Chapter 7

Review Report

BIOINTENSIVE INTEGRATED MANAGEMENT OF TEA PESTS FOR SUSTAINABLE TEA PRODUCTION IN NORTH EAST INDIA

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Abstract

This publication provides the rationale for Biointensive Integrated Pest Management (BIPM), outlines the concepts and tools of biointensive IPM, and suggests steps and provides informational resources for implementing IPM. It is targeted to tea growers especially small holders interested in organic agriculture at all levels.

INTRODUCTION

India is amongst the two largest producing and consuming countries of tea in the world. Tea plantations, located in backward rural and remote parts of the country, supplement the economy of these regions through employment generation and social welfare. The tea industry provides direct employment to more than a million workers of whom most belong to backward and tribal classes and more than half are women. More than two million people derive their livelihood from ancillary activities associated with the tea industry (Anonymous, 2007)

Small tea growers, more than 2.5 lakh, in India contribute more than 30% of the country's tea production. While 39% of the small tea gardens are in Assam, Tamil Nadu has 34% of the gardens; North Bengal and Kerala have 24% and 10% of the small holdings, respectively. According to the statistics of Tea Board, India (2007), there are 1033 large and 53457 small tea gardens (Table 1) in North East India. Though the cultivation area under small tea gardens (54489 ha) in NE India is substantially smaller in comparison with big tea estates

Table 1. State wise small grower in tea in India

State	Number	Area (ha)	Production (000 Kg)
Assam	42492	41249	62770
West Bengal	8398	9 00	32245
Tripura	1068	1338	345
Arunachal Pradesh	23	97	NA
Manipur	316	381	47
Sikkim	73	127	NA
Nagaland	1105	1800	141
Meghalaya	12	36	NA
Mizoram	43	88	NA
Uttaranchal	2	13	NA
Himachal Pradesh	3655	1625	375
Bihar	980	1850	1200
Total North India	**58167**	**58104**	**97123**
TamilNadu	61985	43157	78764
Kerala	5999	4810	1969
Karnataka	16	83	232
Total South India	**68000**	**48050**	**80965**
All India	**126167**	**106154**	**178088**

Source: Tea Board of India Statistics 2007.

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(358875 ha) the small tea growers play an important role, complimentary to the tea industry, by way of using limited resources more efficiently and producing tea at lower overhead costs. This in addition to encouraging individual enterprises and decentralized employment generation (Anonymous, 2007).

Pests Scenario in Tea

More than one thousand species of arthropod pests are known to attack tea all over the world, of which only about 300 species of insects are recorded from India, in that 167 species from North-East India (Das, 1965), causing 11 to 55 percent annual loss in yield of tea. The list of serious pests comprises of sucking pests such as tea mosquito bug, red spider mite, thrips and jassids and chewing pests like looper and red slug caterpillar. They become a menace during the flushing period, attaining peak populations during March-July. Other pests are: 1. Termites, both live and dead wood eating in tea, are active in Cachar and North Bank of Brahmaputra during winter season (October February); 2. Root knot nematode, one of the major problems in tea nursery, is more prominent in young tea up to the age of one year: proper care must, therefore, be taken at the time of selection of soil for raising nursery (Table 2) (Gurusubramanian and Borthakur, 2005).

Table 2. Important pest of tea in N.E. India

Pests	Site of Attack
Tea Mosquito Bug (*Helopeltis theivora* Waterhouse)	Buds, Young succulent shoots & tender stems
Red Spider Mite (*Oligonychus coffeae* Nietner)	Upper surface of Mature Leaves
Tea Thrips (*Scirtothrips dorsalis* Hood)	Buds and Young leaves
Tea Jassids (*Empoasca flavescens*)	Mature Leaves
Red Slug Caterpillar (*Eterusia magnifica*)	Mature leaves and bark of 1 or 2 yr old stem
Looper Caterpillar (*Buzura suppressaria*)	Young and mature leaves
Live wood termites (*Microcerotermes* sp.)	Trunk, branches and stems
Root knot nematode (*Meloidogyne* sp.)	Seedlings and root system of young plant (I yr)
Cockchafer grubs (*Sophrops plagiatala*)	Collar & root region of young tea (<3 yrs), Seedlings

