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Mini Review

Integrated pest management in tea: prospects and future strategies in Bangladesh

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A B S T R A C T

Tea, *Camellia sinensis* (L.) O. Kuntze, is a perennial crop and grown as a monoculture on large contiguous areas. Tea plant is subjected to the attack of several notorious pests such as insects, mites, nematodes, diseases and weeds. Globally 1034 species of arthropods and 82 species of nematodes are associated with tea plants. Among them 25 species of insects, 4 species of mites and 10 species of nematodes are recorded from Bangladesh. Enormous crop loss was incurred due to the attack of these pests and largely responsible for the declining productivity of tea. Extensive use of chemical pesticides began only a few decades ago with tremendous immediate economic gains but its abuses were not foreseen or ignored. As a consequence there arose the development of resistance to pesticides, pest resurgence and undesirable pesticide residue in the made tea as the major problems. Current trends in eco-friendly insect pest management practices emphasize the host plant resistance, preparation and application methods of new botanicals and microbial pesticide formulations, evaluation of field bio-efficacy and conservation of biological agents, cultural control measures, genetic techniques and sex pheromones technology. In tea husbandry, cultural control measures such as plucking, pruning, shade regulation, field sanitation, fertilizer application, manipulation or destruction of alternate hosts and selection of pest resistant/tolerant varieties and mechanical mechanisms like manual removal, heat treatments, light traps, use of bio-pesticides, bio-control agents and sex pheromone trap need to be given more importance in pest management programme. A tentative IPM strategy for tea cultivation in Bangladesh has been proposed in this paper. Thus the proposed integrated pest management (IPM) strategy should help tea industry for successful long lasting plantations which will ensure consistent crop with much care but lesser cost.

***Keywords*:** Tea, pest management, prospect, future strategies, IPM, Bangladesh

Introduction

Tea, *Camellia sinensis* (L.) O. Kuntze, is a perennial crop and grown as a monoculture over large contagious areas. 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 in Bangladesh. 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. As a long-lived woody perennial and monoculture, tea provides a stable microclimate and a continuous supply of food for rapid build up of phytophagous arthropod species that includes insects & mites. Some tea pests are cosmopolitan and widely distributed over a wide range of ecological zones but many are found in the restricted areas of the tea world.

Tea pest spectrum

Since the dawn of tea culture, a wide range of pests have been associating with tea plantations. Tea pests and tea productivity are two antagonistic factors. Pests and diseases have largely contributed to the declining productivity of tea. Each tea growing country has its own distinctive pests, diseases and weeds. Globally 1034 species of arthropods and 82 species of nematodes are associated with tea plants (Chen & Chen 1989). Among them, 25 species of insects, 4 species of mites and 10 species of nematodes are recorded from Bangladesh (Ahmed 2005). Only few of them have become major pests while most of them are minor and localized and cause occasional damage. In tea, a major pest of today may be minor of tomorrow. Of the production, about 10-15% 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. Most of the pests are polyphagous, but all the pests infest throughout the year and complete their life cycle in the tea fields. 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 & Iyengar 2010). Major insect pests of tea recorded in Bangladesh are shown in Fig. 1.

