J	J	A	S	O	N	D	J	F	M	A	M	
1	Project planning	→													
2	Design and layout of IPM laboratory, Procurement of desired equipments and materials, Set up the equipments and materials in IPM laboratory		→	→											
3	Raising of tea plants in pots, collection & rearing of major insects pests of tea and available biocontrol agents in IPM laboratory.			→	→										
4	Evaluation of some cultural control measures			→	→	→	→	→	→	→	→	→	→	→	
5	Screening of tea clones against major insects				→	→	→	→	→	→	→	→	→	→	
6	Evaluation of different traps-light traps & sticky traps					→	→	→	→	→	→	→	→	→	
7	Predation capacity of biocontrol agents				→	→	→	→	→	→	→	→	→	→	
8	Evaluation of some indigenous plant extracts and commercial products				→	→	→	→	→	→	→	→	→	→	
9	Evaluation of some commercial entomopathogens				→	→	→	→	→	→	→	→	→	→	
10	Training and Workshop														→
11	Final Reporting														→

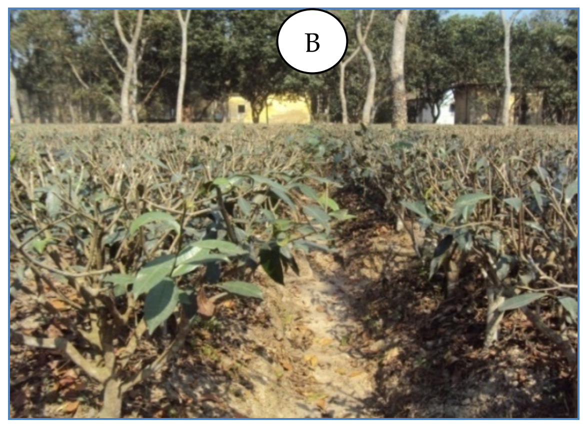
Expt. 1. Evaluation of some cultural control measures against *Helopeltis*, Red spider mite, Thrips and Looper Caterpillar in tea

1.1. Effect of pruning operations on the incidence of Helopeltis, Red spider mite, Thrips and Looper Caterpillar in tea

An experiment was conducted to determine the effect of different pruning operations on the incidence of red spider mites infesting tea at the Panchagarh sub station of Bangladesh Tea Research Institute during the period from January 2018 to June 2018. The experiment was set up following randomized complete block design (RCBD) with three replications. Different types of pruning operations i.e. Light Pruning (LP), Deep Skiff (DSK), Medium Skiff (MSK) and Light Skiff (LSK) were made in the respective plots according to BTRI (1986) and these different types of pruning cycle were considered as treatments (Plate 5). Untouched/unpruned section was considered as control. Each plot with 5 m x 5 m having thirty bushes was separated by two buffer rows of non-experimental tea. Systematic random sampling was made on the leaf count method. Pretreatment observation was made before pruning operation performs. Post treatment data on the infestation of pests were recorded at weekly interval.



Light Pruned (LP) Section



Deep Skiffed (DSK) Section

Medium Skiffed (MSK) section

Light Skiffed (LSK) Section

Plate. 5. Different types of pruning operations i.e. LP (A), DSK (B), MSK (C) and LSK (D) in the experiment.

The different pruning cycles with pruning height and scheduled followed in the present study are presented in **Table 1**.

Table 1. Pruning schedule of mature tea followed in the experiment.

Treatments (Pruning type)	Pruning height	Pruning time
T_1: Light Pruning (LP)	55 cm	1st week of December to last week of December
T_2: Deep Skiff (DSK)	65 cm	1st week of January to last week of January
T_3: Medium Skiff (MSK)	70 cm	Middle of January to 1st week of February
T_4: Light Skiff (LSK)	75 cm	Last week of January to whole month of February

1.2. Effect of plucking systems on the incidence of Helopletis

An experiment was carried out to know the effect plucking systems as a cultural control measures against *Helopeltis* in tea at Bangladesh Tea Research Institute (BTRI) substation, Panchagarh and small tea growers' field during January 2018 - June 2018 (Plate 6). The experiment was set up following Randomized Complete Block Design (RCBD). Four treatments such as T_1: 7 days interval of plucking, T_2: 10 days interval of plucking, T_3: 15 days interval of plucking, and T_4: 20 days interval of plucking were considered in the study. Each treatment was replicated thrice. Percent (%) shoot infestation by *Helopletis* were collected at weekly interval.

Plate 6. Experimental field at BTRI sub station and farmers' field, Panchagarh

1.3. Effect of weeding as a cultural measure for the control of red spider mite in tea

An experiment was carried out to know the effect of weeding as a cultural control measures against red spider mite in tea at Bangladesh Tea Research Institute (BTRI) substation, Panchagarh during January – June 2018 (Plate 7). The experiment was set up following Randomized Complete Block Design (RCBD). Four treatments such as T_1: Weeding, T_2: Weeding + Spraying, T_3: No weeding + Spraying and T_4: No weeding (control) were considered in the study. Each treatment was replicated thrice. Systematic random sampling was made on the leaf count method. Pretreatment observation was made before weeding operation performs. Post treatment observations on the infestation of mites were recorded at weekly interval up to 4 weeks.

Plate 7. Experimental plot on weeding for the control of pests of tea.

Expt. 2. Evaluation of different traps such as solar light traps, sticky traps against Thrips and Looper Caterpillar in tea

An experiment was carried out to evaluate the solar light traps and sticky traps as mechanical control measures against thrips and Looper Caterpillar in tea at Bangladesh Tea Research Institute (BTRI) main farm, Srimangal and BTRI substation, Panchagarh during 2017-2018 (Plate 8 & 9). The experiment was set up following Randomized Complete Block Design (RCBD) with three replications. Three treatments such as light trap (T_1), yellow sticky trap (T_2) and blue sticky trap (T_3) were considered in the study. Solar power light trap were used at night to attract the flying pests of tea i.e. thrips and moths of caterpillar. UV lights (220 V, 18 W, 5.2 nm; Philips) in the light traps were used in the experiment. The two light traps in the pair are to be placed approximately 600 m apart. Yellow and blue sticky trap were placed in the infested sections. Bright yellow or blue colour sunpack boards or corrugated plastic boards were cut into small pieces (12" x 12") and both sides coated with a thin film of a sticky adhesive. The Yellow sticky cards traps should be placed in the tea field above the bush canopy (plucking table) at an angle 60° facing against wind by securing them on top of bamboo sticks. 8-10 sticky traps per 1000 m^2 were used in the study. A total of 80-100 traps are required per hectare. Post treatment observations on the attraction of pests were recorded at weekly interval up to 4 weeks.

Plate 8. Solar power light traps for the control of pests of tea.

Plate 9. Yellow and blue coloured sticky traps for the control of pests of tea.

Expt. 3. Screening of tea clones against *Helopeltis*, Red spider mite and Thrips in tea

An experiment was carried out to screen the susceptibility of different tea clones against *Helopeltis*, Red spider mite and Thrips at the clonal block of BTRI main farm, Srimangal, Moulvibazar during May 2017 to September 2018 (Plate 10 & 11). Susceptibility to *Helopeltis*, Red spider mite and Thrips of different tea clones released by BTRI namely, BT1, BT2, BT3, BT4, BT5, BT6, BT7, BT8, BT9, BT10, BT11, BT12, BT13, BT14, BT15, BT16, BT17, BT18, BT19 and BT20 were evaluated against these pests infesting tea. These 20 BT clones were considered as treatments (T_1-T_{20}). The experiment was laid out in a Randomized Complete Block Design (RCBD) and replicated thrice. Each plot consisting of 20 plants. From the clonal block of BTRI, the population of different pests was estimated every month by sampling randomly observing and monitoring.

Plate 10. Experimental plots of clonal susceptibility of pests of tea.

Plate 11. Experimental clonal blocks of BTRI release clones (BT1-BT18) at BTRI main farm

Expt. 4. Evaluation of some indigenous plant extracts against *Helopeltis*, Red spider mite and Thrips in tea

An experiment was conducted both in the Entomology Laboratory and farm of Bangladesh Tea Research Institute (BTRI), Srimangal, Moulvibazar and BTRI Substation, Panchagarh. Fresh leaves, succulent stems, seeds of were Akonda *(Calotropis procera),* Basok (*Adhatoda vasica*), Bishkatali (*Polygonum hydropiper*), Bhat (*Clerodendron infortunatum*), Burweed (*Xanthium strumarium*), Castor bean (*Ricinus communis*), Datura (*Datura metel*), Garlic (*Alium sativum),* Lantana (*Lantana camara*), Mahogani (*Swietenia mahagoni*), Nishinda (*Vitex negundo*) and Tobacco (*Nicotiana tabacum*) collected locally from nearby areas of the campus (Table 2 & Plate 12).