Pesticide residue in made tea

The demand for residue free tea has increased in tea importing countries. Pest management is now subject to the regulatory measures imposed by the importing countries as well as to those of the Government of India - Central Insecticide Board (CIB) and Prevention of Food Adulteration (PFA). The latest surveillance report of the European Community (EC) recording the presence of residues in Assam tea, is a cause of great concern. Authorization of 300 pesticide compounds has already been withdrawn by EC for use on agriculture products. Amongst them the withdrawal of the approval for ethion, which is extensively used for mite control in tea, has adversely affected tea exports of many countries including India (Table 3).

TABLE 3. Year Wise Surveillance Report By European Tea Committer On Pesticide Residue In Indian Tea Imported Into European Union Contries

Pesticide	Per cent 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	-

Assam and Darjeeling teas continue to record a large number of positive values for residues of organochlorines and synthetic pyrethroids pesticides, but very few of them exceeded the EU maximum residue level. The DDT has been banned long back for use in pest management in agriculture but a few samples of Assam tea contained more than the limit of 0.2 mg/kg which may lead to surmise that the use of DDT in is increasing. The European Union analyzed 6217 tea samples imported by them from all over the world for residue contents. The Indian teas (783 samples) have been classified under the group "Higher incidence of pesticide residues". The Maximum Residue Limit (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, 2003, 2004).

"Conventional" and "Biointensive" IPM

Pest management is a matter of ecological balance. The size of a pest population and the damage it inflicts is largely a reflection of the design and management of agricultural ecosystem of tea. The tea growers compete with other organisms to harvest pest and residue free product from tea plantations, wanting to secure maximum productivity from a given area with minimum input of resources and energy. However, a faulty tea agricultural system design and/or management make it easy for pests to develop and expand their populations while making it difficult for predators and parasites of pests to exist. In such a situation, the growers will be investing resources unnecessarily for pest management. The approach to the design and management of our tea agricultural system need re-examining. The first step in sustainable and effective pest management is looking at the design of the tea agricultural ecosystem and considering what ecological concepts can be applied to better manage pests and their parasites and predators. We have come to accept routine use of biological poisons in our tea ecosystem as normal. But routine use of synthetic chemicals represents significant energy inputs into the tea agricultural system, and carries both obvious and hidden costs to the tea grower and the society. Attempting to implement an ecology-based discipline like IPM if not properly thought out, in large monocultures like tea, where chemical inputs substitute for ecological design, can be an exercise in futility and inefficiency.

It is now generally agreed that the reliance on insecticides for pest control should give way to different pest management strategies that integrate various other methods such as host plant resistance, cultural alternatives, biological control, and physical control by using ultrasonic waves, even including the use of behaviour modifying chemicals and plant products for pest control. In this context, information on naturally occurring predators, parasites, utilization of wild and weed plants as plant based pesticides and microbial biocides is required to develop nonpolluting, safe methods of pest control in tea. Sustainable tea agriculture is ecologically, economically, and socially viable, in the short as well as in the long term. Rather than standing for a specific set of farming practices, it represents the goal of developing a good practice in tea production system that:

- yields plentiful, affordable, high-quality tea
- does not deplete or damage natural resources (such as soil, water, wildlife, fossil fuels, or the germplasm base)
- promotes the environmental health.
- supports a broad base and diversity of the tea producing unit/s and the health of rural communities
- depends on energy from the sun and on natural biological processes for fertility and pest management
- can be practiced indefinitely.

Biointensive Integrated Management of Tea Pests

Biointensive integrated pest management (BIPM) is "a systems approach to pest management based on an understanding of the pest ecology. It begins with steps to accurately diagnose the nature and source of pest problems, and relies on a range of preventive tactics and biological controls to keep pest populations within acceptable limits." Further, it is an ecosystem-based strategy that focuses on long-term prevention of pests and their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties.