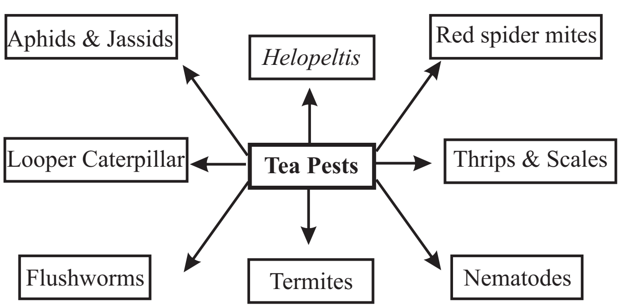

Fig. 1 Major insect pests of tea in Bangladesh

Integrated Pest Management

Tea crop protection is an essential component of tea husbandry to safeguard of the tea plants from the ravages of a multitude of pests, diseases and other maladies. The development of a specific pest control programme depends on many factors, such as the nature of pest spectrum, type of crops to be protected, economics of pest control technologies available, etc. In view of tea ecosystem and diversity of pest complex, a multiple approach of pest management is adopted for Bangladesh tea. At present, the control of insect pests of tea tends to depend on insecticide spraying. Over the past few decades, the application of organosynthetic pesticides has resulted in the resurgence of primary pests, secondary pest outbreaks, and resistance development, as well as the presence of environmental contaminants including residues in made tea. To reduce these problems, IPM tactics have emerged as an alternative solution. From the view point of safe use of agricultural chemicals in ecosystem and possible development of resistance, insecticide applications must be kept at a minimum, and integrated pest management (IPM) system should be considered. Today we realize that an integrated pest management programme (IPM) involving biological and cultural methods with judicious use of chemicals alone will help to reduce the pest pressure.

IPM is a cohesive system of selection, integration and implementation of pest control strategies/methods based on the predicted, economic and socio-ecological consequences. According to FAO definition, IPM is a 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. IPM is recognized as the most robust construction to arise in the agricultural science during the second half of the twentieth century. Concern research efforts have been made to develop various control techniques (cultural, biological and chemical) which could be harnessed for integrated management of important pests of tea in Bangladesh.

Economic Threshold Level

One of the basic requirements of pest control is the economic threshold levels (ETL) at which control measures are justified. The ETL is a matter of judgment, giving time for the farmer to take action for the control measure to take effect before economic injury level itself is reached. Without this information it is not possible to decide whether an insect is indeed a pest in a particular situation. Critical studies on crop loss due to pests and establishment of economic threshold levels of major pest species are pre-requisites for minimizing the use of pesticides. In choosing the kind and amount of pest control, one should establish the ETL first.

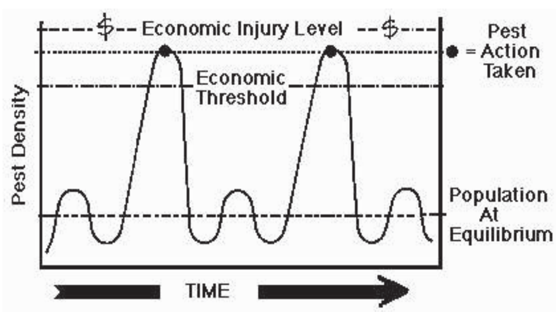

Fig. 2 Showing Economic injury level (EIL) and Economic Threshold Level (ETL) for pests of tea

The economic threshold Level (ETL) is the population density at which control measures should be determined to prevent an increasing pest population from reaching the Economic injury level (Fig. 2). EIL is the lowest pest population which will cause economic damage. EIL is very low for the pests infesting the new shoots since their injury directly affects both the yield and quality of tea. On the other hand, EIL is high for the pests infesting other parts of the tea plants because their injury affects the growth of the new shoots of the next crop and light injuries do not affect the yield and quality. An action threshold for *H. theivora* in Bangladesh was determined through population modeling studies (Ahmed *et al.* 1992). The ETL of the major pests of tea in Bangladesh is given in Table 1:

Integrated Pest Management in Tea

Many different tactics are used in IPM strategy in tea plantation, including cultural practices, biological control agents, chemical pesticides, pest-resistant varieties, and physical barriers. Of all standard control strategies such as natural control like- Climatic factors, Topographic features, Predators and Parasites, etc.; applied control like- Cultural control, Physical control, Mechanical control, Biological control, Microbial control, Regulatory control, Chemical control, and Integrated control, Breeding of resistant agrotypes, Ionizing radiation, Chaemosterilant, etc. has been incorporated and still to be continued because of immediate protection of tea and various constraints to

Table 1.

Economic Threshold Level (ETL) of the major pests of tea in Bangladesh

Name of the Pest	Economic Threshold Level (ETL)
Tea mosquito bug	5% infestation
Aphids	20% infestation
Thrips	3 Thrips per shoot
Jassids	50 nymphs per 100 leaves
Looper caterpillar	4-5 Lopper per plant
Flushworm, Leaf rollers	5 infested rolls per bush
Red spider mites, Pink and Purple mites	5 mites per leaf
Termites	10% infestation
Nematodes	7 nematodes per 10 g soil

employ with different control methods (Muraleedharan 1991). The various components of the IPM practices are enumerated below with a few specific examples, since the success stories with the use of IPM practices are numerous and increasing day by day.

