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Review Paper

Pesticide usage pattern in tea ecosystem, their retrospects and alternative measures

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Abstract: *Tea is a perennial plantation crop grown under monoculture providing favorable conditions for a variety of pests. The concept of pest control has undergone a considerable change over the past few decades. In recent years there has been a greater dependence on the use of pesticides (7.35-16.75 kgha^{-1}) with little importance laid on other safe control methods for the management of tea pests. Due to this practice, the tea pests showed a higher tolerance/ resistance status due to formation of greater amount of esterases, glutathione S-transferase and acetylcholinesterase. Thus, over reliance on pesticides end up with pesticide residue in made tea (DDT – 10.4 – 47.1%; endosulfan – 41.1 – 98.0%; dicofol – 0.0 – 82.4%; ethion – 0.0 – 36.2%; cypermethrin – 6.0 – 45.1%). The growing concern about the pesticide residue in made tea, its toxicity hazards to consumers, the spiraling cost of pesticides and their application have necessitated a suitable planning which will ensure a safe, economic as well as effective pest management in tea. At present it is a global concern to minimize chemical residue in tea and European union and German law imposed stringent measures for the application of chemicals in tea and fixed MRL values at < 0.1 mgkg^{-1} for the most commonly used pesticides which will not be met out in the real practice and has been a major constraint to tea exporting countries like India. In order to regulate the situation of the Indian market at global level, central insecticide board and prevention of food adulteration regulation committee have reviewed the MRL position for tea and has recommended 10 insecticides, 5 acaricides, 9 herbicides and 5 fungicides for use in tea and issued the tea distribution and export control order 2005 which will help the country to limit the presence of undesirable substances in tea. This review attempts to provide the readers with a comprehensive account of pesticide use in North East in tea, surveillance report of the European community regarding the residue level in Assam and Darjeeling tea, recent amendments by international and national regulatory bodies, revised MRL values of pesticides in tea, an update about the current strategies for the management of tea pests with more focus on the use of biological control agents and a possible beneficial role or judicious use of chemical pesticides in complement with other alternative measures to achieve optimum effects in terms of limiting agricultural input, lowering production costs, reducing environmental contamination and the effect on non-target organisms, delaying the development of resistant pest biotypes and above all minimizing the pesticide residues in tea to increase the exports.*

Key words: *Pesticide use, Pesticide residues, MRL, Pesticide regulation, IPM, Bio-control agents, Alternative measures*
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Introduction

Tea, the truly ubiquitous common man's drink in India was introduced by the British to this country from neighbouring China. The tea industry is one of the oldest organized industries in India and Indian teas are appreciated world over as health drink for their unique flavour, aroma, and medicinal properties. India produces three speciality teas – Darjeeling, Assam and Nilgris, which are exported world over. Tea is grown in 13 states and Assam, West Bengal, Tamil Nadu and Kerala are the largest producers. Total consumption of tea was estimated to be 870 and 900 million kg in 2003 and 2004 , out of which approximately 78% was harvested from North East India. Of this, 173 and 190 million kg were exported and 697 and 710 million kg were consumed domestically in 2003 and 2004 respectively. The country today accounts for 27.49 per cent of the global tea production and 13.09 per cent of the world trade (Muraleedharan, 2006). In the total Indian tea production, major portion of the produce is exported to countries like Germany, UK, Japan, and USA, both as bulk exports as well as value added products. The perception that "Assam tea and Darjeeling tea" is a premium tea acknowledged by consumers, or a quality product, or the very fact that it is special, is the subject matter of an intellectual property. There is a steady increase in the production over the years since its day of first cultivation, which is due to extensive cultivation, improved technology, nutrition and fertility management (Saraswathy *et al.,* 2007), introduction of high yielding clones and longer pruning cycle. These factors, on the other hand, have encouraged biotic stresses like insect pests and diseases to limit the productivity of this crop (Gurusubramanian, 2005). More than one thousand species of arthropod pests are known to attack tea all over the world, though only about 300 species of insects are recorded from India in that 167 species from North-East India (Das, 1965), resulting 11 to 55% annual loss in yield. In North-East India, tea plant is colonized by a complex of insect species including the tea mosquito bug, red, pink and purple mites, thrips, termites, red slug caterpillar, looper caterpillar, green leafhopper *etc.* (Gurusubramanian and Borthakur, 2005).

Current trend of over-reliance on the use of synthetic pesticides in tea crop protection programs around the North-East

Table - 1: Comparison of effective field dosages with recommended dosages of different insecticides against *Helopeltis theivora* Waterhouse

Insecticides	LC_{50} (%)	Expected effective concentration	Expected effective dose (*a.i.* ha^{-1})	Recommended dose (*a.i.* ha^{-1})	Times increase
Endosulfan 35 EC	0.0079	0.0158	1264	350	3.61
Dimethoate 30 EC	0.0029	0.0058	464	300	1.54
Deltamethrin 2.8 EC	0.0029	0.0058	464	5.6	82.85
Cypermethrin 10 EC	0.00029	0.00058	46.4	10	4.64
Imidacloprid 17.8 SL	0.0039	0.0078	624	23.49	26.56
Oxydemeton methyl 25 EC	0.0039	0.0078	624	250	2.49
λ-cyhalothrin 5 EC	0.0003	0.0006	48	10	4.80
Phosalone 35 EC	0.0058	0.0116	928	350	2.65
Quinalphos 25 EC	0.0079	0.0158	1264	250	5.04
Thiomethoxam 25 WG	0.0010	0.0020	160	50	3.20
Acephate 75 SP	0.0014	0.0028	224	750	0.29
Fenpropathrin 30 EC	0.00049	0.00098	78.4	75	1.04
Profenophos 50EC	0.0019	0.0038	304	200	1.52

India has resulted in disturbances to the environment, pest resurgence, variation in susceptibility, residue problems in made tea, impedance for natural regulatory agents and lethal and sub-lethal effects on non-target organisms, including humans (Gurusubramanian *et al*., 2005; Borthakur *et al*., 2005; Bora *et al.,* 2007a,b). These side effects have raised public concern about the routine use and safety of pesticides. In the recent years, it has become a major concern to the tea industry as the importing countries are imposing stringent restrictions for acceptability of the made tea due to pesticide residues. Changes in pest management measures are resulting from a) environmental and human safety concerns, b) susceptibility change in insect pests and c) increased cost of pesticides (Rahman *et al.,* 2005b).

Reducing dependence on chemical pesticides in favour of ecosystem manipulations is a good strategy for planters. In the present article, pesticide consumption and usage pattern in Northeast India, its constraints, the current knowledge of fixation of maximum residue limits (MRL) for pesticides, pesticide regulation in India and other international bodies, alternative measures and future strategies are reviewed.