Tools of biointensive IPM

1) Proactive Strategies (Cultural Control)

- Healthy, biologically active soils (increasing belowground diversity)
- Habitat for beneficial organisms (increasing aboveground diversity)
- Appropriate mixing of quality planting materials

The package of cultural practices for the management of different tea pests are enumerated in the following paragraphs:

a) Tea Mosquito Bug:

1) Heavily shaded (89 percent) and unshaded conditions are detrimental in terms of attack and crop loss is concerned.
2) Thinning out of the shade trees in heavy shaded areas.
3) Removal of all the infested shoots to check the pest population.
4) Follow hard plucking or level of skiff in heavily infested sections.
5) During cold weather operations, pruning/ skiffing should be started from periphery and move towards the centre.

Around 50 - 60 bushes should be kept untouched for a day or two in the centre to serve as a trap for adults.

After thorough spraying of biopesticides, these bushes should also be pruned/skiffed (Gurusubramanian, 2005).

6) Cultural operations like black plucking (BP) and level off skiff (LOS) along with chemical spraying, significantly decreased the infestation level (9 50 fold) of H. theivora and increased the crop yield (2-3 times) in comparison with spraying chemicals only 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 from H. theivora attack and crop loss (Rahman et al., 2005a; Rahman et al., 2006) and
7) Hand collection of the adults and nymphs during early morning, late afternoon and evening on the top hamper of bushes (Gurusubramanian, 2005).

b) Tea Thrips:

1) Caustic washing of the trunk of the bushes after cleaning the mosses and lichens, will kill the thrip pupae.
2) Soil stirring around the collar region helps to kill the pupae.
3) Hard plucking or level off skiff in heavily thrip infested section (Das, 1981) and
4) Yellow coloured sticky traps/yellow pan water traps may be used for monitoring thrips (Muraleedharan and Selvasundaram, 2002).

c) Red Spider mite:

1) Unshaded condition is favorable for red spider mite infestation.
2) To prevent migration of red spider mites, the pluckers should be prevented from

entering into un-infested areas from infested areas and cattle trespass inside the tea sections should be stopped and
3) Improve drainage and nutrition status.

d) Caterpillar pests:

1) Soil stirring and collection of chrysalids during November and December for bunch caterpillar, December and February for red slug and October, December and March to April for looper caterpillar.
2) Caustic washing of bush frame during cold weather for red slug.
3) Collection of the caterpillars manually during the months of October November and MarchMay (bunch caterpillar); November-January and FebruaryApril (red slug); and MarchApril and SeptemberOctober (looper caterpillar).
4) Light trapping of moths during OctoberNovember and MarchMay (bunch caterpillar), September-October and DecemberMarch (red slug) and February March (looper caterpillar) and
5) Spread used engine oil along the paths in severely infested sections to avoid migration of red slug (Das, 1965; Borthakur and Singh, 2002).

e) Termites:

1) Bushes should be properly cleaned out at the time of pruning by removing the snags and dead and diseased branches.
2) Pruning cuts should be painted with Indoplast or copper fungicides or Trichoderma bioagents
3) Improve drainage and shade status
4) Destroy termite mounds and queens
5) Remove earth runs and fork the soil around collar region before application of pesticides
6) Soil within a radius of 30 cm from the collar of the bushes should be cleaned of grasses weeds etc.
7) In tea sections where live wood eating termite is present (in Cachar) the mulching materials at the hot slope, should not be left unsprayed.
8) Trunk of the infested shade trees and soil around the collar should be cleaned and sprayed and
9) Spraying when the soil is in moist condition is more effective. Slight irrigation before and after spraying improves the hard and dry condition of the soil for absorption of the applied pesticide.

f) Cockshafers:

1) Planting should be done after proper cleaning of the ground.
2) Cattle manure should not be used in cockchafer prone areas, as it is known to be a source of infestation.
3) Since the beetles and the grubs are attracted to mulched areas, mulch materials should be removed away from the collar region from April on wards.
4) Hand collection of beetles from shade trees, fencing, pillars and wooden posts from March to May and
5) All clonal and seedling areas should be kept weed free.

g) Eelworms:

1) Soil from the nursery site should be tested for eelworm population and acidity status. If the population of eelworm is found to be 6 or above per 10 g of soil tested, it is considered to be unsuitable for use for raising nursery plants
2) Cultivation work (ploughing and harrowing) for preparing the nursery bed should be done to expose and dry the undecomposed weeds and roots of the plants. All sorts of mulch materials should be kept away from the seed nursery to avoid nematode infestation.
3) Plant parasitic nematodes can be killed

by uniform heating (after sieving) of the soil up to 60-70C for 4-5 minutes on plain tin sheets. The soil can be used after heat treatment.

4) Remove weed hosts from nursery beds.

2) Farmscaping

Creation of habitat to enhance the chances for survival and reproduction of beneficial organisms is a concept included in the definition of natural biocontrol. Farmscaping is a term coined to describe such efforts on farms. Habitat enhancement for beneficial insects, for example, focuses on the establishment of flowering annual or perennial plants that provide pollen and nectar needed during certain parts of the insect life cycle. Other habitat features provided by farmscaping include water, alternative prey, perching sites, over wintering sites, and wind protection. The success of such efforts depends on the knowledge of pests and beneficial organisms within the cropping system.

Shade trees play a major role in tea ecosystem to protect the tea bushes from sun scorch and hail damage, drought stress, and conserve soil moisture (Anonymous, 2001). The widely used permanent, semi-permanent/temporary, green crops and fuel wood trees in tea plantations of Northeast India are shown in Table 4. Due to deforestation, firewood scarcity is increasing day by day. It is no longer feasible for the tea estates to depend on the forest for meeting their requirement of firewood. Therefore, where ever possible, the tea estates should make concerted efforts to become self-sufficient in this aspect. Roadsides, sectional boundaries, low lying areas and wastelands can be profitably utilized to grow a variety of trees as sources of fire wood as shown in Table 4.

Table 4. Permanet, Semi-permanent, Temporary Shade Trees, Green And Fuel Wood Trees Widely Used In Tea Cultivation

Permanent shade trees	Semi-permanent & temporary shade trees	Green crops/ hedge planting	Fuel wood trees	
			High sandy loam	Sandy soil
Albizzia odoratissima *A.chinensis* *A. lebbek* *Acacia lenticularis* *A.lenticularis* *Dalbergia sericea* *D. sissoo* *Derris robusta* *Adenanthera pavonina* *Piptadenia falcata*	*Indigofera teysmanni* *Glyricidia sepium* *Albizzia moluccana* *A.procera* *Melia azaderach* *Dalbergia sisso* *Leucaena leucocephala*	*Crotolaria anagyroides* *C.grahamianna* *Tephrosia candida* *T.vogelii*	*Acacia mangium* *Ailanthus grandis* *Albizzia maranguinses* *A.richardiana* *Anthocephalus cadamba* *Artocarpus chaplasa* *Cedrela toona* *Chikrassia tabularis* *Duabanga sonneratioides* *Enterolobium excelsum* *Grevillea robusta* *Melia azaderach* *Parkia rozburghii*	*Acacia auriculiformis* *A.lenticularis* *A.leucocephala* *Cassia siamea*

Further, shade trees are the ideal habitation for many beneficial insects (Rahman et al., 2007). Chemical cues used by herbivores to locate host plants may be altered in an agroforestry system. Trees, shrubs and grasses may exhibit a dramatically different chemical profile masking or lessening the impact of the chemical profile produced by the annual crop (Altieri and Nicholls, 2004). Tea under unshaded conditions is prone to tea mosquito bug, red spider mite and thrips. Planting of Melia azaderach, Adhatoda vasica, lemon grass and Lantana camara as a hedge in tea plantations and growing guaetamala grass during rehabilitation period, ward off different tea pests due to the action of infochemicals produced by the pests.