Table 2. Plants evaluated for insecticidal activities against *Helopeltis,* and Red spider mite in tea

Common name	**Scientific name**	**Family**	**Plant parts used**
Akonda	*Calotropis procera*	Apocynaceae	Leaves, flowers
Basok	*Adhatoda vasica*	Acanthaceae	Leaves, flowers
Bishkatali	*Polygonum hydropiper*	Polygonaceae	Whole plant
Bhat	*Clerodendron infortunatum*	Lamiaceae	Leaves, flowers
Burweed	*Xanthium strumarium*	Asteraceae	Seeds
Castor bean	*Ricinus communis*	Euphorbiaceae	Seeds
Datura	*Datura metel*	Solanaceae	Fruits
Garlic	*Allium sativum*	Amaryllidaceae	Cloves
Lantana	*Lantana camara*	Verbenaceae	Twigs
Mahogani	*Swietenia mahagoni*	Meliaceae	Seeds
Nishinda	*Vitex negundo*	Lamiaceae	Leaves
Tobacco	*Nicotiana tabacum*	Solanaceae	Leaves

Each plant material was dried under shade and powdered by using electric grinder and pass through a 20 mesh sieve and kept in a 1 kg capacity polypropylene bag. 150 g of each powdered plant material were taken into a 1 litre capacity conical flask and 500 ml of distilled water was added to it and shaken for 8 hrs in a mechanical shaker and then kept it for 24 hrs. The extract was separated using fine muslin cloth and then filtered. The filtrate was collected in a 1 litre capacity conical flask and volume was made up to 500 ml. This was considered as stock solution (Plate 13 & 14). Three different concentrations of each plant extracts (5.0, 7.50 and 10.0%) were prepared with water from the stock solution.

Plate 12. Plants evaluated for insecticidal activities against *Helopeltis* and Red spider mite

Plate 13. Preparation of plant extracts and experimental set up at the Entomology laboratory, BTRI

Laboratory bioassay

The experiment was designed in Completely Randomized Design (CRD) with three replications. Different plants were considered as treatments. In case of *Helopeltis,* direct toxicity test by topical application method was conducted according to the method of Talukder and Howse (1993) with slight modification. One microliter (µl) of prepared solution was applied to the dorsal surface of the thorax of each *Helopelits* using a micropipette. Ten insects per replication were treated and each treatment was replicated thrice. In addition, the same numbers of insects were treated with solvent only for control. After treatment, the insects were transferred into 9 cm diameter petri dishes (10 insects/petri dish) containing tea shoots (two leaves and a bud). Insect mortalities were recorded at 24, 48 and 72 hours after treatment (HAT).

In case of red spider mite and thrips, detached leaf culture method of Helle and Sabelis (1985) with slight modifications was followed. Each concentration of plant extracts (2.5, 5.0 and 10.0%) was sprayed onto the adaxial (upper) and abaxial (lower) surfaces of leaf using glass atomizer. Original data were corrected by Abbott's (1987) formula.

Field evaluation

A field trial was conducted to evaluate the efficacy of different plant extracts against *Helopeltis,* red spider mite and thrips at BTRI main farm, BTRI Sub Station & Farmers' field at Panchagarh. Randomized complete block design (RCBD) with three replications was followed (Plate 15). Each plot in the experiment was separated by two buffer rows of non-experimental tea. Thirty bushes per replication were considered for each treatment along with unsprayed control. 25 kg of powder of collected dried plant/plant parts adding with 250 ml adjuvant (soak) were taken in 50 liter of water overnight; Extract and filter through fine cloth and add 500 liter of water; Spray the solution in one hectare area of tea plantation with a knapsack hand sprayer. In case of *Helopeltis,* One hundred shoots were randomly collected from the harvested shoots of each plot and infested shoots were counted. A shoot was considered as infested, if it contained even a single feeding spot.

In case of mite and thrips, pest populations were assessed at weekly interval by collecting 10 mature leaves at random from each block and from each leaf; mites/thrips were counted using mite brushing machine (Model-Leedom Engineering, USA) and a compound microscope. Effectiveness of the plant extracts was calculated by using Henderson & Tilton's (1955) formula.

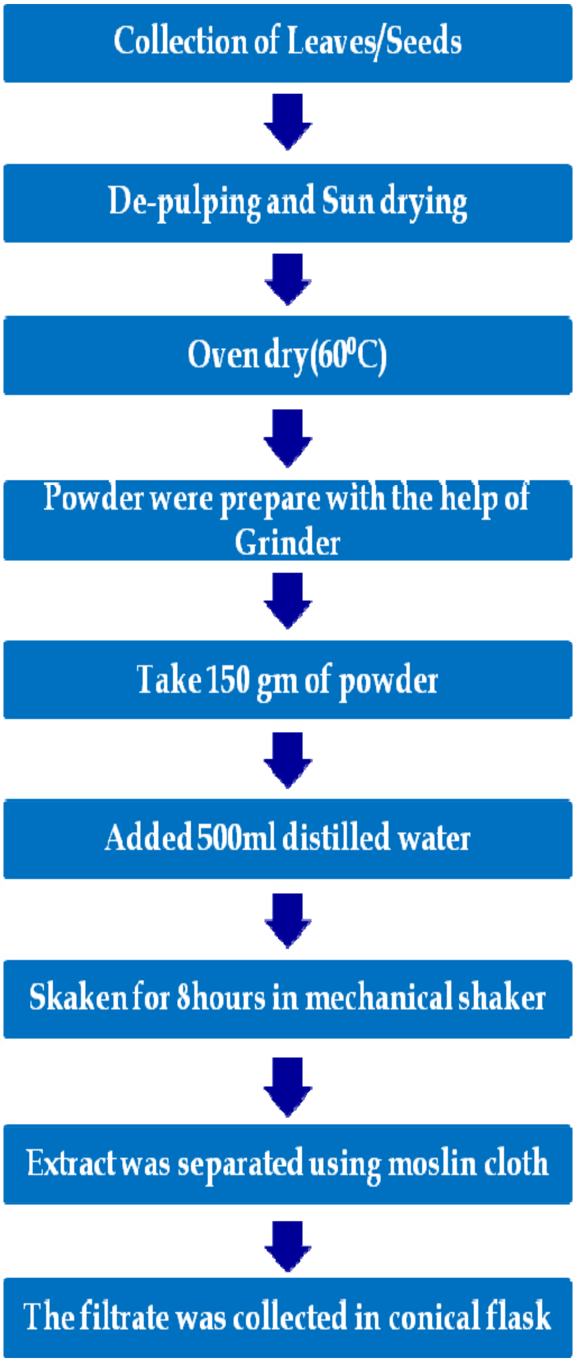


Plate 14. Flow chart of preparation of stock solution

Plate 15. Experimental plot of plant extracts at Srimangal and Panchagarh

Expt. 5. ***Potential effects of Bracon hebetor as a bio-control agent for sustainable management of Looper caterpillar***

An experiment was carried out to determine the efficacy of bio-control agents *i.e. Bracon hebetor* as a larval parasitoid against Looper caterpillar infesting tea in laboratory conditions. The caterpillar was collected from different sections of BTRI main farm and Bilashcherra Experimental Farm and reared in the Entomology Laboratory, BTRI. The *Bracon hebetor* @ 5 adults/30 larvae considered as treatment (T_1) with three replications (Plate 16). The source of the bio-control agents is Ispahani Biotech Limited. The potentiality of parasitoid on mortality of looper caterpillar was studied. Mortality data of looper caterpillar were collected at 24, 48, 72 hours after release (HAR) in the laboratory condition.

Plate 16. Laboratory experiment of *Bracon hebetor* at Entomology laboratory, BTRI, Srimangal

Expt. 6. Evaluation of entomopathogens against Red spider mite and Looper caterpillar infesting tea

6.1 Evaluation of two commercial entomopathogens (microbials) against red spider mite in tea

An experiment was carried out to evaluate the potentiality of two microbial pesticides (entomopathogens) viz., *Metarhizium anisopliae* and *Pseudomonas fluorescens* against red spider mite, *Oligonychus coffeae* infesting tea in laboratory and field condition at Entomology Laboratory and BTRI main farm, respectively. The Red spider mite was collected from different sections of BTRI main farm and reared in the Entomology Laboratory, BTRI on a susceptible tea clone, BT2 by following detached leaf culture method of Helle and Sabelis (1985) with slight modifications. The mite pests were reared on tea leaves in rectangular jars (9.5 cm x 7.5 cm x 20 cm).

Technical Name	Commercial Name	Manufacturer/Supplier Name
Metarhizium anisopliae	PEAK MOTI	Peak Chemical Industries Limited, India
Pseudomonas fluorescens	PEAK MONA	Peak Chemical Industries Limited, India

The entomopathogens @ 0.5, 1.0 & 1.5 ml/L, concentration, respectively are considered as treatments (T_1, T_2, T_3). The experiment was set up following CRD with three replications. Each concentration of entomopathogens (5.0, 1.0 and 1.5 ml/L) was sprayed onto the adaxial (upper) and abaxial (lower) surfaces of leaf using glass atomizer. Data were collected at 24 HAT, 48HAT, 72HAT in the laboratory condition. Field experiment was set up following Randomized complete block design (RCBD) with three replications (Plate 17). Each plot in the experiment was separated by two buffer rows of non-experimental tea. Thirty bushes per replication were considered for each treatment along with unsprayed control. Mite populations were assessed at weekly interval by collecting 10 mature leaves at random from each block and from each leaf; mites/thrips were counted using mite brushing machine (Model-Leedom Engineering, USA) and a compound microscope.

Plate 17. Experiment of two commercial entomopathogens (microbials) against red spider mite in tea

6.2. Evaluation of Bacillus thuringiensis against looper caterpillar in tea

A laboratory experiment was conducted to determine the bioefficacy of *Bacillus thuringiensis* (Antario 32K, Russell IPM Ltd., UK) against looper caterpillar at Pest Management Laboratory, BTRI sub station Panchagarh during May- July 2018. The dosage of the *Bacillus thuringiensis* (Antario 32K) was 1.0g, 1.5g, 2.0g per litre of water against looper caterpillar and were considered as treatments. Each treatment was replicated thrice. Mortality data were collected at 24 HAT, 48HAT, 72HAT in the laboratory condition.