Pesticide consumption in tea and its impact: In North East India, Tocklai Experimental Station, Tea Research Association (TRA), Jorhat, is the premier institute to test and certify the plant protection chemicals for use in tea plantations. Earlier, TRA recommended different pesticides [endosulfan, quinalphos, phosphamidon, phosalone, acephate, dimethoate, chlorpyrifos, monocrotophos, oxydemeton methyl, λ-cyhalothrin, β-cyfluthrin, ethofenprox, cartap hydrochloride, alphamethrin, cypermethrin, deltamethrin, profenophos, thiomethoxam, imidacloprid, dicofol, ethion, propargite, fenazaquin, sulfur and neem formulations] for controlling tea pests (Anonymous, 1993, 1999). During the last several decades, the control of pests, diseases and weeds in tea fields is predominantly by the use of synthetic chemicals. Though broad-spectrum pesticides offer powerful incentives in the form of excellent control, increased yield and high economic returns, they have serious drawbacks such as development of resistance to pesticides, resurgence of pests, outbreak of secondary pests, harmful effects on human health and environment and presence of undesirable residue (Das, 1959; Gurusubramanian *et al*., 2005; Sarnaik *et al.,* 2006). The consumption of pesticide in India is one of the lowest in the world. India uses a low amount of 0.5 kg ha^{-1} pesticide compared to 7.0 kg ha^{-1} in USA, 2.5 kg ha^{-1} in Europe, 12 kg ha^{-1} in Japan and 6.6 kg ha^{-1} in Korea (Anonymous, 2003a). The average use pattern of chemical pesticides was estimated to be 11.5 kg ha^{-1} in the Assam valley and Cachar, 16.75 kg ha^{-1} in Dooars and Terai and 7.35 kg ha^{-1} in Darjeeling (Barbora and Biswas, 1996). In a recent survey, synthetic pesticides constituted 85% of the total pesticides used, while 15% were of organic and inorganic origin in tea gardens of Dooars. In which, acaricides accounted for 25% (3.60 litre ha^{-1}) and insecticides 60% (8.46 litre ha^{-1}). Within the synthetic insecticides, organophosphate compounds (64% - 5 rounds per year) were most preferred followed by organochlorine (26% - 2 rounds $year^{-1}$) and synthetic pyrethroids (9% - 7 rounds per year) (Sannigrahi and Talukdar, 2003). It has been estimated that tea industry in India harbour about 300 species of pests and therefore, extreme care must be excercised before a pesticide is introduced to tea for pest control (Das and Das, 1962) to avoid residue build-up. Organophosphate, organochlorines, carbamate, synthetic pyrethroid insecticide have been in use on tea in North-East India for the past 100 years. Much of the efficacy and sustainability of these groups of insecticides in tea pest management would depend on the susceptibility of the major target pests. Variation in relative toxicity was observed between male and female populations of Jorhat and Darjeeling and among the populations of *Helopeltis theivora* collected from different sub districts of Dooars and in populations of *Buzura suppressaria* caterpillars collected from Jorhat to the tested insecticides due to selection pressure by insecticides (Rahman *et al*., 2005b; Bora *et al.*, 2007a,b). A comparison of expected effective dose of thirteen insecticides against tea mosquito bug based on their LC_{50} values with recommended dose revealed a pronounced shift in the level of susceptibility of *H. theivora* to all the chosen insecticides except

Table - 2: Chemical compatibility of agrochemicals* against tea mosquito bug and red spider mite

Pests	Chemicals	Compatible with	PR	Incompatible with	PR
Tea mosquito bug	Propargite	Alphamethrin	87.72	Deltamethrin	65.41
				Endosulfan	41.79
				β-cyfluthrin	78.55
				λ-cyhalothrin	64.25
	Fenazaquin	Thiomethoxam	86.41	Deltamethrin	38.35
		Endosulfan	89.27	Alphamethrin	43.33
		Imidacloprid	97.33	β-cyfluthrin	8.37
				λ-cyhalothrin	50.06
	Sulfur	Endosulfan	79.80	Deltamethrin	46.60
		β-cyfluthrin	85.40		
		λ-cyhalothrin	89.60		
		Alphamethrin	88.93		
		Thiomethoxam	93.60		
		Imidacloprid	93.00		
	Cypermethrin	Fenazaquin	88.30	Propargite	70.00
		Fenpyroximate	86.00		
		MOP	98.64		
		Urea	93.00		
		Zinc sulphate	82.00		
Red spider mite	Neem			Ethion	36.65
				Sulfur	32.62

PR - Percent reduction in infestation,
* = Chemical compatibility was determined based on the per cent infestation of the pest after chemical spray individually as well as in combination

Table - 3: Year wise surveillance report by European tea committee on pesticide residue in Indian tea imported into European union countries

Pesticides	Percent incidence level in tea samples					
	2001 – 2002		2002 – 2003		2003 – 2004	
	Assam	Darjeeling	Assam	Darjeeling	Assam	Darjeeling
DDT	13.8	-	10.4	-	47.1	-
Endosulfan 35 EC	72.9	49.3	72.2	41.1	98.0	53.8
Dicofol 18.5 EC	70.4	44.1	65.6	31.3	82.4	-
Cypermethrin 10 EC	14.2	6.0	13.2	15.3	45.1	7.7
Deltamethrin 2.8 EC	-	-	-	-	35.3	-
Fenvalerate 25 EC	-	-	-	1.2		-
Ethion 50 EC	22.3	16.9	16.7	36.2	7.8	-
Monocrotophos 36 EC	-	-	-	6.1	5.9	-
Acephate 75 SP	-	-	-	-	3.9	

acephate. The recommended dose of synthetic pyrethroids (fenpropathrin, cypermethrin, λ-cyhalothrin and deltamethrin), organophosphates (profenophos, dimethoate, oxydemeton methyl, phosalone and quinalphos) neonicotinoids (thiomethoxam and imidacloprid) and organochlorine (endosulfan), however, was practically ineffective against this pest (Table 1). The presence of various oxido-reductase enzymes in the salivary and mid gut along with the basic hydrolyzing enzymes enable *H. theivora* to become one of the most destructive pests of tea by depredating the young leaves and growing shoots of tea (Sarker and Mukhopadhyay, 2006a). In addition, qualitative and quantitative changes were recorded in the enzymes pattern of the tea mosquito bug (General esterase - Sarker and Mukhopadhyay, 2003; glutathione S-transferase and acetylcholinesterase – Sarker and Mukhopadhyay, 2006d), red spider mite (General esterase - Sarker and Mukhopadhyay, 2006b), and looper caterpillar (General esterase - Sarker and Mukhopadhyay, 2006c) indicated a higher tolerance/ resistance status due to formation of greater amount of esterases, glutathione S-transferase and acetylcholinesterase. One of the main reasons for higher tolerance or resistance by tea mosquito bug and red spider mite to different pesticides was due to mixing of incompatible insecticides with acaricides to combat mixed infestation which, not only decreased the insecticide toxicity but also shifted the level of relative toxicity (Rahman *et al*., 2005b). Table 2 showing the chemical