Tea plants under shaded condition withstood the drought effect and suffered from low pest infestation than the unshaded sections where most of the plants were severely infested and died (Rahman et al., 2007). The roadside bushes can be protected from dust by growing hedge, Phlogacanthus thrysiflorus (titaphool) to minimize the red spider attack. Regular monitoring or removal of alternate or prone host plants pave the way for minimizing pest attack in tea plantations. The list of alternate host plants for different pest species is as follows:

1) Tea mosquito bug Missi (Wild Rhododendron), Mikania, Acalypha sp.(Ornamental plant), Bortengeshi (Oxalis acetosella), Guava, Nooni, Kadam, Jamun, Boal;
2) Red spider mite - Melastoma malabathricum, L. Polyantha, Borreria hispida,Scoparia dulcis, many jungle plants, coffee, jute, cotton caster, mulberry etc.;
3) Melastoma malabrithricum, Borreria hispida, Litsaea polyantha, etc. and young shade trees like A. odoratissima, A. lebbek and A. lucida;
4) Bunch caterpillar - Melastoma malabathricum and Messi;
5) Looper caterpillar - Bormedeloa (Dalbergia assamica), Indigofera teysmanii, A. odoratissima, A. sinensis, Ehratia acuminata (Boal tree) and in A. lebbek. The bushes under these trees may be badly affected by looper caterpillars; and
6) Root knot nematodes - several species of weeds, namely Ageratum conyzoides, Leucas aspera, Oldelandia corymbosa, Oxalis acetosella, Scoperia dulcis and Solanum melongena are more susceptible to eel worm attack.

3) Naturally occurring predators and parasites

Natural enemies play an important role in the tea pest population suppression and prevent the pest from attaining critical level. Rahman et al (2005a) and Roy et al (2005) have reported 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 (Rahman et al., 2005a). For tea jassid, drynid wasp is an important parasitoid of the nymphs and adults of E. flavescens (Das, 1974). Larvae and adults of Sthethorus gilvifrons, Verania vincta, Jauravia quadrinotata, and Scymnus sp., staphylinid beetle, C. carnea, and predatory mites - Agistemus hystrix, Exothorhis caudata, Cunaxa sp. are important natural enemies of tea mites (Borthakur et al., 2005 and 2005a). 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 effective natural enemies on lepidopteran pests (Das et al., 2005 and 2006). Geocoris ochropterus is the potent predator of tea thrips (Sannigrahi and Mukhopadhyay, 1992).

The intensity of predator activity was the highest in Terai (96.46%) followed by Darjeeling (79.37%) and Dooars (77.19%). Regarding the parasites, Terai region exhibited lowest activity of parasites (3.53%) but 20.0 22.80% registered in Dooars and Darjeeling region. Amongst the predators, ladybird beetles (17.34 89.07 %) and spiders (9.61 84.64 %) were predominant in tea ecosystem, which predate upon soft-bodied insects. Syrphids population was recorded more in Darjeeling that checks the aphids and helps in pollination. Praying mantis was more or less at par in all the three regions (0.25 14.42 %). Brown and green lacewings were registered to the tune of 0.15 17.74 and 0.00 3.50 % (Table 5).