Plate 18. Experiment on *Bacillus thuringiensis* against looper caterpillar in tea

11. Results and Discussion

Expt. 1. Evaluation of some cultural control measures against *Helopeltis*, Red spider mite, Thrips and Looper Caterpillar in tea

1.1. Effect of pruning operations on the incidence of Helopeltis, Red spider mite, Thrips and Looper Caterpillar in tea

Pruning has a significant effect on the incidence of foliar pests like *Helopeltis*, Red spider mite, Thrips and Looper caterpillar in tea. Result revealed that incidence of all the pest population was found the lowest in LP (1.24 - 3.21%) where the highest population in LSK section (18.33 – 22.41%) (Fig. 4).

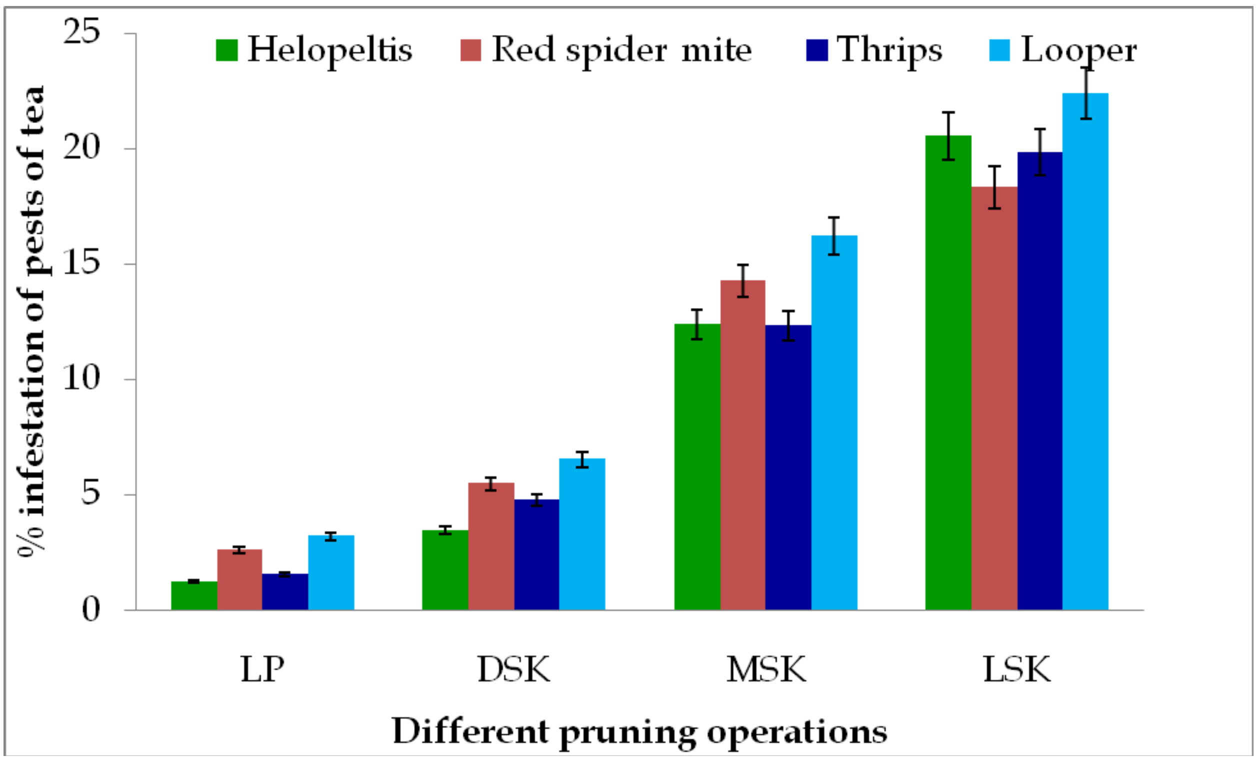


Fig. 4. Percent (%) infestation of pests of tea in different pruning cycles

Light Skiff (LS) helps remove unproductive shoots and eggs of *Helopeltis* and thrips (Rabindra, 2012). Prune the badly affected sections by *Helopeltis* before December ending. The effect of pruning has been demonstrated for *Xyleborus fornicatus* in Sri Lanka (Sivapalan, 1985). Similar works have been done for *Brevipalpus phoenicis* in Kenya and *Oligonychus coffeae* in North East India by Ratan (1992) and Das (1960), respectively. Dutta (1960) found that blister blight could be fully removed by doing LP operation in India. Ahmed and Mamun (2012) also found the similar trends in case of major pests of tea in Bangladesh. The harder or cleaner the pruning, the more leaves together with mites on them are removed and infestation remains low during the first year after pruning (Das, 1960). Harrison (1937) also concluded that tea left unpruned (skiffed) and carrying much old leaf and banjhi growth especially susceptible to red spider mite. It is to be noted that the incidence of red spider mite depending on the various factors, varies from country to country, circle to circle, estate to estate and even section to section in the same tea estate. So, Light pruning (LP) significantly reduced the infestation of pests of tea other than skiff treatments.

1.2. Effect of plucking systems on the incidence of Helopletis

Result revealed that the incidence of *Helopeltis* was found less in 7 days plucking sections than other treatments (Fig. 5). So, seven days plucking can help to control the pest populations of *H. theivora,* by removing either eggs deposited in the young stems or larvae present in the young leaves.

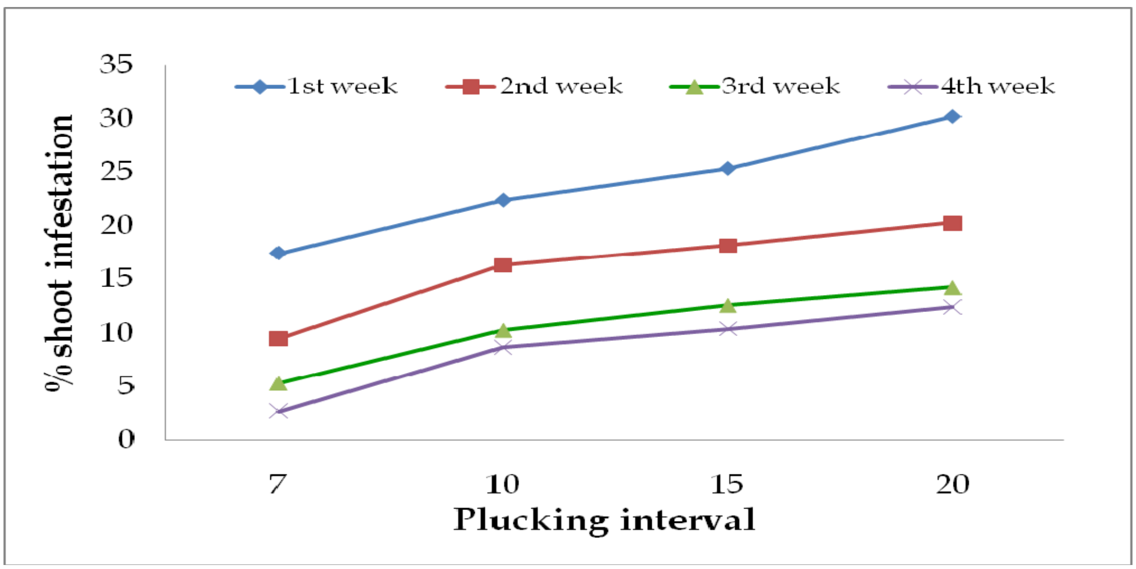


Fig. 5. Effect of plucking systems on the incidence of *Helopletis*

However, plucking intensity is important; the higher the intensity, the greater the reduction in pest population (Satake *et al.*, 2006). Intensive removal of stalks during plucking will reduce the incidence of this pest.

1.3. Effect of weeding as a cultural measure for the control of red spider mite in tea

Result revealed that weeding significantly reduced the infestation of red spider mite in tea. From the study it was found that weeding followed by spraying showed the highest reduction of mite (from 44.62 to 4.20) than the other treatments within the four weeks of time (**Table 2**).

Table 2. Effect weeding on the population of red spider mite in tea.

Treatment	Pre-treatment observation (No. of mites /10 mature leaves)	Post treatment observation (No. of mites/ 10 mature leaves)			
		1st week	2nd week	3rd week	4th week
T_1: Weeding	41.22	50.60±0.76b	58.20±0.81b	64.80±0.88b	73.40±0.94b
T_2: Weeding + Spraying	44.62	17.60±0.40d	13.60±0.36d	8.60±0.22d	4.20±0.16d
T_3: No weeding + Spraying	47.38	23.20±0.48c	30.20±0.56c	34.80±0.62c	44.20±0.72c
T_4: No weeding	38.34	72.80±0.94a	89.20±0.98a	105.60±1.24a	122.40±1.36a

Within column values followed by different letter(s) are significantly different by DMRT ($p>0.05$)

No weeding (T_4) plots suffer too much by red spider mites. It was found that areas, which are periodically cleaned of weeds, suffer less by red spider mite than unclean/weeded areas. Weed free tea cultivation reduces the infestation of red spider mite in tea. Saraiva *et al.* (2015) also control physic nut mite by adopting weed management practices. So, the growth of host plants, jungles, weeds in and around tea fields should be controlled and this will help reducing the growth of pest population infesting tea.