Table - 4: Central insecticide board (CIB) approved insecticides, acaricides, fungicides and herbicides for the use in tea in India

Insecticides	Acaricides	Fungicides	Herbicides
Dimethoate 30 EC	Dicofol 18.5 EC	Sulphur 80 WG	Dalapon 85 WP
Phosalone 35 EC	Ethion 50 EC	Propiconazole 25 EC	Diuron 80 WP
Quinalphos 25 EC/ 20 AF	Sulfur 80 WG	Hexaconazole 5 EC	Glyphosate 41 SL
Profenophos 50 EC	Propargite 57 EC	Copperoxychloride 50 WP	Simazine 50 W
Deltamethrin 2.8 EC	Fenazaquin 10 EC	Copperoxychloride 77 WP	2,4–D Amine Salt 58 SL
Fenpropathrin 10 EC / 30 EC		Oxyfluorfen 23.5 EC	
Fluvalinate 25 EC			2,4–D Sodium Salt 80 SL
Diflubenzuron 25 WP			Glufosinate Ammonium 13.5 SL
Azadirachtin 5% W/W			Paraquat Dichloride 24 WCS
Flufenoxuron 10 EC			
Fenvalerate 25 EC			

Table - 5: Maximum residue limit (MRL) of pesticides in tea (mg kg^{-1}) fixed by international regulatory bodies for tea exporting countries

Pesticides	FAO / WHO	EPA	CODEX	GL	JAPAN	EC	RUSSIA
Abamectin	-	-	-	-	-	0.02	-
Acephate	-	-	-	0.05	-	0.05	-
Aldrin/Dieldrin	-	-	-	-	-	0.02	-
Bifenthrin	-	-	-	-	-	5.0	-
Buprofezin	-	-	-	0.02	-	-	-
Carbendazim	-	-	-	-	-	0.1	-
Carbofuran	-	-	-	-	-	0.2	-
Cartap	20	-	-	-	-	0.1	-
Chlorpyriphos	0.1	-	-	-	3.0	0.1	-
Copperoxychloride	-	-	-	-	-	*	100
β-cyfluthrin	-	-	-	-	-	0.1	-
Cypermethrin	20	20	-	-	20	0.5	-
Deltamethrin	10	-	10	-	10	5	-
Dicofol	5	45	8	2	-	20	-
Diflubenzuron	-	-	-	0.05	20	-	-
Dimethoate	-	-	-	-	-	0.05	-
Endosulfan	30	24	30	-	-	30	-
Ethion	7	10	5	2	-	3	-
Fenitrothion	0.5	-	-	-	-	0.5	-
Fenpropathrin	-	-	-	0.05	-	-	-
Fenvalerate	-	-	-	-	-	0.05	-
Formothion	-	-	-	-	-	0.05	-
Glyphosate	-	-	-	-	0.5	2.0	-
Hexaconazole	-	-	-	-	-	0.05	-
λ-cyhalothrin	-	-	-	-	-	1.0	-
Lindane	-	-	-	0.2	-	0.05	-
Malathion	-	-	-	-	-	0.5	-
Monocrotophos	-	-	-	-	-	0.1	-
Oxydemeton methyl	-	-	-	-	-	0.05	-
Paraquat	-	-	-	-	-	0.1	-
Phosalone	-	-	-	0.1	-	-	-
Profenophos	-	-	-	-	-	0.1	0.2
Propargite	-	-	-	5	-	5	-
Propiconazole	-	-	-	-	-	0.1	-
Quinalphos	-	-	-	0.1	-	0.1	-
S-421	-	-	-	0.01	-	-	-
Simazine	-	-	-	-	-	-	0.5
Sulphur formulation	-	-	-	-	-	*	-
Tridemorph	-	-	-	-	-	20	-
2,4-D amine salt	-	-	-	-	0.1	0.1	0.5

EPA = Environmental protection agency, GL = German law, EC = European countries, * = Exempted

Table - 6: Safe pre-harvest interval period of different pesticides and their terminal residues (mg kg^{-1}) in made tea

Pesticides	Pre-harvest interval period (days)	Terminal residues (mg kg^{-1})
Dicofol 18.5 EC	7	1.90 – 15.50
	14	0.26 – 8.00
Endosulfan 35 EC	7	1.47 – 10.50
	14	1.15 – 1.26
Quinalphos 25 EC	7	0.02 – 0.08
	14	< 0.02
Ethion 50 EC	7	0.59 – 2.80
	14	0.02 – 0.03
Hexaconazole 5 EC	7	0.48 – 0.49
	14	< 0.1
Copper 50 WP	7	92.6
	14	53.3
Hexaconazole 5 EC	7	0.48 and 81.5
and copper 50 WP	14	< 0.1 & 40.8 copper
Fenazaquin 10 EC	7	7.62 – 10.52
	14	1.63 – 1.96
Neem 0.03 EC and 0.15 EC	1	Below detectable limit
Flufenoxuron 10 WDC	7	0.07 – 0.09
	14	Below detectable limit

compatibility of propargite, fenazaquin, sulfur, cypermethrin with other chemicals against tea mosquito bug and neem with sulfur and ethion against red spider mite. This observation was very important one while handling pesticides as tank-mix and really an eye opener for compatibility experiments and further proper, judicious care will be taken before spraying any tank-mix in tea ecosystem to avoid or delayed the cross-resistance problems.

The effective control of pests on tea is essential to ensure the marketability of this crop. However, despite the low consumption of pesticides, India has more problem of pesticide residue *vis-a-vis* other countries, and these have entered into food products and underground water because of the non-prescribed pesticide use, inappropriate advice and supply of pesticides to planters, non-observance of prescribed waiting period, use of sub-standard pesticides, effluents from pesticide manufacturing units, continued use of persistent pesticides for public health programmes, and lack of awareness and aggressive educational programme for planters/ consumers (Anonymous, 2003a).