Table 5. Abundance of Prodators and Parasitcs in Dooars, Terai and Darjecling Tea Plantations

Natural enemies	Dooars	Terai	Darjeeling
Predators	**per cent population incidence**		
Lady bird beetles	20.84 – 57.77	58.24 – 89.07	17.34 – 33.02
Spiders	32.94 – 61.52	9.61 – 84.64	23.18 – 53.48
Brown lace wing	1.94 – 6.85	0.15 – 2.00	6.89 – 17.74
Syrphids	0.00 – 7.00	0.0 – 9.00	3.00 – 15.00
Praying mantis	0.25 – 15.38	0.57 – 11.94	1.16 – 14.42
Geocoris	0.00 – 5.00	0.00 – 2.00	0.00 – 4.00
Green lace wing	0.50 – 3.50	0.20 – 2.50	0.00 – 0.50
Predatory Pentatomid	0.00 – 4.00	0.00	0.00 – 1.30
Parasites	**per cent population incidence**		
Braconids	42.85 – 80.55	25.00 – 72.72	49.18 – 75.00
Icneumonids	11.11 – 33.62	70.00 – 100.00	42.40 – 48.33
Tachinids	0.92 – 19.71	50.00 – 77.77	1.36 – 21.31
Chalcids	1.00 – 17.50	2.00 – 16.66	2.38 – 5.47

Four parasites were observed in our survey and braconids were abundant in all the regions of North Bengal. Icneumonids and tachinids are predominant in Terai region (50.00 100.00 %) (Table 6) (Rahman et al., 2005a). Somnath Roy et al (2005) surveyed the species richness and seasonal abundance of spider and ladybird fauna in tea ecosystem of North Bengal and found 35 species of spiders and 25 species of lady bird beetles. In that the predominant spiders and ladybird beetles were Oxyopes, Plexippus, Phidippus, Marpissa, Coccinella septumpunctata, Menochilus sexmaculatus,

Table 6: Pesticidal activity of some plants available in and around Ica garden for the management of management of Ilelopelties theivora Waterhouse and Microcerotermes sp. (Aqucous extract - 1.0 and 10.0% concentration)

Target pest	Stage	Plant	Part used	Pesticidal activity (%)		
				Ovicidal	Antifeedant	Insecticidal
Helopeltis theivora	Nymph and adult	*Clerodendron infortunatum*	Leaves	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	13.56 – 33.94
			Leaves	-	8.45 – 14.52	10.52 – 26.39
		Vitex negundo	Leaves	-	-	7.88 – 34.66
		Urtica dioica	Leaves	-	-	12.43 – 21.74
		Nicotiana tabacum	Leaves	32.94 – 70.52	-	40.86 – 90.52
		Datura metel	Leaves	-	-	34.56 – 87.75
		Ageratum conyzoides	Whole plant	-	-	15.54 – 28.93
		Pongamia pinnata	Seed cake	-	45.78 – 66.82	-
		Azadirachta indica	Neem oil	20.55 – 39.03	38.56 – 55.82	-
			Kernal	40.62 – 58.92	42.89 – 83.92	-
		Eupatorium glandulosum	Leaves	29.03 – 48.62	-	46.47 – 67.42
		Artimesia vulgaris	Leaves	22.72 – 34.82	-	38.54 – 49.02
		Helianthus angustifolia	Leaves	29.02 – 36.29	-	34.67 – 48.92
Microcerotermes sp.	Workers	*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

Scymnnus spp. and Micrapis discolor.

4) Plant based pesticides

Certain weeds and wild plants available in and around tea gardens are 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 Tables 6-9 against major pests of tea (Rahman et al., 2005, 2006 and 2007; Sarmah et al., 2006, 2006a, 2007 and 2009). Plant based pesticides can be prepared in the tea estates itself. Leaves,

Table 7: Pesticidal activity of some plants available in and around tea garden for the management of Scirtothrips dorsalis Hood and Empoasca flavescens (Aqueous extract - 1.0 and 10.0% concentration)

Stage	Plant	Part used	Insecticidal activity (%)	
			Scirtothrips dorsalis	*Empoasca flavescens*
Nymphs and Adult	*Ageratum conyzoides*	Whole plant	25.66 – 34.29	18.65 – 32.94
	Eupatorium glandulosum	Leaves	34.86 – 54.68	39.65 – 52.62
	Eupatorium odoratum	Leaves	23.56 – 33.82	34.98 – 50.56
	Artemesia vulgaris	Leaves	29.03 – 33.02	25.64 – 39.33
	Helianthus angustifolia	Leaves	28.90 – 43.22	34.66 – 54.78
	Melia azaderach	seeds	34.90 – 42.16	14.56 – 22.94
		Leaves	12.90 – 19.00	8.64 – 11.34
	Azadirachta indica	Neem oil	54.28 – 69.34	59.43 – 69.66
		Kernal	55.29 – 72.29	55.44 – 70.62
	Helianthus angustifolia	Leaves	30.00 – 38.92	45.68-52.04