Expt. 2. Evaluation of different traps such as solar light traps, sticky traps against Thrips and Looper Caterpillar in tea

Result revealed that solar power light trap (T_1) captured greater number of moths (62.44/trap) of looper caterpillar, *B. suppressaria* at 7 days intervals (Fig. 6). These were gradually increased with the increase of time up to 21 days interval. On the other hand, yellow sticky traps (T_2) captured greater number of thrips, *S. dorsalis* (48.46/trap) than blue sticky traps (T_3) (36.42/trap) at 7 days interval (Fig. 7). These were gradually increased with the increase of time up to 21 days interval. However, the traps also captured a large number of non-target insects.

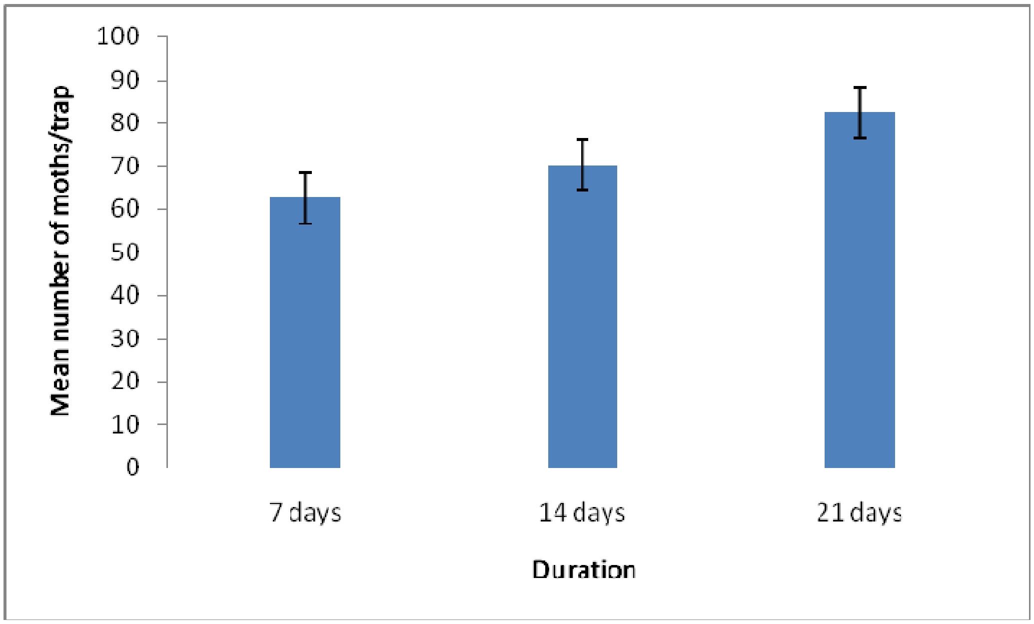


Fig. 6. Performance of solar power light trap against looper moth in tea

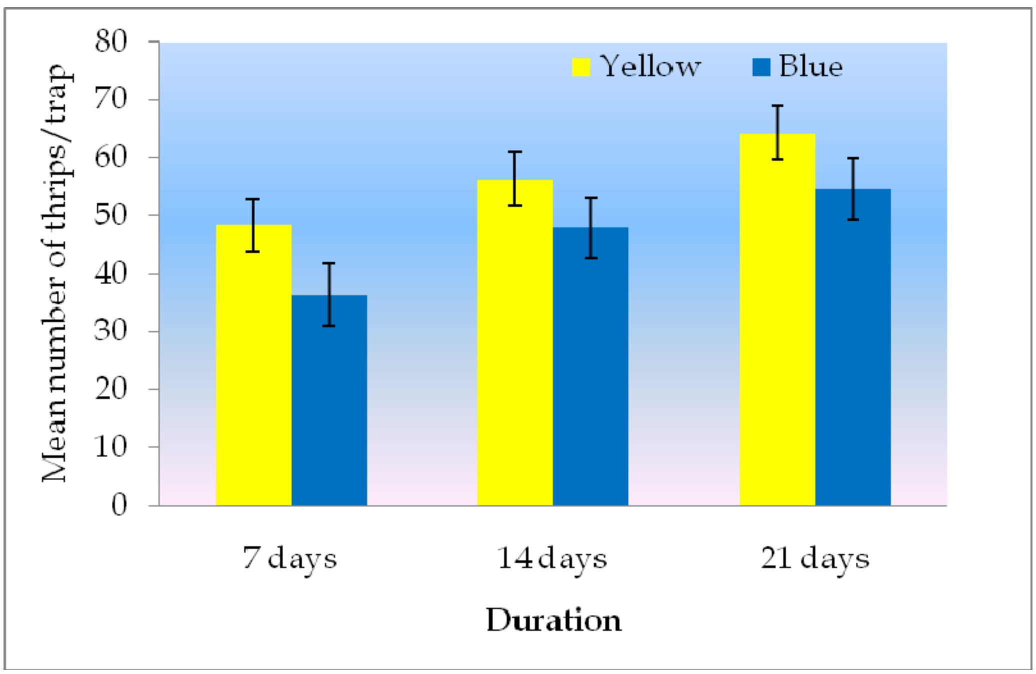


Fig. 7. Performance of yellow and blue sticky traps against thrips in tea

Expt. 3. Screening of tea clones against *Helopeltis*, Red spider mite and Thrips in tea

Susceptibility to BTRI released tea clones namely, BT1, BT2, BT3, BT4, BT5, BT6, BT7, BT8, BT9, BT10, BT11, BT12, BT13, BT14, BT15, BT16, BT17, BT18, BT19 & BT20 against major pests of tea i.e. *Helopeltis*, Red spider mite and Thrips were studied. The maximum pest population of *Helopeltis*, Red spider mite and thrips obtained from all the three replicates of each clone, are presented Fig. 8, 9 and 10**.** These numbers indicate the relative resistance or susceptibility of the clones to the respective pest infestation.