Cultural control

Cultural control apparently is the most economical and widely applicable method of pest control. This involves the intelligent manipulation of all aspects of crop husbandry. In tea culture, certain routine cultural practices such as plucking rounds, adjustment of pruning cycles, the modification of shade trees and timely weed control may be effectively employed as pre-emptive measures of pest control (Sasidhar & Sanjay 2000). This approach of pest control is cheap, risk free and often effective for long period without adverse effect on the environment.

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, aphid, jassids, scales and leaf folding caterpillars such as flushworms and leaf rollers. The shorter the plucking rounds, the more removal of eggs, larvae and juvenile stages of pests from the bush will take place. Tea mosquito bug laid eggs on the broken ends (stalks) of plucked shoots. Intensive removal of stalks during plucking will reduce the incidence of this pest (Mamun 2011a).

Pruning: Pruning is an essential agronomic practice implemented in winter for renovating vegetative growth at the expense of reproduction, to increase crop productivity in subsequent years. Pruning removes a large part of the pest populations present on the foliage and stems. Most of the foliar pests like tea mosquito bug, flushworm, aphid, jassid, thrips, red spider mite, scarlet mite and purple mite are removed during pruning operation (Mamun 2011b). Three years pruning cycle is preferred in severe pest infested areas. When an attack by *Helopeltis* becomes unmanageable the affected bushes may be skiffed to reduce the damage.

Shade regulation: The culture of shade trees and many ancillary crops in the tea ecosystem is considered to be a necessary evil. In tea, shade regulation plays a predominant role in pest suppression. Infested by mites and thrips is seen more in tea fields devoid of shade. Dense shaded areas are prone to the attack of *Helopeltis*. Certain shade trees like *Indigofera* and *Albizia* are the alternate hosts of several caterpillar pests. So, the recommendation of shade management will help to prevent the excessive build up of thrips, mites and *Helopeltis*.

Filed sanitation: Field sanitation assumes significance in the management of several pests. Weeds offer excellent hiding places and serve as alternate hosts for *Helopeltis* and Red spider mites. Weeds like *Mikania cordata, Bidens biternata, Emilia* sp., *Polygonum chinese, Oxalis acetosella, Malastoma malabethricum* and *Lantana camara* offer excellent hiding places and serve as alternate hosts for the Tea mosquito bug. *Malastoma malabethricum* and *Urena lobata* weeds act as alternate host of Red spider mite. Weed free cultivation and preventing trespassing of cattle, goat, and other animals from RSM-infested fields reduce its spread. *Ageratum conizoides, Borreria hispida, Commelina benghalensis, 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. Besides, the improved drainage system helps to minimize the pest infestations.

Planting of rehabilitation crops: As an ecofriendly concept, recent research findings showed the nematode population in soils could be contained remaining below critical level (7.00/10g soil) by planting and lopping the green crops named Guatemala and Citronella. Nematode population in Guatemala and Citronella were 2.98 and 4.56 respectively which were below the critical level. So, Guatemala and Citronella can be planted before establishing tea nursery for improving soil properties as well as suppressing the nematode population in tea soil (Mamun *et al.* 2011).

Trap crop: Studies related to the use of trap crops in tea are scarce. A trap crop also manipulates the habitat in an agroecosystem, which can be included under the ecological engineering approaches for the purpose of IPM (Gurr *et al.* 2004). However, Marigold is an ornamental plant and in tea it can be used as a trap crop of red spider mite. In cases where part of a garden becomes badly affected with Red spider mite every year it is essential to put down a protective barrier between the affected and unaffected tea. One row of marigold can be planted at the outer periphery and also in the vacant area of the section. Border plantings of *Adhatoda vesica* serve as a barrier for red spider mite, *Oligonychus coffeae* (Watt & Mann 1903). As such, susceptible tea clones such as Tocklai vegetative clone TV1 to *H. theivora* may be utilized as the trap crop (Hazarika *et al.* 2009).