Pesticide residues in made tea and the regulations on national and international bodies: After the detection of pesticide residues in food products, the two regulatory bodies -Prevention of food adulteration (PFA) and central Insecticide Board (CIB) imposed stringent rules and regulations for the use of pesticides in tea gardens of India. Now we have been facing two constraints with respect to pest management, *i.e.*, regulatory measures imposed by the exporting countries and Government of India (CIB and PFA). The latest surveillance report of the European Community (EC) indicating the presence of residues in Assam tea is a cause of great concern. Authorization of 300 compounds has already been withdrawn by EC for use on agriculture products, (for example, it withdraws the approval for ethion, which is extensively used for mite control in tea) adversely affected the tea exports of many countries including India. The ethion residue in Indian tea imported into European union countries was higher than the prescribed maximum residue limit (MRL) to the tune of 22.3%, 16.7% and 7.8% in Assam tea and 16.9%, 36.2% and nil in Darjeeling tea in the year 2002, 2003 and 2004 respectively (Anonymous, 2002, 2003b, 2004) (Table 3). Assam and Darjeeling teas continue to record high number of positive values for organochlorine and synthetic pyrethroids pesticide residues, very few of which exceeded the EU maximum residue level. Thus, use of DDT (10.4 to 47.1%), endosulfan (41.1 to 98.0%), dicofol (0.0 - 82.4%) and cypermethrin (6.0 - 45.1) remain comparatively high during 2002 to 2004 in different tea growing areas of North-East states of India (Table 3) (Anonymous, 2002, 2003b, 2004). The use of DDT in Assam tea is increasing and also few samples contained more than 0.2 mg kg^{-1} limits. Further, it is pointed out that impurity in dicofol, which contains DDT as contaminant might cause the adverse effect. The DDT has been banned long back for use in pest management in agriculture. The European Union, after analyzing teas (783 samples out of 6217 tea samples all over the world) imported by them for residue contents, have classified the Indian tea under "higher incidence of pesticide residues group". The MRL for most of the chemicals in EU have been fixed at < 0.1, which has been a major constraint to tea exporting countries (Anonymous, 2002, 2003b, 2004). Thus, the demand for residue free tea is being increased in tea importing countries. Currently, the CIB and PFA regulation committee in India have reviewed the maximum residue limit position for tea and have recommended the use of only ten insecticides, five acaricides, nine herbicides and five fungicides for use in tea (Table 4).

Fixation of maximum residue limits (MRLs): The joint meeting on pesticide residues (JMPR), is an international expert group that consists of the food and agriculture organization (FAO), panel of experts on pesticide residues in food and environment and the world health organization (WHO) core assessment group, has been meeting regularly since 1963. The objective of the JMPR is to recommend MRLs for pesticide residues in food and feed, based on scientific evaluations which are adopted by CODEX through codex committee on pesticide residues (CCPR) for use as international standards by the World Trade Organization (WTO) under the Sanitation and Phytosanitation (SPS) agreement in agricultural commodities moving in international trade. The FAO panel of experts is responsible for reviewing the residue, analytical aspects, metabolism, environmental fate and use pattern of pesticides and for estimating MRLs that might occur as a result of the use of pesticides according to good agricultural practices (GAP). The WHO core assessment group is responsible for reviewing toxicological and related data and for estimating, where possible, acceptable daily intakes (ADIs) for humans of the pesticides (Barooah, 2005; Gurusubramanian *et al*., 2005).

Table - 7: Package of pesticides for managing the different sucking, caterpillar and mite pests in North East India

Pests	Month	Pesticides/biologicals used in Assam and West Bengal tea gardens	Darjeeling tea gardens
Sucking pests (tea mosquito bug, thrips, jassids)	Jan. - Feb.	Neem extract -5% @ 1:1500 *Beauveria bassiana* @3 kg ha^{-1}	Neem extract -5% @ 1:1500 *Beauveria bassiana* @3 kg ha^{-1} *Eupatorium glandulosum* @ 4 kg ha^{-1}
	Mar. - Apr.	Fenpropathrin @ 1:1600 Neem extract -5% @ 1:1500/	Fenpropathrin @ 1:1600 Neem extract -5% @ 1:1500/ *Verticilium leucanii* @1:200
	May - June	Thiomethoxam @ 1:2000 Profenofos @1:1000 *Clerodendron infortunatum* @ 4 kg ha^{-1}	Thiomethoxam @ 1:2000 Profenofos @1:1000/ *Artimisia vulgaris* @ 4 kg ha^{-1}
	July - Aug.	Deltamethrin @ 1:2000 Phosalone @1:400/ *Artimisia vulgaris* @ 4 kg ha^{-1}	Deltamethrin @ 1:2000 Phosalone @1:400/ *Clerodendron infortunatum* @ 4 kg ha^{-1}
	Sept. - Oct.	Dimethoate @ 1:400 Quinalphos @ 1:400	Neem extract –5% @ 1:1500/ *Clerodendron infortunatum* @ 4 kg ha^{-1}
	Nov. - Dec.	Diflubenzuron @ 1:1000 *Beauveria bassiana* @3 kg ha^{-1}	Diflubenzuron @ 1:1000 *Beauveria bassiana* @3 kg ha^{-1}
Mite pests (red spider, pink, scarlet and purple)	Jan. - Feb.	Dicofol @ 1:400 Neem extract-5% @ 1:1500	*Hirsutella thompsoni* @ 1:200 Neem extract @ 1:1500
	Mar. - Apr.	Fenpropathrin @ 1:1600 Phosalone @1:400/ *Clerodendron infortunatum* @ 4 kg ha^{-1}	Fenpropathrin @ 1:1600 Phosalone @1:400/ *Eupatorium glandulosum* @ 4 kg ha^{-1}
	May - June	Fenazaquine @ 1:400 Profenofos @1:1000/ *Polygonum hydropiper* @ 3 kg ha^{-1}	Fenazaquine @ 1:400 Profenofos @1:1000
	July - Aug.	Propargite @ 1:400 Neem extract -5% @ 1:1500	Propargite @ 1:400 Neem extract -5% @ 1:1500
	Sept. - Oct.	Dimethoate @ 1:400 Neem extract @1:1500/ *Acorus calamus* @ 4 kg ha^{-1}	*Verticillium leucanii* @ 1:200 Neem extract @1:1500/ *Artimisia vulgaris* @ 4 kg ha^{-1}
	Nov. - Dec.	Ethion @ 1:400 Sulfur @ 1:400/ 1:200/ *Polygonum hydropiper* @ 3 kg ha^{-1}	*Metarhizium anisopliae* @ 1:200/ Sulfur @ 1:400/ 1:200
Caterpillar pests (red slug, looper, bunch, psychids, flush worm, leaf roller and nettle grub)	Mar. - Apr.	Fenpropathrin @ 1:1600 Profenophos @ 1:1000/ Phosalone @1:400/ *Eupatorium glandulosum* @ 4 kg ha^{-1}	Fenpropathrin @ 1:1600 Profenophos @ 1:1000/ Phosalone @1:400/ *Eupatorium glandulosum* @ 4 kg ha^{-1}
	May - June	Deltamethrin @ 1:2000 Quinalphos @1:400/ Dimethoate @ 1:400/ *Polygonum hydropiper* @ 3 kg ha^{-1}	Deltamethrin @ 1:2000 B.t. formulations @1: 1500/ Dimethoate @ 1:400/ *Artimisia vulgaris* @ 4 kg ha^{-1}
	July - Aug.	Diflubenzuron @ 1:1000 Neem extract @1:1500	Diflubenzuron @ 1:1000 Neem extract @1:1500
	Sept. - Oct.	Dimethoate @ 1:400 Neem extract @1:1500	B.t. formulations @ 1:1500 Neem extract @1:1500