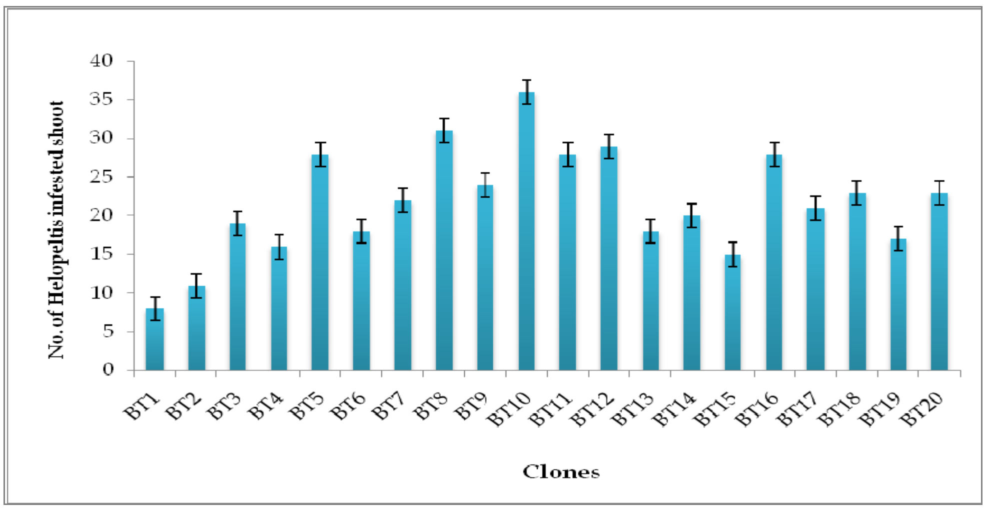


Fig. 8. Clonal susceptibility against Helopeltis

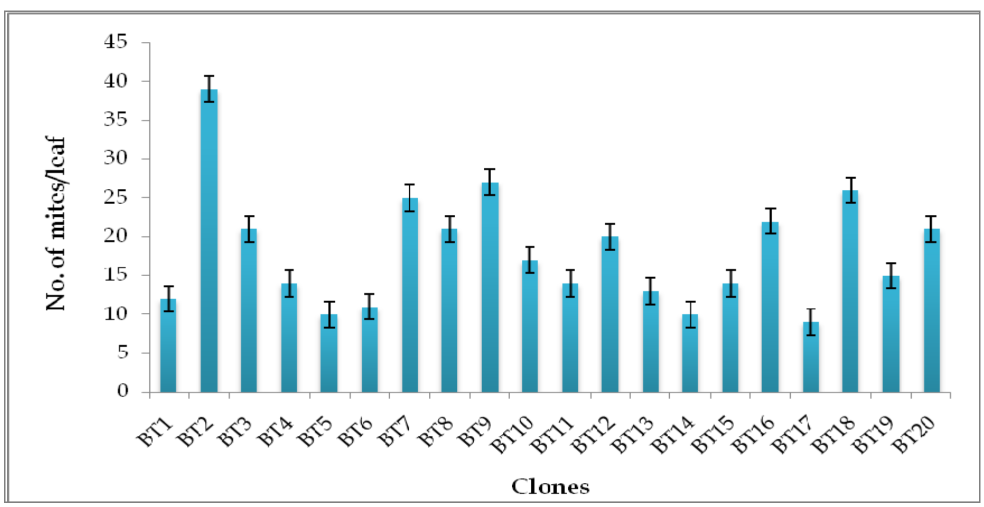


Fig. 9. Clonal susceptibility against Red spider mite

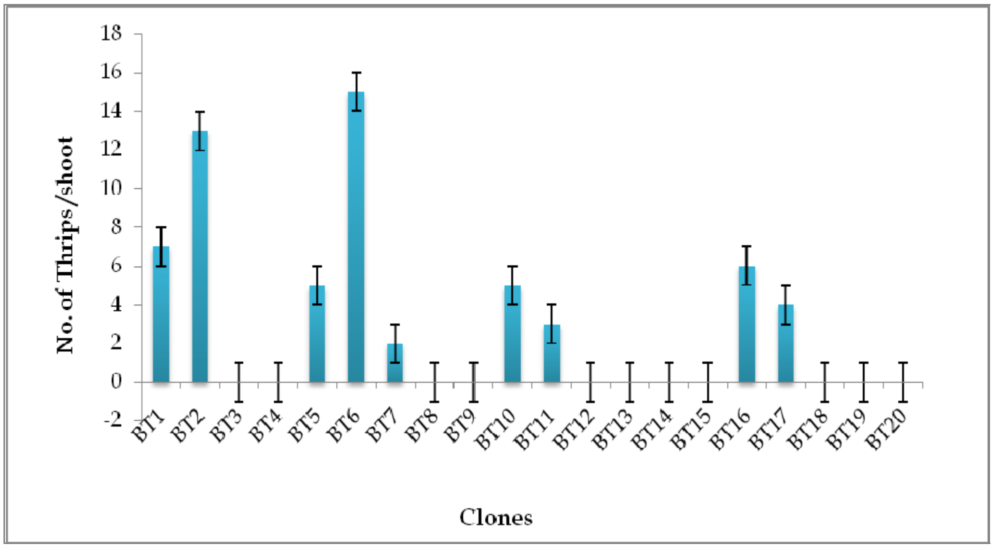


Fig. 10. Clonal susceptibility against Thrips

Observations made on 20 BTRI clones for the susceptibility to *Helopeltis,* red spider mite and thrips infesting tea. Result revealed that BT1, BT2 & BT15 clones were found less attacked by *Helopeltis* (Fig. 8). BT5, BT6 & BT17 clones were found less attacked by Red spider mite (Fig. 9). BT3, BT4, BT8, BT9, BT12, BT13, BT14, BT15, BT18, BT19, BT20 were found less infested by thrips (Fig. 10). The average pest population varied significantly ($P \leq 0.05$) in the different clones. The significant variability in damage may perhaps be attributed to physical or biological attributes of the agrotypes and clones. Since the light coloured varieties are more affected than the dark leaved varieties. Similar observations were also reported to tea mosquito bug, *H. theivora* made by Sudhakaran (2000), Chowdhury *et al.* (2008); Termite by Ahmed *et al.* (1999) and Thrips, *S. bispinosus* by Mahendran (2011). Thirugnasundaram and Amarasinghe (1990) in Sri Lanka and Sudarmani (2004) in India studied the susceptibility of different tea clones to *Oligonychus coffeae*. In South India, UPASI-3 and UPASI-12 are more susceptible to mite attack, whereas the leaves of UPASI-6 and UPASI-10 harbored few mites. In Sri Lanka, the clones MT 18 and TRI 2027 are resistant, while the clones CY 9 and DT 1 are susceptible to mite pest. Sivapalan *et al.* (1980) studied the susceptibility of different tea clones to *Glyptotermes dilatatus.* Oomen (1979) studied the resistance of tea clones to *Brevipalpus phoenicis* in Indonesia. Differences in susceptibility of tea clones were studied by Calnaido (1971) in Ceylon to the shot-hole borer (*Xyleborus fornicatus*) infestation.

Expt. 4. Evaluation of some indigenous plant extracts against *Helopeltis*, Red spider mite and Thrips in tea

The toxic effect of plant extracts against *Helopeltis* and red spider mite is presented in Table 4.

Table 4. Mean mortality percentage of *Helopeltis* and red spider mite treated with different plant extracts under laboratory condition

Name of the plant	Dose (%)	Mortality rate (%)						Mean (%)	
		24HAT		48HAT		72HAT			
		Helopeltis	RSM	*Helopeltis*	RSM	*Helopeltis*	RSM	*Helopeltis*	RSM
Akonda	5.0	48.36	50.26	53.42	54.68	60.84	62.94	54.21k	55.96j
	7.5	52.28	52.88	56.74	57.46	64.20	66.06	57.74i	58.80i
	10.0	61.14	62.48	65.44	66.98	70.08	72.32	65.55f	67.26e
Basok	5.0	50.22	52.06	55.24	57.24	62.66	64.76	56.04j	58.02i
	7.5	53.53	54.88	58.04	60.26	66.28	68.48	59.28h	61.21h
	10.0	62.66	63.42	67.98	68.28	70.86	72.66	67.17e	68.12e
Bishkatali	5.0	55.45	56.38	60.28	64.54	68.72	70.12	61.48g	63.68g
	7.5	59.20	61.36	62.88	65.98	72.04	73.22	64.71f	66.85e
	10.0	69.66	68.08	74.44	74.24	77.46	79.38	73.85b	73.90b
Bhat	5.0	54.06	55.86	59.24	63.26	68.12	69.00	60.47h	62.71g
	7.5	58.18	60.28	62.34	65.43	71.42	72.08	63.98f	65.93f
	10.0	66.88	67.34	73.26	73.46	76.39	78.04	72.18c	72.95c
Bur-weed	5.0	57.06	58.86	62.35	66.64	70.26	72.38	63.22f	65.96f
	7.5	61.40	63.49	64.32	67.44	74.58	75.48	66.77e	68.80e
	10.0	71.46	71.48	76.88	77.24	80.04	81.56	76.13a	76.76a
Castor bean	5.0	51.50	53.25	57.28	60.28	64.08	66.06	57.62i	59.86i
	7.5	55.34	56.32	59.06	62.06	68.62	70.23	61.01g	62.87g
	10.0	63.98	65.18	70.06	70.24	72.26	74.30	68.77e	69.91d
Datura	5.0	51.88	53.48	57.84	60.88	65.00	66.67	58.24i	60.34h
	7.5	55.98	56.84	60.02	63.05	68.23	70.65	61.41g	63.51g
	10.0	64.06	65.62	71.24	71.08	73.48	74.88	69.59d	70.53d
Garlic	5.0	53.28	55.04	58.88	62.36	66.77	68.54	59.64h	61.98h
	7.5	57.72	59.24	62.08	64.08	70.46	71.78	63.42f	65.03f
	10.0	66.28	66.66	72.38	72.68	75.86	77.04	71.51d	72.13d
Lantana	5.0	52.24	53.87	58.08	61.09	65.66	67.20	58.66i	60.72h
	7.5	56.32	57.46	60.68	63.22	68.88	70.86	61.96g	63.85g
	10.0	64.42	65.88	71.66	71.64	74.08	75.32	70.05d	70.95d
Mahogani	5.0	56.20	57.38	61.25	65.42	69.04	71.66	62.16g	64.82f
	7.5	60.24	62.32	63.66	66.48	73.24	74.06	65.71f	67.62e
	10.0	70.28	69.08	75.56	75.64	78.66	80.28	74.83b	75.00b
Nishinda	5.0	50.88	52.86	56.12	58.76	63.22	65.40	56.74	59.01i
	7.5	54.08	55.42	58.66	61.29	67.04	69.76	59.93h	62.16g
	10.0	63.54	64.32	68.74	70.04	71.05	73.24	67.78e	69.20d
Tobacco	5.0	52.96	54.46	58.48	61.76	66.04	68.06	59.16h	61.43h
	7.5	57.06	58.24	61.28	63.48	69.34	71.27	62.56g	64.33f
	10.0	65.78	66.06	72.08	72.34	75.32	76.38	71.06d	71.59d
Probability level		NS						0.01	

Mean of three observations; HAT= Hours after treatment; NS=Not Significant
Within column values followed by different letter(s) are significantly different by DMRT

Results from the laboratory bioassay of *Helopeltis* and Red spider mite at 24, 48 and 72 hours after treatment indicated that Bur-weed extract possessed the highest (76.13 and 76.76%) toxic effect whereas Akonda extract possessed the lowest (65.55 and 67.26%) toxic effect under laboratory condition at the highest (10%) concentration, respectively (Table 4). Similar trend of toxicity was found at 7.5% and 10% concentration.