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. The mechanism of pest resistance in plants is generally *physiological* (i.e. plant toxins inhibit pest) or *mechanical* (i.e. plant morphology leaf structure, pubescence, distastefulness of sap, vigour or antibiosis, etc.) which may be controlled by single gene or multiple genes. The use and development of pest-resistance cultivars have been effectively applied for the control of plant nematodes, diseases and some insects in many crops, but it is difficult in plantation crop like tea because of its breeding nature and prolonged longevity. However, another type of pest-resistance, that is, tolerance in which plants may sustain a high level of pest attack without an economic damage, may be successfully incorporated in the pest control strategy for tea.

China varieties are more susceptible to the attack of red spider mites because of their higher rhodoxanthin and l-arginine content and lower tannin content; while Assam cultivars are apparently more susceptible to the attack of pink mites have less pubescence, stronger cuticularization on the undersurface, lower stomatal density, and low sugar, but are rich in total antioxidant activity, theamine, gibberellic acid, and caffeine (Xu *et al.* 1996). Attempts have been made at the institute to screen some well known tea agrotypes/clones against termites by Ahmed *et al*. 1994 and 1999. From the view point of termite resistance, B207/39 and B233/39 (Munipuri type); BT4, BT6, BT7, BT8 and BT9 (Munipuri-China hybrid) and Tingamara seedling (broad leaf Assam hybrid) were found to have best while AN1, TV9, BT1, TV18 and BT2 (hybrids or Camboid type of small to intermediate leaf size) may be in the second preference from termite resistance point of view. BT10 and BT11 had been found to be the most susceptible clones to termite attack. Try to avoid termite susceptible variety.

Chowdhury *et al.* (2008) classified clones as 'fairly resistant', 'resistant', 'susceptible' and 'very susceptible' to *Helopeltis* by feeding method with 4^{th} instar nymph for 7 days. Based on the findings, 7 clones (BT1, BT2, BT7, BT8, BT10, BT12 and BT16) appeared fairly resistant, 8 clones with two seed jats bi-clonal seed and general seed (BT4, BT5, BT6, BT9, BT13, BT14, T15 and BT17) showed susceptible reaction while two clones (BT3 and BT11) were found to be very susceptible to *Helopeltis.*

Physical control

Physical control is one of the important approaches to the integrated pest management programme. Such controls aim to reduce pest populations by using devices which affect them physically or alter their physical environment. The only method in this category which has really stood the test of time is hot water treatment of plant organs like roots to kill concealed pests such as eelworms.

Manual removal: Collection and destruction of Lepidopteran caterpillars are economical and useful either for small plantations or for plantations with a large labor force. Population of foliage feeding caterpillars such as looper caterpillar, faggot worms, flush worms and leaf roller can be reduced to a great extend by manual removal of larvae and pupae.

Heat treatment and soil solarisation: Soil is the medium for growing tea plants. Many insects like eelworm, cockchafer grubs, termites, root mealy bugs live or hibernate in suitable temperature and humidity conditions relatively under or near the soil surface. Soil used in the nursery may be heated to 60-65˚C for killing the infective juveniles of soil nematodes.

Use of light traps: Light traps are an important component of physical control methods and have significance in tea pest management. 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.

Mechanical control

Mechanical methods are manual devices utilized for pest suppression. There have only been a few attempts to utilize this method for tea pest management. However, few methods have been developed and practiced in tea plantation in Bangladesh for the control of termites.

Mound digging process: Termitaria (Termite mound) are architecturally designed dome-shaped close system earthen mounds that provide natural protection from adverse environment. '*Queen*' lives inside the mound and reproduce infinitesimal progenies to build up the population. The mechanical control method to destroy the termitaria seems to be a plausible solution for termite control. The destruction of isolated termitaria is widely practiced in tea plantation in Bangladesh (Ahmed 2011). To minimize termite population destruction of colony and the queen is a very good practice. It is apparent that mound digging process is very effective to reduce the termite density in the plantation because supplementary queens could not develop within three years and thereby the termite population will obviously decline.

Destruction of termite colony by cocktail mixture: Experiment on integrated control aspect of termite colony show that insecticide like Thiodan 35EC and Calixin 75EC could be used with an injecting rod having 3/8" diameter and 94cm length directly inside the termite colony having effective results. It is understood that the Thiodan 35EC is a broad spectrum non-selective contact insecticide and has a direct action on termite whereas Calixin is used as a systematic fungicide which is used to prevent the fungal combs of the termitaria. Consequently, termite present in the soil surrounding the dug hole will be drastically reduced by the application of cocktail (Thiodan + Calixin) solution. The above method of controlling termite colony is very simple and less expensive in comparison with other methods such as Dig out method.