Table - 8: Persistence, residual toxicity, ovicidal action and rain free gap period of different insecticides against adults of *Helopeltis theivora* Waterhouse

Insecticides (hr)	Concentration (%)	Persistence (days)	Residual toxicity(%)	Corrected egg mortality (%)	Rain free gap period after spraying to retain toxicity
Imidacloprid	1:3200	12	48.00	–	4.0
Deltamethrin	1:2000	13	31.66	20.00	0.0
Alphamethrin	1:2000	23	77.00	–	0.0
Thiomethoxam	1:2000	20	52.00	16.80	8.0
Cartap hydrochloride	1:1000	10	30.00	–	0.5
Cypermethrin	1:2000	13	33.00	10.40	3.0
β-cyfluthrin	1:2000	16	62.00	8.80	4.0
λ-cyhalothrin	1:2000	14	67.00	21.60	3.0
Phosalone	1:400	11	65.00	–	8.0
Endosulfan	1:400	12	50.00	0.00	0.0
Oxydemeton methyl	1:400	14	45.00	28.00	4.0
Profenophos	1:400	11	63.25	23.20	5.0

MRL for pesticide application in tea: Tea being the most popular beverage is also monitored most scientifically for detection of any pesticide residues. Various international agencies like environmental protection agency (EPA), food and agricultural organization (FAO), world health organization (WHO), German Laws (GL), European Economic Commission (EEC/EC) *etc.* have fixed the MRL values for tea growing countries. Table 5 shows the recent update position of the MRL values of pesticides fixed by different international agencies and MRL values of the pesticides used in India are <0.1 except a few (cypermethrin – 0.5, dicofol – 20, endosulfan – 30 and propargite – 5). The new rules on the hygiene of foodstuffs (Regulations EC No. 852/2004, 853/2004 and 854/2004), and of the rules on officials controls (Regulation EC No. 882/2004) have already been published by EU. Regulation EC No. 178/2002 of the European parliament and of the council lays down the general principles and requirements of food law, establishing the European Food Safety Authority and procedures in matters of food safety (is also referred to as the General Food Law). The new EU Regulation (No. 852/2004) based on hazard analysis and critical control point (HACCP) principles will be in force from 2006 (EU, 2004). As per the new legislation acephate, bromopropylate, ethion, fenpropathrin, monocrotophos, permethrin, quinalphos, tetradifon, buprofezin, chlorpyrifos, diflubenzuron, S-421, phosalone, profenophos are not authorized for use in EU and their use in tea should be avoided (EU, 2004).

If made tea contains residues in excess of permissible limits, it will not only affect the export of Indian tea but also will reduce the domestic consumption. TRA has organized awareness campaigns among the tea planters of this region since 1994, through seminars and conferences highlighting the need for safer plant protection schedules for minimizing residues so that tea continues to be a health drink. TRA has also generated data on commonly used pesticides in tea through extensive supervised field trials for fixing realistic permissible limits. A number of invoice tea samples have also been monitored for pesticide residues recently, which reveal that most of the tea samples analyzed have their residue level well below the MRL values (Barooah, 2005). In the light of stringent regulations imposed by many tea-importing countries and to enable the planters to offer quality products to their consumers, proper evaluation of safe plant protection schedules is of utmost importance for this premium export oriented crop. A series of supervised field experiments were conducted at different locations to study the dissipation and terminal residues of different pesticides in tea under the actual growing conditions and the results (Table 6) indicated that pesticide residues declined rapidly with time. The above information can help adjust pesticide use. For example, those pesticides that leave residues near or slightly above MRLs in 7 days should be restricted to spot sprays only as and when their use become inevitable. Plucking 3-4 days after application of pesticides will stand a great risk of exceeding MRLs (Barooah *et al*., 1994; Roy *et al*., 2000; Barooah, 2005; Manikandan *et al*., 2006a,b).

Pesticide regulations in India: The objective of the regulation is to ensure protection of citizens against the exposure to pesticides known to be hazardous to human health and environment. In India there are two laws to regulate the pesticide in food (1) prevention of food adulteration act 1954 and (2) the insecticide act 1968. The MRL for some pesticide have been fixed under the prevention of food adulteration act 1954 enacted by Ministry of health and family welfare. The new pesticides molecules are to be registered before their actual use in agriculture.

The registration committee of central insecticide board formed under the insecticide act 1968 has the responsibility to check the data requirement of new pesticides and to ensure that pesticide allowed for use will not leave the residues on food commodities above MRLs. It is also liased with international bodies like EPA, FAO,WHO, Codex *etc.* on pesticide residues in various issues arising out of the pesticide use in developing world. According to FAO international code of distribution of pesticide, it is the duty of manufacturer to provide toxicity data of pesticides use on any agricultural crops. These data should be generated under supervised experiments under GAP and sample collected and analysed under GLP (good laboratory practice) laboratory. Complete current GAP information on pesticides under consideration should be made available to JMPR for recommendation of MRLs along with other relevant data including residue data from

Table - 9: Pesticidal activity of some plants available in and around tea garden for the management of different tea pests