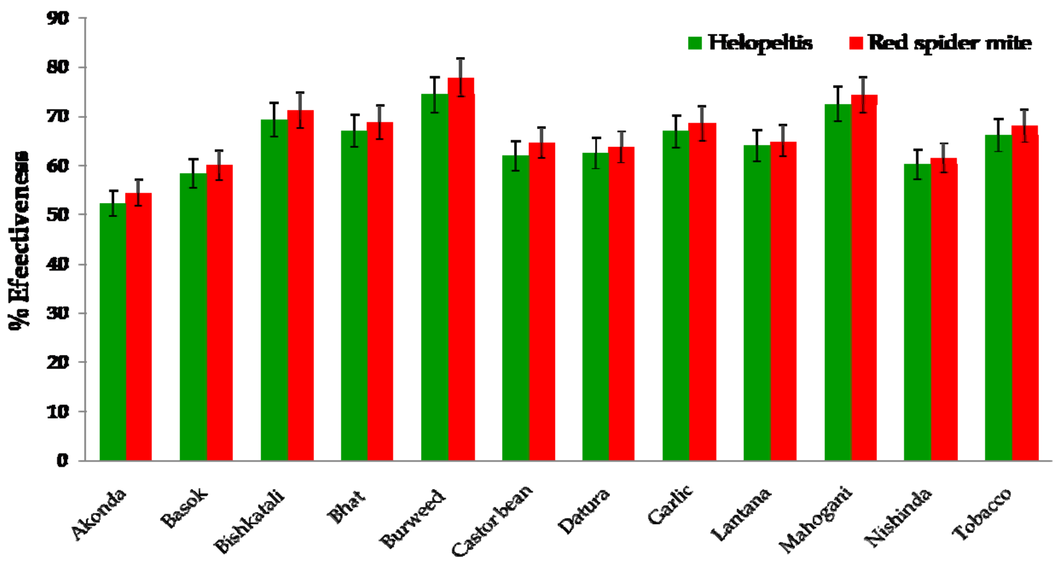


Fig. 11. Field efficacy of some indigenous plant extracts against *Helopeltis* and Red spider mite in tea

Result revealed that all the plant extracts have the pesticidal properties to reduce the pest infestation. The order of the toxicity of plant extracts against *Helopeltis* & red spider mite were Bur-weed>Mahogani>Bishkatali>Bhat>Garlic>Tobacco>Lantana>Datura>Castor-bean>Nishinda>Basok>Akonda (Fig. 11).

Average mortality percentage of thrips at 24, 48 and 72 hours after treatment indicated that Garlic extract possessed the highest (78.93%) toxic effect whereas Akonda extract possessed the lowest (55.63%) toxic effect under laboratory condition at the highest (10%) concentration (Table 5). Laboratory evaluation of plant extracts recorded to be 53.69-73.77% and 55.63-78.93% mortality of Thrips at 7.5% and 10% concentration, respectively. The maximum average mortality (68.62%) was observed at the highest concentration (10%) of plant extract and the mortality percentage was directly proportional to the level of concentration of plant extract. The order of the toxicity of plant extracts were Garlic>Tobacco>Neem>Castor bean>Nishinda>Akonda against thrips (Fig. 12).

Table 5. Mean mortality percentage of thrips treated with different plant extracts under laboratory condition

Name of the plant	Dose (%)	Mortality rate (%)			Mean (%)
		24HAT	48HAT	72HAT	
Akonda	5.0	45.68	50.39	54.17	50.08i
	7.5	51.32	53.46	56.28	53.69h
	10.0	52.66	55.81	58.41	55.63g
Castor bean	5.0	51.76	62.55	64.57	59.63f
	7.5	65.14	69.78	67.07	67.33e
	10.0	71.35	70.25	69.74	70.45d
Garlic	5.0	78.27	71.82	77.53	75.87b
	7.5	71.61	73.49	76.21	73.77c
	10.0	76.38	80.57	79.84	78.93a
Nishinda	5.0	51.08	54.98	53.04	53.03h
	7.5	55.27	61.75	60.72	59.25f
	10.0	60.33	56.48	59.12	58.64f
Tobacco	5.0	68.75	66.14	70.65	68.51e
	7.5	73.29	65.47	69.72	69.49d
	10.0	71.35	76.19	78.28	75.27b
Neem	5.0	69.55	62.28	70.14	67.32e
	7.5	71.83	69.64	67.52	69.66d
	10.0	73.35	70.44	74.61	72.80c
Probability level		NS			0.01

Mean of three observations; HAT= Hours after treatment; NS=Not Significant
Within column values followed by different letter(s) are significantly different by DMRT

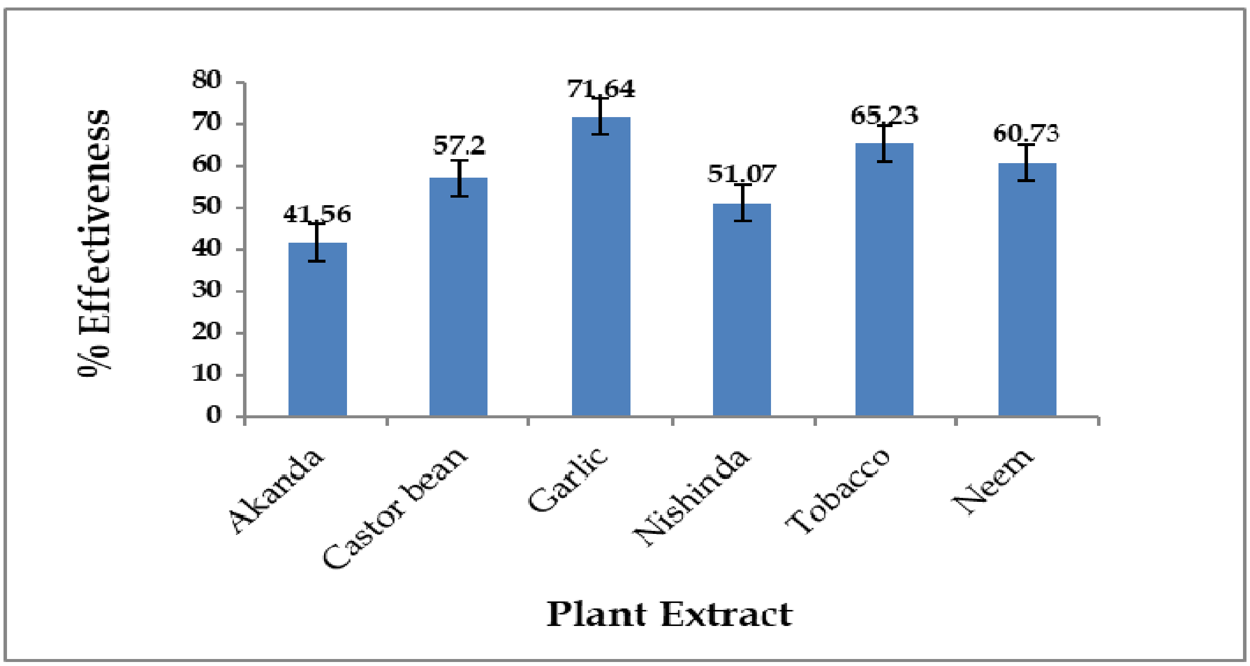


Fig. 12. Effectiveness of some indigenous plant extracts against Thrips in tea

Expt. 5. *Potential effects of Bracon hebetor as a bio-control agents for sustainable management of Looper caterpillar*

Result revealed that parasitism of *B. hebetor* was found at 24 HAR (48.13%) and the maximum mortality (93.60%) of looper caterpillar by the larval parasitoid of *Bracon hebetor* was found at 96 hours after release (HAR) in the laboratory condition (Fig. 13). Further experiment should be conducted at field level for the confirmation of the parasitism of the biocontrol agents. However, the *Bracon hebetor* may be used as a larval parasitoid for the control of looper caterpillar infesting tea as one of the strong IPM component.

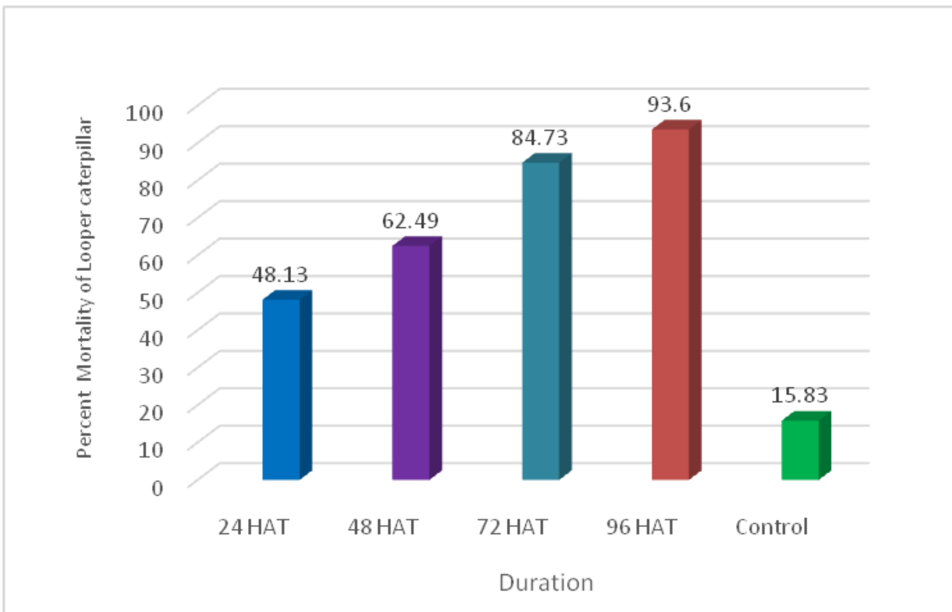


Fig. 13. Percent mortality of looper caterpillar by the larval parasitoid of *Bracon hebetor*

Expt. 6. Evaluation of entomopathogens against Red spider mite and Looper caterpillar infesting tea

6.1 Evaluation of two commercial entomopathogens (microbials) against red spider mite in tea

Results revealed that both two entomopathogens showed the toxic effect on red spider mite in tea and significantly reduced mite population. In laboratory condition, the maximum mortality (72.6%) of red spider mites was found in *M. anisopliae* at 1.0 ml/L followed by *P. fluorescens* (63.74%) at 48 HAT (Fig. 14). Similar trend was also found at 72 HAT after spraying of biopesticides. Satisfactory efficacy of *M. anisopliae* (51.88-75.38%) was also found than *P. fluorescens* (46.24-70.46%) for control of red spider mite using three different concentrations of entomopathogens at field level (Fig. 15).