Field testing device: *Use of food traps to monitor termite population*

In order to monitor termite population and determine the damage matrix on those variable food materials in plantation areas or in rehabilitation areas and subsequently to control the invading termites, simple field testing device using food traps was constructed. Six types of food traps, such as 1) Saw dust, 2) Tissue paper, 3) Dried tender bamboo splits, 4) Jute sticks, 5) Susceptible soft timber, and 6) *Bogamedeloa* branch were selected. It was observed in the practical field that the use of food traps especially bamboo splits and or soft timber induce termite infestation in derelict redundant tea sections and subsequent use of proper pesticide to control them might provide an environmentally sustainable control method for termite. So food traps like bamboo splits, soft timber and *Bogamedeloa* are considered to be a suitable tool for destruction and management of termite.

Biological control

Biological methods of control involve the conservation, preservation and introduction of natural enemies like predators, parasitoids and pathogens for suppression of pests within tolerable levels. More than hundred species parasitoids, predators and pathogens have been recorded from the tea estates. The minor status of several pests such as aphids, scale insects, jassids, flushworms and leaf rollers 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. The effects of artificial management including insecticide application are negligible on the bush below the plucking surface. The bush below the plucking surface is very important as refuge for natural enemies. For example, the population densities of several natural enemies of *Oligonychus coffeae* are high at the bush below plucking surface.

Predator: Several predatory mites, mostly belonging to Phytoseiidae, Stigmaeidae and Tydeidae, mainly prey upon phytophagous mites infesting tea. *Oligota flaviceps* is identified as a predator of Red spider mite in tea (Babu *et al.* 2008a). *Amblyseius herbicolus* and *Euseius ovalis* are the two main common predators of *Acaphylla theae* and *Calacarus carinatus*. Anthocorids belonging to *Anthocoris* and *Orius* and the predatory thrips, *Aelothrips intermedius* and *Mymarothrips garuda* are important natural enemies of thrips. Recently, *Chrysoperla carnea* has been identified as a predator of thrips and *Helopeltis*. The several species of coccinellids and syrphids exert tremendous influence on the population of *T. aurantii* (Muraleedharan *et al.* 1988). Tea aphids may be controlled effectively by the lady bird beetle, *Hippodamia divergens* (Ahmed *et al.* 2009). Preying mantids are identified as the potential predator of *Helopeltis theivora* and *Verania vincta, Verania discolor* are identified as the potential predator of red spider mite.

Parasitoid: Leaf rolling caterpillar, *Cydia leucostoma* is parasitized by nine species of braconids, two ichneumonids and one encyrtid in addition to a pupal parasitoid belonging to *Ascogaster.* Among the larval parasitoids, *Apanteles aristaeus* is the most common species on flushworms. The leaf roller, *Caloptilia theivora* is heavily parasitized by the eulophid, *Sympiesis dolichogaster*. *Apanteles fabiae* and *Apanteles taprobanae* parasitise the looper caterpillar, *Buzura suppressaria*. The egg parasitoid, *Erythmelus helopeltidis* was found effective against tea mosquito bug, *Helopeltis theivora* (Sudhakaran & Muraleedharan 1998).

Pathogens: Use of entomopathogenic fungi is a new area of research for integrated pest control in tea. Several microbes are pathogenic to tea pests. Formulations of the bacterial insecticides, *Bacillus thuringiensis* have been effectively used for the control of looper caterpillars, cutworms, flushworms and other lepidopterous pests (Muraleedharan & Radhakrishnan 1989). Certain entomopathogenic fungi, *Verticillium lecani, Paecilomyces fumosoroseus* and *Hirsutella thompsonii* were evaluated and found effective against pink, purple and red spider mites (Babu *et al.* 2008b). *Cladosporium* sp., *Aspergillus niger, A. flavus* found to be the potential entomopathogenic fungi for the management of *Helopeltis* in tea (Bordoloi *et al.* 2011). *Metarhizium anisopliae* is the commonest entomopathogenic fungi that reduced the population of red spider mites, thrips and live wood termites in tea. Sana (1989) stated that an entomopathogenic fungus, *Cephalosporium* sp. is reported to be parasitic on the nymph of tea jassid.