Target pests	Plant	Part used	Pesticidal activity (%)		
			Ovicidal	Antifeedant	Insecticidal / acaricidal
Helopeltis theivora	*Clerodendron infortunatum*	Leaves and succulent stem	0-16.6	61.52 – 71.14	32.2 – 60.0
	Pongamia glabra	Leaves	-	68.67 – 82.33	-
	Pogostemon paniflorus	Leaves	-	72.00 – 87.33	-
	Annona squamosa	Leaves	-	66.00 – 82.00	-
	Lantana camara	Leaves	33.33 – 43.33	35.67 – 40.17	-
	Adhatoda vasica	Leaves	36.67 – 45.71	32.00 – 47.67	-
	Clerodendron inerme	Leaves	32.12 – 46.67	27.33 – 37.00	-
	Pongamia pinnata	Leaves	33.33 – 36.67	33.67 – 35.33	-
	Polygonum orientale	Leaves	39.39 – 46.67	33.33 – 45.00	-
	Melia azaderach	Seeds	-	12.26 – 18.65	-
Oligonychus coffeae	*Clerodendron infortunatum*	Leaves and succulent stem	6.00 – 20.58	-	23.00 – 100.00
	Xanthium strumarium	Whole plant	44.90 – 87.09	-	15.60 – 91.80
	Acorus calamus	Rhizome	33.33 – 70.62	-	06.40 – 88.70
	Polygonum hydropiper	Whole plant	13.29 – 30.86	26.58 – 96.34	12.80 – 84.20
	Pongamia pinnata	Leaves and succulent stem	0.0 – 0.0	-	0.00 – 85.40
	Azadirachta indica	Kernal	14.00 – 65.00	-	30.70 – 95.60
	Lantana camara	Leaves	0.0 – 15.70	-	23.30 – 95.20
Andraca bipunctata	*Clerodendron infortunatum*	Leaves and succulent stem	-	84.5 – 100.00	45.00 – 80.00
	Polygonum hydropiper	Whole plant	-	02.12 – 64.17	-
	Azadirachta indica	Kernal	-	62.00 – 93.58	-
	Eupatorium glandulosum	Leaves and stems	-	35.00 – 62.78	-
	Urtica dioica	Leaves and stems	-	42.85 – 68.96	-
	Polygonum runcinatum	Leaves and stems	-	56.87 – 72.64	-
	Artimisia vulgaris	Leaves and stems	-	62.49 – 78.62	-
Clania cramerii	*Azadirachta indica*	Kernal		80.00 – 90.00	
Microcerotermes sp	*Azadirachta indica*	Seed	-	-	33.2 – 35.6
	Carica papaya	Unripe Fruit	-	-	17.3 – 22.6
	Tagetes erecta	Whole plant	-	-	10.8 – 15.6
	Camellia sinensis	Leaves	-	-	20.8 – 24.6

Table - 10: Different entomopathogens and their effect on different tea pests

Target pests	Entomopathogen	Concentration (%)	Percent mortality
Helopeltis theivora	*Beauveria bassiana*	0.75	34.86 – 58.45
		2.5	41.99 – 61.56
Microcerotermes sp	*Metarhizium anisopliae* (Green)	5.0	46.88 – 48.80
		10.0	49.50 – 56.50
		20.0	53.60 – 59.24
	Paecilomyces lilacinus	5.0	42.15 – 44.67
		10.0	47.25 – 52.86
		20.0	50.67 – 53.78
	Metarhizium anisopliae (Brown)	5.0	40.00 – 42.65
		10.0	43.64 – 45.82
		20.0	45.32 – 49.27
Buzura suppressaria	*Bacillus thuringiensis* var kurstaki	0.001	45.50 – 95.50
		0.002	39.45 – 90.46
		0.004	31.47 – 91.65
		0.006	31.45 – 89.75
		0.008	31.89 – 86.73
		0.01	30.35 – 78.70
	Bacillus sp	0.02	71.45 – 82.35
		0.01	60.00 – 67.46
		0.005	25.46 – 45.75
Andraca bipunctata	*Bacillus* sp	0.02	75.45 – 78.40
		0.01	50.00 – 47.00
		0.005	35.55 – 40.75
Scirtothrips dorsalis	*Verticillium leucanii*	0.01	45.65 – 56.87
		0.005	18.54 – 36.45
Oligonychus coffeae	*Hirsutella thompsonii*	0.01	23.68 – 44.67
		0.005	12.64 – 28.78

supervised trials. The Government of India, ministry of commerce and industry, vide its order ref. S0486 (E) dated 01.04.2005 has issued the tea distribution and export control order 2005 which will help the country to limit the presence of undesirable substances in tea.

Alternative measures: Integrated pest management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and non-target organisms, and the environment. Furthermore emphasis has also been given to the alternative measures complimented with the current practices of chemical control (Gurusubramanian, 2005; Gurusubramanian and Borthakur, 2005; Gurusubramanian *et al*., 2005; Rahman *et al*., 2005a,b).

Cultural practices: Pest prone sections will be kept free from weeds and alternate host plants. For tea mosquito bug control, thinning out the shade trees in heavy shaded areas, removal of all the infested shoots to check the population, follow hard plucking or level of skiff in heavily infested section and during cold weather practices, pruning/ skiffing from periphery towards the centre and around 50 - 60 bushes should be kept untouched for a day or two in the centre to serve as a trap for adults and after thorough spraying of pesticides these bushes should be pruned/skiffed (Gurusubramanian, 2005).

Cultural operations like black plucking (BP) and level of skiff (LOS) along with chemical spraying significantly decreased the infestation level of *H. theivora* (9-50 fold) and increased the crop yield (2-3 times) in comparison with spraying only chemicals without cultural operations. Moderate shade status (60%) coupled with cultural operations (BP and LOS) protected the crop from *H. theivora* with lesser rounds of spray. Unshaded plots suffered more *H. theivora* attack and crop loss (Rahman *et al*., 2005b; Rahman *et al*., 2006).

To check the thrips and red slug population, caustic washing of the trunk of the bushes after cleaning the mosses and lichens and soil stirring around the collar region will kill the pupae and follow hard plucking or level of skiff in heavily infested section (Das, 1981). Red spider mite could be minimized through the correction of shade status, protect the roadside bushes from dust by growing hedge, *Phlogacanthus thrysiflorus* (titaphool), through prevention of migration of red spider mites from infested areas to un-infested areas, through stoppage of cattle trespass inside the tea sections, and through improvement in drainage and nutrition status. *Dalbergia assamica* (Bormedeloa) shade plants should be avoided in looper prone area (Gurusubramanian and Borthakur, 2005).

Mechanical control: Tea mosquito bug: Hand collection of the adults and nymphs during early morning, late afternoon and night on the top hamper of bushes (Gurusubramanian, 2005).

Caterpillar pests: Collection of bunch caterpillar manually during the month of October–November and March – May (bunch caterpillar); November - January and February – April (red slug); and March – April and September – October (looper caterpillar) and soil stirring and collection of pupae during November and December for bunch caterpillar, December and February for red slug, and October - December and March – April for looper caterpillar are the helpful mechanical tools for the management of these pests (Muraleedharan and Selvasundaram, 2002; Gurusubramanian, 2005).

Physical control : The yellow colour sticky traps or yellow pan water traps for monitoring of thrips, light trapping of moths during October – November and March – May for bunch caterpillar, September-October and December – March for red slug, and February – March for looper caterpillar, and spread the used engine oil along the paths in severely infested sections to avoid migration of red slug are used (Das, 1965; Borthakur and Singh, 2002; Muraleedharan and Selvasundaram, 2002).

Chemical control:

Selection and usage of pesticides: Based on the different multilocational trials a package of pesticides in complement with biocides and plant based insecticides for the Assam, Dooars and Darjeeling tea gardens for managing the different sucking, caterpillar and mite pests was developed and their sequence of spraying are shown in Table 7.