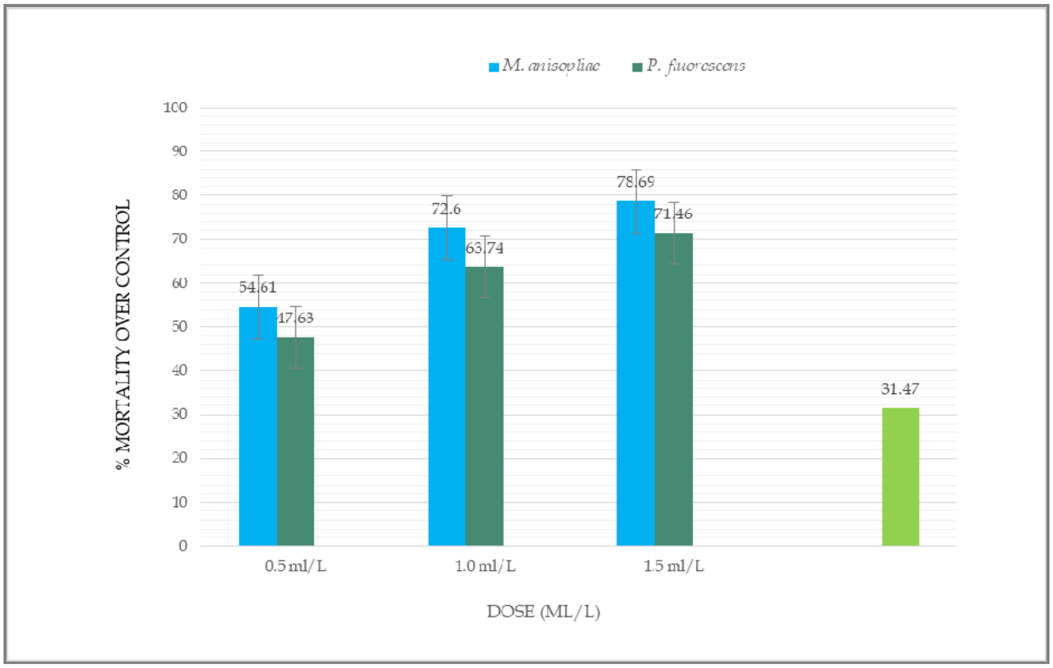


Fig. 14. Percent mortality of red spider mite using entomopathogens at Laboratory condition

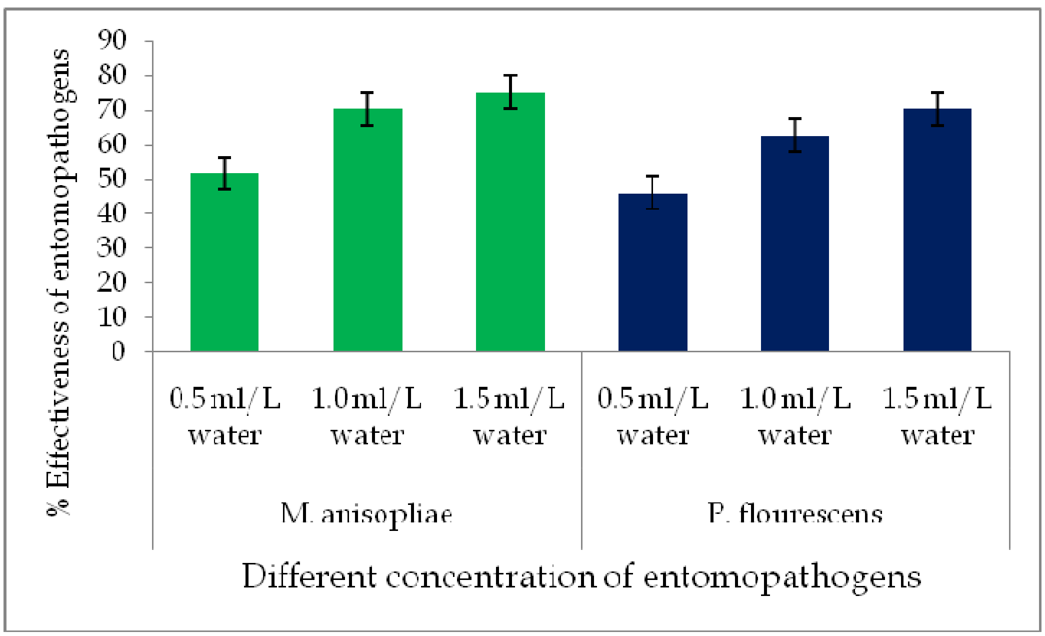


Fig. 15. Effectiveness of two entomopathogens against red spider mite at Field condition

6.2. Evaluation of Bacillus thuringiensis against looper caterpillar in tea

Results revealed that entomopathogen of bacterial formulation of *Bacillus thuringiensis* showed the toxic effect on looper caterpillar in tea and significantly reduced the pest population. In laboratory condition, the maximum mortality (88.96%) of looper caterpillar was found in using *B. thuringiensis* @ 2.0 g/L at 72 HAT (Fig. 15). Similar trend was also found at 24HAT and 48 HAT at other concentrations after spraying of biopesticides. Further experiment should be conducted at field level for the confirmation of the pathogenecity of the biocontrol agents. However, *Bacillus thuringiensis* can be used for the control of looper caterpillar infesting tea.

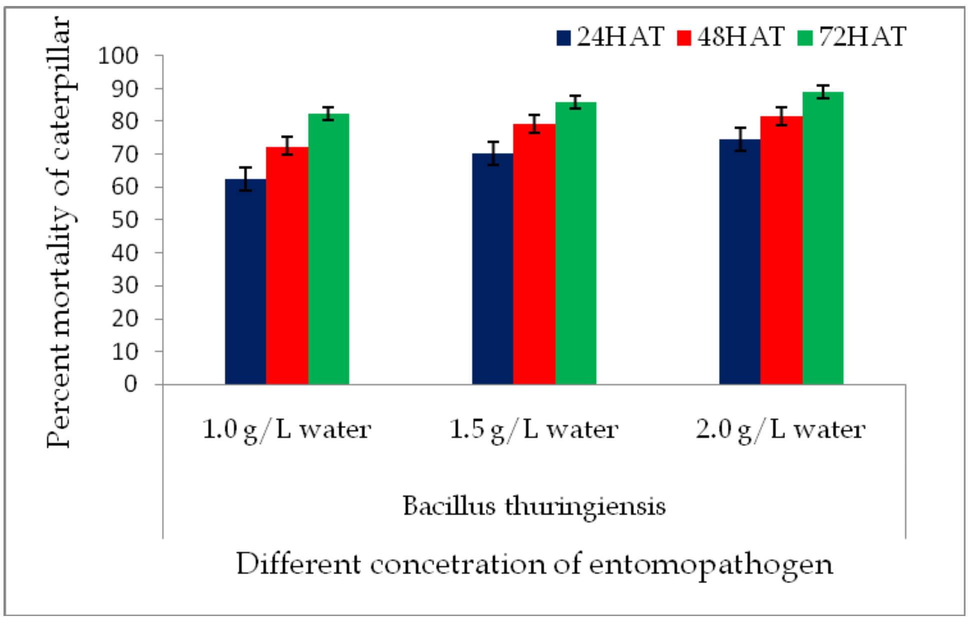


Fig. 15. Percent mortality of looper caterpillar using entomopathogens *Bacillus thuringiensis*

Conclusion

Need based, judicious and safe application of pesticides is the most vital aspect of chemical control measures under IPM strategy. It involves developing IPM skills to play safe with environment by proper crop health monitoring, observing ETL and conserving the natural bio-control potential before deciding in favor of use of chemical pesticides as a last resort. Habitat management, exploitation of hitherto under used natural enemies such as predator, parasitoid & entomopathogen, use of the novel biorational pesticides, management of pesticides to extend their useful life, proper use of semiochemicals and the use of information technology are some major tactics to be employed in the IPM programme in tea in the coming years.

12. Research highlight/findings (Bullet point – max 10 nos.)

- A pest management laboratory with modern scientific equipments has been established at BTRI sub station, Pancahgarh .
- An IPM field laboratory have been established at BTRI sub station, Pancahgarh.
- Strong based IPM techniques in tea such as cultural control measures i.e. plucking, pruning & weeding against *Helopeltis,* Red spider mite and thrips infesting tea have been evaluated and standardized.
- Resistant or susceptible clones against *Helopeltis,* Red spider mite and thrips infesting tea have been screened out.
- Solar power light traps, yellow & blue sticky traps as mechanical control measures Looper caterpillar and Thrips infesting tea have been evaluated.
- Some indigenous plant extracts against *Helopeltis,* Red spider mite and thrips infesting tea have been evaluated and standardized.
- Bio-control agent *Bracon hebetor* as larval parasitoid against looper caterpillar has been evaluated.
- Some commercial entomopathogens (*Metarhizium anisopliae, Pseudomonas fluorescens* & *Bacillus thuringiensis*) against Red spider mite and Looper Caterpillar have been evaluated.