Use of botanicals

Botanical products are environmentally safe, less hazardous, economic and easily available. Certain products derived from indigenous plants are used for tea pest control. Recently, Mamun & Ahmed (2011) reviewed some works on botanicals and their uses in tea pest management. Products containing azadirachtin, an oxygenated triterpenoid obtained from the seed kernel of neem, *Azadirachta indica* is now being evaluated against certain tea pests and has been found effective against *Helopeltis,* Red spider mites, flushworm etc. Application of neemcake @ 2kg/bush was found to be effective for the plants suffering from the attack of root knot nematodes, *Meloidogyne brevicauda* (Radhakrishnan 2006). Besides, Mahogany, Karanja, Datura, Tobacco, Bishkatali, Katamehedi, Lantana, *Xanthium* and *Clerodendrum* extracts may also effective against major pests of tea such as tea mosquito bug, red spider mites etc (Mamun & Ahmed 2012a). The use of plant extracts should be incorporated in the IPM programme in tea in Bangladesh. The indigenous plants are available surrounding the estates as well as throughout the country. Tea planters may use these plants for the management of pests of tea.

Use of sex pheromone

Sex pheromones have been utilized extensively in IPM programme in field crops but their use is rather unknown in plantation crops like tea. Sex pheromones could be integrated into the pest management programme in tea (Noguchi *et al.* 1981; Hiyori *et al.* 1986). Sex pheromone traps obtained from Japan were successfully used for monitoring the populations of leaf roller moths in South India (Selvasundaram 1990). The components of sex pheromone of *Cydia leucostoma,* the flushworm of tea have identified. Sudhakaran *et al.* (2000) carried out an experiment in the laboratory and field to determine the presence and activity of sex pheromone in the tea mosquito bug, *Helopeltis theivora.* The study revealed that the homogenized solution of the test insects with dichloromethane attracted more males when compared to other solvents like n-hexane and heptane. Communication disruption using sex pheromones of *Helopeltis,* flushworm, Looper caterpillar, leaf roller may be effective and this technique would be incorporated in IPM strategy in tea plantation in Bangladesh.

Chemical Control

Pesticide will continue to play a vital role in pest control programme in the foreseeable future. Pesticides have been considered to be one of the most essential agricultural inputs for increasing crop production. The correct choice of pesticides, dosage, timing and method of application are of paramount importance for the successful control of insects and mite pests of tea. Over the years, the pattern of pesticide usages on tea in India has followed the world trend. Insecticides ranging from DDT to the most recent synthetic pyrethroids do find a place in the schedule of pest control programmes in tea. The recommendation on chemical control on tea pests in Bangladesh is presented in the Table 2.

Spraying calendar is prepared, viewing the trend of seasonal occurrence of pests and economy of spraying, to synchronize pest control measures with farm management practices. The spraying calendar may be different in different crops having different pest spectrum. Majority of pests are found to be prevalent during mid season, June-September, while few pests become active in localized area during the onset or tail end of the cropping season. Therefore, it is necessary to assess the degree of incidence by a sequential survey before the application. Having considered the

Table 2.
Recommendation on chemical control on major tea pests in Bangladesh
(Mamun & Ahmed 2012b)

Chemical	Target pest	Dosage	Spray volume
Sulphur 80WP	All mites	2.25 kg/ha	1000 lit/ha
Propargite 57EC	All mites	1.00 lit/ha	1000 lit/ha
Fenpopathrin 10EC	All mites	1.00 lit/ha	1000 lit/ha
Ethion 46.5EC	All mites	1.25 lit/ha	1000 lit/ha
Fenproximate 5EC	All mites	300 ml/ha	1000 lit/ha
Fenazaquin 10EC	All mites	600 ml/ha	1000 lit/ha
Thiacloprid 240SC	Thrips, Aphids, Jassids, *Helopeltis,* scale insect	375 ml/ha	500 lit/ha
Quinalphos 25EC	Caterpillar, thrips, *Helopeltis*, aphids, all mites	750 ml/ha	500 lit/ha
Deltamethrin 2.5EC	Caterpillar, *Helopeltis,* thrips	500 ml/ha	500 lit/ha
Cypermethrin 10EC	Caterpillar, *Helopeltis,* thrips	500 ml/ha	500 lit/ha
Chlorpyrifos 20EC	Termites	10.0 lit/ha	1000 lit/ha
Imidacloprid 200SL	Termites	1.5 lit/ha	1000 lit/ha
Carbofuran 5G	Nematodes	165 gm/m^3	-
Fipronil 3GR	Nematodes	165 gm/m^3	