Tea mosquito bug: 1) Measures should be taken in prone sections (One round of spray) during Jan-Feb in unpruned sections and late February – early March in pruned and skiffed sections immediately after bud breaking; 2) spraying should be done either in the early morning or in the late afternoon to hit the adults; 3) adults are highly chitinous and longer longevity period (25-55 days) than nymphs. Nymphs are more susceptible to pesticides; 4) after severe attack of pest impose two rounds of applications must be followed at an interval of 7 – 15 days (May – Sept – 7 days; Oct-April – 15 days); 5) mixing of insecticides with foliar nutrients, acaricides and others should be avoided for retaining the toxicity of the pesticides and better control in *H. theivora* prone sections (Table 2); 6) thorough drenching of top, middle and bottom hamper of bushes with spray fluid is mandatory to kill the residual population; and 7) spraying at infestation site – upper and lower surface of the leaves, leaf axils and growing succulent shoots (Table 7) (Gurusubramanian and Borthakur, 2005).

Ovicidal action, bioefficacy, field persistence and rain free gap period to retain the toxicity of pesticides during rainy season of different insecticides were studied against *H. theivora* (Table 8). Highest ovicidal activity was observed in dimethoate. Profenofos, λ-cyhalothrin and oxydemeton methyl gave 20-28 percent egg mortality followed by deltamethrin and thiometoxam (20%). Cypermethrin, β-cyfluthrin, etofenprox (6.56 – 10.4%) were least effective as ovicides. No ovicidal action was observed in endosulfan. Neonate killing of nymphs was recorded in deltamethrin, endosulfan and etofenprox (Table 8). Different new generation molecules have been tested under field conditions and bifenthrin, clothianidin, β-cyfluthrin, imidacloprid, λ-cyhalothrin and thiomethoxam were found effective. Field persistency of different classes of pesticides was evaluated and ranged between 10 and 23 days. Imidacloprid, thiomethoxam and β-cycluthrin persisted for longer period (Table 8). Zero hour rain free gap period was required for endosulfan, etofenprox, deltamethrin, cartaphydrochloride, alphamethrin, fenvalerate, and monocrotophos; 2 hr for dimethoate; 3 hr for cypermethrin; 4 hr for imidacloprid, β cyfluthrin and oxydemeton methyl; 5 hr for quinalphos and profenofos; and 6 hr for acephate after spraying to retain their toxicity. More than 6 hr time was required in case of phosalone and thiomethoxam (Rahman *et al*., 2007) (Table 8).

Tea thrips and jassids: Nymphs cause damage more than adults. Target the nymphs that are susceptible to pesticides. Effective control measures should be taken up during early or middle of February when the initial symptom of attack is noticed on the bushes. Two rounds of application at fortnightly intervals should be done during early part of the season. During peak period of incidence (May – June) two spraying should be done immediately after hard plucking with the recommended pesticides (Table 7) (Gurusubramanian, 2005).

Red spider mite: 1) Measures should be taken (Two rounds of spray at 15 days interval) during December and January in young and unprune tea; skiffed tea - February ; pruned tea – early March; 2) after severe attack of mite impose two rounds of applications (Table 7) must be followed at an interval of 7 – 10 days (April – October – 7 days and Nov-March – 10 days); 3) avoid application of sulfur formulation during hot sunshine and dry spell; 4) coverage of both surfaces of foliage is necessary; 5) during full cropping seasons spraying should be undertaken as spot treatment only; 6) for pruned tea monitoring is necessary soon after tipping; 7) avoid spraying during middle hours of the day in sunny weather; 8) mixing of acaricides with foliar nutrients, insecticides and others should be avoided for retaining the toxicity of the acaricides and better control in red spider prone sections (Table 2); 9) if the attack is heavy, pluck the sections by raising one leaf; and 10) thorough drenching of top, middle and bottom hamper of bushes with spray fluid is mandatory to kill the residual population (Das, 1960; Gurusubramanian and Borthakur, 2005).

Bunch caterpillar, red slug and looper caterpillar: 1) The caterpillar can be controlled by spraying profenophos /phosalone/ quinalphos @ 1:400 / neem formulations 5% @ 1:1500 / diflubenzuron @ 1:1000 in early instars; 2) excellent control can be achieved in late instar by using deltamethrin @ 1:2000; and 3) lower part of the shade tree trunk should be treated with insecticides in the case of red slug infestation (Table 7). Organophosphates (profenophos, and quinalphos)are highly effective against the larvae of tea looper in terms of time mortality, reduction in food consumption and nutritional indices, leaf area protection and preference index than synthetic pyrethroids, organochlorine and neonicotinoids (Bora *et al*., 2007a).

Biological control :

Natural enemies: Natural enemies play an important role in the tea pest population suppression and prevent the pest from attaining critical level. Das (1965, 1974), Borthakur (1981), Borthakur and Das (1987), Das *et al.* (1988), Borthakur *et al.* (1993), Muraleedharan *et al.* (2001), Rahman *et al.* (2005b), Roy *et al.* (2005) have reported the different types of predators and parasites in North East India and their role in suppressing the tea pests. For example, *Chrysoperla carnea, Oxyopes* sp, *Plexippus* sp, *Phidippus* sp, *Marpissa* sp, praying mantids, mermethid nematode (*Hexamermis* sp), and reduviid bug are predatory on tea mosquito bug (Das, 1965, 1974; Das and Barua, 1990; Hazarika and Chakraborti, 1998; Rahman *et al*., 2005b). For the management tea jassid, drynid wasp is an important parasitoid of the nymphs and adults of *E. flavescens* (Das, 1974; Hazarika *et al*., 1994). Larvae and adults of *Sthethorus gilvifrons*, *Verania vincta, Jauravia quadrinotata,* and *Scymnus* sp, staphylinid beetle, *C. carnea*, and predatory mites - *Agistemus hystrix*, *Exothorhis caudate*, *Cunaxa* sp are important natural enemies of tea mites (Borthakur, 1981; Borthakur and Das, 1987; Borthakur *et al.,* 1993, 1997, 2005a,b; Somchoudhury *et al*., 1997; Sarmah and Bhattacharyya, 2002). Tachinid fly, *Cylindromya* sp; larval parasitoids, *Apanteles taprobanae*, *Cotesia* sp, *Asympiesiella* sp, *Elachertus* sp, *Cylindromya* sp, *Argyrophylax* sp and the pupal parasitoid, *Sarcophagous* sp are the effective natural enemies on lepidopteran pests (Das, 1965; Sengupta, 1967; Das and Barua, 1990; Das *et al*., 2006). *Geocoris ochropterus* is the potent predator of tea thrips (Sannigrahi and Mukhopadhyay, 1992).