B. Implementation Position

1. Procurement:

Description of equipment and capital items	PP Target		Achievement		Remarks
	Phy (#)	Fin (Tk)	Phy (#)	Fin (Tk)	
(a) Office equipment	Desktop Computer Laptop Laser Printer Digital Camera UPS Scanner	1,85,000	Desktop Computer Laptop Laser Printer Digital Camera UPS Scanner	1,79,000	
(b) Lab & field equipment	Computerized Stereomicroscope Micropipette Refrigerator Glassware & Chemicals	4,51,000	Computerized Stereomicroscope Micropipette Refrigerator Glassware & Chemicals	4,48,000	
(c) Other capital items	Executive Table Executive Chair File Cabinet Steel Almira Visitor chair Computer Table Computer Chair Lab Chair	1,22,500	Executive Table Executive Chair File Cabinet Steel Almira Visitor chair Computer Table Computer Chair Lab Chair	1,22,000	

2. Establishment/renovation facilities:

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	
Establishment of Pest Management Laboratory	100%	100%			
Establishment IPM Field Laboratory	100%	100%			

3. Training/study tour/ seminar/workshop/conference organized: Not done

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training					
(b) Workshop					

C. Financial and physical progress

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Honorarium/Contractual staff salary	158600	156020	156020	0	75%	
B. Field research/lab expenses and supplies	951916	944007	951866	0	100%	
C. Operating expenses	279008	259667	262013	0	100%	
D. Vehicle hire and fuel, oil & maintenance	132710	124508	132710	0	100%	
E. Training/workshop/seminar etc.	100000	0	0	0	0%	
F. Publications and printing	104500	88825	24500	68000	50%	
G. Miscellaneous	97866	94804	95349	0	97%	
H. Capital expenses	307000	285950	301000	0	100%	
Total	2131600	1953781	1923458	68000		

D. Achievement of Sub-project by objectives: (Tangible form)

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e. product obtained, visible, measurable)	Outcome (short term effect of the research)
i) To develop integrated pest management (IPM) strategy by incorporating all the suitable methods in a compatible manner for the management of major pests of tea for sustainable tea production in Bangladesh. ii) To introduce a permanent control measures with safety of natural enemies and reducing comparative use of synthetic pesticides to keep the surroundings healthy. iii) To minimize the risk of pesticide residue in made tea through utilization of IPM practices and ensure consumers safety.	i) Design and layout of IPM laboratory, Set up the equipment and materials in IPM laboratory ii) Raising of tea plants in pots, collection & rearing of major insects pests of tea and available bio-control agents in IPM laboratory. iii) Evaluation of various components of IPM strategies against major pests of tea iv) Timely field visits & demonstration of IPM technology to tea industry	IPM strategy (Pruning, Plucking, Weeding, Clonal selection, Solar light trap, yellow & blue trap, plant extracts, bio-control agents i.e. parasitoid, entomopathogens etc.) in tea has been developed and implemented in tea gardens.	Reduce chemical load on tea and Pesticide residue free tea will be produced.

E. Materials Development/Publication made under the Sub-project:

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.		1	Leaflet (describing IPM strategies in tea)
Journal publication			
Information development			
Other publications, if any			

F. Technology/Knowledge generation/Policy Support (as applied):

i. Generation of technology (Commodity & Non-commodity)

IPM strategy (Cultural, Mechanical, Host Plant Resistance, Botanicals, Biocontrol agents *etc.*) developed for judiciously control of major pests of tea as well as safe production of tea for consumers.

ii. **Generation of new knowledge that help in developing more technology in future**

Knowledge on rearing technique and potentiality of biological control (Parasitoid and entomopathogens) against pests of tea that helps in developing more technology in future.

iii. Technology transferred that help increased agricultural productivity and farmers' income

IPM technology (Cultural, Mechanical, Host Plant Resistance, Botanicals & Entomopathogens) that help increased tea productivity and planters'/farmers' income.

iv. Policy Support

Development of IPM strategy in tea plantation will help in national IPM policy.

G. Information regarding Desk and Field Monitoring

i) Desk Monitoring [description & output of consultation meeting, monitoring workshops/seminars etc.]: N/A

ii) Field Monitoring (Time & No. of visit, Team visit and output):

Date of visit	Team Member	Remarks
09.01.2018	Major General Md. Shafeenul Islam, Chairman, BTB	Good performance
30.01.2018	Dr. Md. Aziz Zilani, Member Director (Crops), BARC Dr. Rina Rani Saha, PSO (Crops), BARC	Satisfactory
22.03.2018	Mr. Md. Abdur Rahman, Monitoring Associate, PIU, BARC Mr. Dipok Kumar Roy, Monitoring Associate, PIU, BARC	Satisfactory
25.04.2018	Md. Irfan Sharif, Joint Secretary & Member (F&T), BTB Dr. Mohammad Ali, Director, BTRI	Good performance
16.07.2018	Major General Md. Jahangir Al Mustahidur Rahman, Chairman, BTB	Good performance

H. Lesson Learned/Challenges (if any)

i) Incorporation of IPM technique in the pest management programme
ii) Reduction of chemical load in tea garden
iii) Safe tea production by using IPM technique in tea plantation

J. Challenges (if any)

Components of IPM strategy i.e. solar light trap, yellow/blue trap, bio-control agents- predators, parasitoids & entomopathogens are not commercially available for the use in large plantation area.

Signature of the Principal Investigator
Date ………………………….
Seal

Counter signature of the Head of the organization/authorized representative
Date …………………………..
Seal

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Appendices: Some pictorials of IPM sub project under CRG

Plate 1. Bangladesh Tea Research Institute, Srimangal, Moulvibazar

Plate 2. Bangladesh Tea Research Institute Substation, Panchagarh

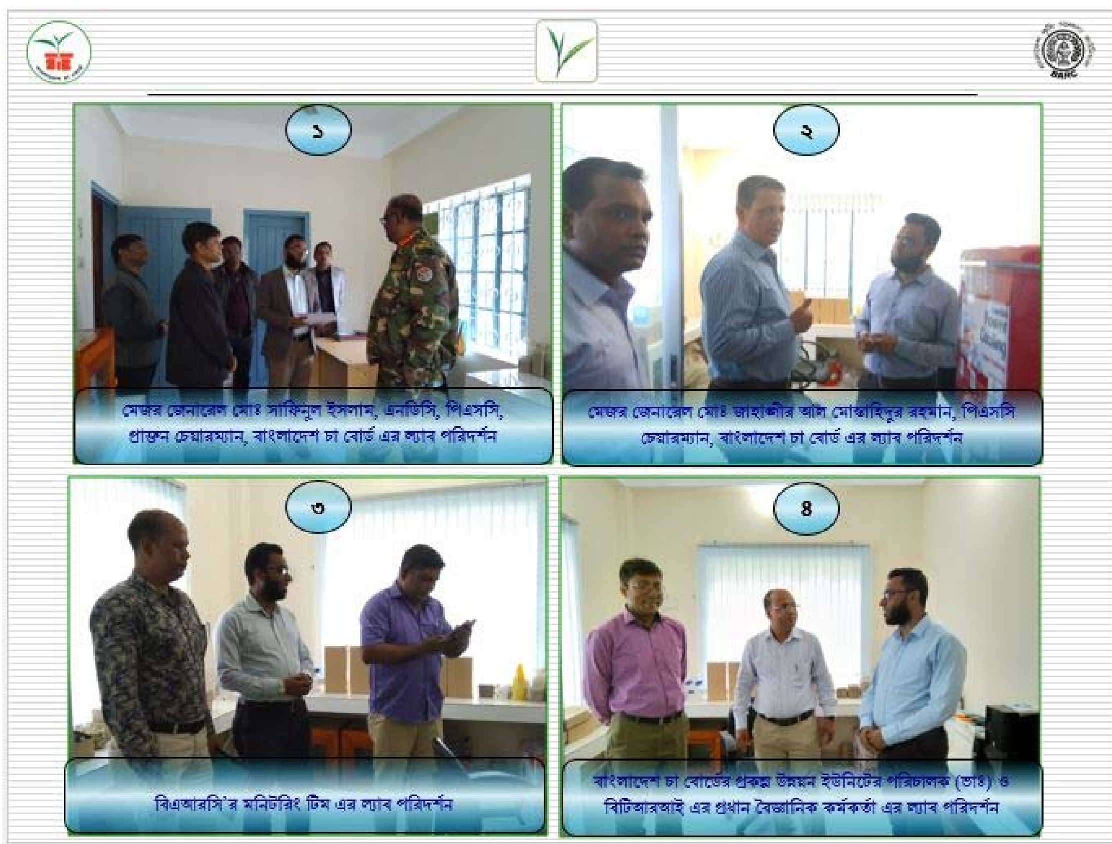
Plate 3. Experimental Field at BTRI Substation, Panchagarh

Plate 4. Experimental Field at BTRI Main Farm, Srimangal, Moulvibazar


টেকসই চা উৎপাদনের লক্ষ্যে চায়ের ক্ষতিকারক পোকামাকড় নিয়ন্ত্রণে
সমন্বিত বালাই ব্যবস্থাপনা (আইপিএম) প্রকল্প


A pest management laboratory with modern scientific equipments has been established at BTRI Substation, Panchagarh
Newly established Pest Management Laboratory under CRG Project

Newly established IPM field laboratory under CRG Project



Some monitoring & field activities of IPM project during 2017-18