seasonal trend of invasion by various pests, a synchronized pest control strategy is adopted so that a balanced and timely action is exercised according to the spraying calendar (Table 3). Barrier spraying has been found to be effective against *H. theivora* (TRA 1994).

Thus, before spraying any chemicals, the tea planters must consider i) the impact of pesticides on non target organisms, human health, wild life habitat and environment and ii) adopt IPM strategies to reduce the pesticide load to produce residue free tea, increase the exports and meet out the consumers' demand. Based on the ecological characteristics of tea fields and production system of tea, a tentative IPM system comprising all suitable control methods in tea cultivation in Bangladesh has been proposed (Fig. 2). In the both natural enemies and insecticides are used complementarily.

Table 3.

Tentative spraying calendar against major insect pests of tea in Bangladesh

Month	INSECTICIDE		ACARICIDE	
	Spray	**Insects**	**Spray**	**Mites**
January				
February		Flushworm, Aphid, Jassid, Thrips		Red spider, Pink, Purple & Scarlet mite
March		Flushworm, Aphid, Jassid, Thrips		Red spider mite
April		*Helopeltis*		
May		*Helopeltis*		Red spider mite
June				
July		*Helopeltis*		Red spider mite
August				
September		*Helopeltis*		
October		*Helopeltis*		Red spider mite
November		*Helopeltis*		
December		Termites		

General spray Spot spray Gen/spot spray

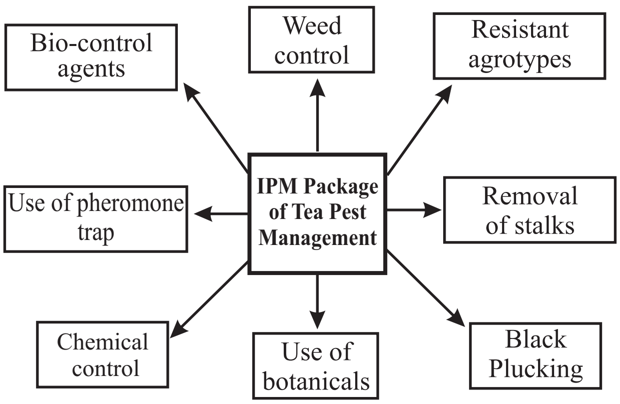

Fig. 2 Component of IPM package of Tea Pest Management

Prospects & future strategies in Bangladesh

The prospects of integrated pest management (IPM) in tea in Bangladesh are bright. The proposed IPM approaches has the scope to utilize in tea plantation in Bangladesh and thus minimize crop losses and ultimately tea production will be more with less environmental disturbance. The future strategies involved an information-based system in which prevention and therapy are combined to reduce the damage caused by pests. Development of molecular markers for identification of pest resistant cultivars may form an area of future research. The molecular biology of these mechanisms must be understood in tea before undertaking any genetic engineering work. We expect that in the future, GM plants will occupy an increasingly large share of tea plantations. Pheromone technology, and pesticide resistant predators/parasitoids, and organic farming with the goal of minimizing intervention, as well as regional/national/international cooperation for proper implementation of system-based IPM programs are the main research areas that require increased attention in the future. Research on adaptation of entomophages to climatic stresses such as temperature and humidity besides tolerance to sunlight or moisture stress among entomopathogens needs to be explored further. Efforts to improve efficiency in mass production and quality control as well as to generate bioefficacy and biosafety data for facilitating product registration should be intensified. There is need and scope to sponsor a more active partnership among the stakeholders, researchers, extensionists, developmental agencies, private enterprises and the end users. Given the right support to research and development, bio-intensive management could emerge as a vital component in tea cropping system.

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.

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