Plant based insecticides: Certain wild and weed plants available in and around tea gardens having pesticidal properties which could be utilized for tea pest control. The ovicidal, antifeedant and insecticidal and/or acaricidal properties of different native plants available in and around tea plantations are summarized in Table 9 against major pests of tea (Rahman *et al*., 2005a, 2006a; Sarmah *et al*., 2006). Different parts of (5 and 10% aqueous extract) *Pongamia pinnata* (Singh *et al*., 1994), *P. glabra* (Gogoi *et al*., 2003), *Lantana camara* (Sarmah *et al*., 1999), *Clerodendron infortunatum* (Rahman *et al*., 2005), *C. inerme* (Deka and Singh, 2005a), *Acorus calamus*, *Xanthium strumarium*, *Melia azaderach*, *Pogostemon parviflorus* (Gogoi *et al*., 2003), *Polygonum hydropiper* (Sarmah *et al*., 1999, 2006), *Annona squamosa* (Gogoi *et al*., 2003), *Equisetum arvensis*, *Eupatorium glandulosum*, *P. runcinetum*, *Urtica dioica*, *Artimisia vulgaris* (Bisen and Kumar, 1997; Ghosh Hajra, 2001, 2002), and seeds (5 and 10% aqueous extract) of *Azadirachta indica* (Kakoty *et al*., 1993) and *Melia azaderach* are effective for the management of sucking and chewing pests in tea ecosystem.

Biocides: The microbial biocides as *Beauveria bassiana* (Gurusubramanian *et al*., 1999; Barthakur *et al*., 2003; Rahman *et al*., 2006b),*Fusarium* sp (Banerjee, 1979), *Cephalosporium* sp (Hazarika *et al*., 1994; Agnihothrudu, 1999), *Verticillium leucanii* (Barua, 1983; Ghosh Hajra, 2002), *Paecilomyces fumoroseus* (Barua, 1983), *P. tenuipes* (Debnath, 1986), *P. carneus* (Hazarika *et al*., 1994), *P. lilacinus* (Gurusubramanian, 2005), *Hirsutella thompsonii* (Debnath, 2004a), *Metarhizium anisopliae* (Agnihothrudu, 1999; Gurusubramanian *et al*., 1999; Debnath, 2004b), *Bacillus thuringiensis* (Borthakur, 1986; Ghosh Hajra *et al*., 1994; Hazarika *et al*., 1994; Barbora, 1995; Barthakur *et al*., 2003; Rahman *et al.,* 2006b), *Bacillus* sp (Hazarika *et al*., 1994; Barthakur *et al*., 2003) and NPV (LT_{50} – 5.11 days for $1x10^5$ POBs of *B. suppressaria* / ml) (De *et al*., 2006) are effective and have been used widely especially in organic gardens of Darjeeling against for the management of tea mosquito bug, tea mites, tea thrips, tea jassids, termites, aphids, scale insects and lepidopteran pests (looper, red slug, bunch caterpillar, flush worm, psychids, leaf rollers) respectively. The entomopathogenicity of some of native microbials against tea mosquito bug, live wood eating termites, looper, bunch caterpillar and tea thrips are summarized in Table 10.

Effect of pesticides, plant products and biocides on natural enemies: Selective use of pesticides to manage tea pests without adversely affecting natural enemies is important for integrated pest management. Tea plantations are considered highly suitable for biological control programme in view of the type of climate, duration of crop, scale of planting and agronomic practices. So far, more than 40 species of predators and parasitoids each on some of the common pest of the tea in North East India (Das, 1965; Rahman *et al*., 2005b; Das *et al*., 2006). Studies made by Mukhopadhyay and Sannigrahi (1993), Borthakur *et al.* (1995, 2005b) and Sarmah *et al.* (2006) using different pesticides, plant extracts, biocides and neem formulations against *G. ochropterus*, *C. carnea*, *S. gilvifrons* and *A. hystrix* showed most of them are highly toxic and some are moderate to least toxic. Therefore, there is need for development of pesticides or any other products with lower toxicity to beneficial organisms which is desirable for biointensive pest management programme.

Available information suggests that the complex interactions of agricultural chemicals and various field management practices may interfere in the build up of predators, parasites and beneficial and entomopathogenic microbial population. If pesticides are used indiscriminately the ecological balance between pests and natural enemies would be disturbed (Banerjee, 1983; Borthakur *et al*., 1993, 1995; Gurusubramanian *et al*., 2005). The activity of natural enemies in the tea ecosystem implies their effective role as biocontrol agents for maintenance of ecological balance and as biological indicators of health of tea agro-ecosystem (Das *et al.*, 2005). Therefore, restricted use of pesticides and integrated pest management is emphasized so that the indigenous predators, parasites and pathogens that exist in tea ecosystem could be preserved for sustainable crop protection (Borthakur *et al*., 2005b) and also gives an inkling for their better use under IPM program ensuring a healthier pesticide-free tea beverage from North East India (Das *et al*., 2005).

Future strategies: In the recent years, it has become a major concern to the tea industry as the importing countries are imposing stringent restrictions for acceptability of the made tea due to pesticide residues. Changes in pest management tactics are resulting from environmental and human safety concerns, development of insect pest susceptibility change against a few insecticides is now a reality, and increases in pesticide cost and availability. Public concerns over pesticide use have resulted in government action such as a mandated 50% cut in European countries' pesticide use (Matteson, 1995); the EPA, USDA and FDA initiative to implement IPM in the US (US Congress OTA, 1995); FIFRA and FQPA requirements and tolerances for pesticides in the U.S. (EPA, 1997; Klassen, 1998) and CIB label claim and PFA clearance for usage of chemicals in tea in India (Gurusubramanian *et al.,* 2005). 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. At this juncture diverse novel approaches as a) push and pull strategy, b) infochemicals, c) precision agriculture, d) genetic engineering technology, f) crop management tactics, and g) mass rearing technology to maximize the abundance and efficiency of biocontrol agents should be combined in a dynamic way to reduce the pest incidence in low- input farming and creation of environment for beneficials – surely the essence of a new integrated pest management approach for the 21st century. Potential cultural practices for conserving and enhancing the natural enemies need to be integrated with our current crop management strategies for developing sustainable crop protection in promising cropping systems. Recent progress in combining molecular methods and conventional taxonomy for identifying the inter- and intra- species diversity offers scope for the selective deployment of biocontrol agents to match the specific needs of the target ecosystems. Combining of yield monitors (YM), variable rate technologies (VRT), global positioning system (GPS) and geographic information system (GIS) for generating data on insect pest and disease monitoring, weed detection, yield data and pesticide application for decision support system. 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. It is also important to strengthen research on the choice of species/strains of biocontrol agents based on their potential for controlling distinct geographical populations of the target pests. Assessment of the compatibility of entomophages to the pesticides commonly used on the target crops can offer improved scope for their integration. 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. Concurrent initiatives to secure policy support and undertake popularization could help to promote the wider availability and utilization of augmentation biocontrol agents. 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.

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