Table 8: Pesticidal activity of some plants available in and around tea garden for the management of Oligonychus coffeae Nietner (Aqueous extract-1.00 and 10.00% concentration)

Target pest	Stage	Plant	Part used	Pesticidal activity (%)		
				Ovicidal	Antifeedant	Acaricidal
Oligonychus coffeae	Adult	*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	-	6.40 – 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 – 85.40
		Azadirachta indica	Kernal	14.00 – 65.00	-	30.70 – 95.60
		Lantana camara	Leaves	0.0 – 15.70	-	23.30 – 95.20
		Melia azaderach	seeds	34.76 – 45.94	43.22 – 56.82	45.66 – 64.33
			Leaves	12.64 – 28.61	20.45 – 31.02	20.72 – 39.82
		Vitex negundo	Leaves	18.56 – 33.82	-	21.98 – 34.82
		Adathoda vasica	Leaves	10.00 – 18.83	-	12.98 – 22 63
		Nicotiana tabacum	Leaves	67.94 – 90.66	-	80.00 – 100.00
		Urtica dioica	Leaves	0.0	-	-
		Datura metel	Leaves	32.02 – 40.72	-	34.90 – 45.82
		Ageratum conyzoides	Whole plant	0.0	-	21.68 – 28.02
		Pongamia pinnata	Seed cake	12.06 – 21.82	-	31.03 – 54.04
		Azadirachta indica	Neem oil	45.92 – 79.02	56.02 – 68.01	-
			Kernal	39.01 – 82.75	49.02 – 75.92	-
		Eupatorium glandulosum	Leaves	23.86 – 56.55	-	43.22 – 49.05
		Eupatorium odoratum	Leaves	13.44 – 28.98	-	34.72 – 41.44
		Artemesia vulgaris	Leaves	21.00 – 34.82	-	38.72 – 54.92
		Helianthus angustifolia	Leaves	30.00 – 38.92	-	45.68 – 52.04

Table 9: Pesticidal activity of some plants available in and around tea garden for the management of lepidopterous tea pests (Aqucous extract 1.0 and 10.0% concentration)

Target pest	Stage	Plant	Part used	Pesticidal activity (%)	
				Antifeedant	Insecticidal
Eterusia magnifica	III instar larva	*Azadirachta indica*	Kernel	-	32.90 54.76
		Melia azaderach	Kernel	-	12.88 42.89
		Vitex negundo	Leaves	-	10.98 43.64
Andraca bipunctata	III instar larva	*Clerodendron infortunatum*	Leaves and succulent stem	84.5 – 100.00	45.00 80.00
		Polygonum hydropiper	Whole plant	2.12 – 64.17	
		Azadirachta indica	Kernel	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	III instar larva	*Azadirachta indica*	Kernel	80.00 – 90.00	

succulent stems and rhizome of available wild/ weed plants are collected locally from tea estates during the slack/ off season, chopped, and dried under shade. The dried material is kept in a 100 kg capacity polypropylene bag. Two to four kg of dried plant material is taken into a 200 litre capacity drum, 200 litres of water is added to it and the material is soaked for 48 h. After 48 hours, the extract is filtered using fine cloth. The filtrate is used for direct spray@ 200 litres per ha of tea area. Fresh plant material (four kg/ha) can also be used instead of dried one (2 kg/ha).

5) Biocides

The microbial biocides viz Beauveria bassiana (Gurusubramanian et al., 1999;), Fusarium sp., Cephalosporium sp., Verticillium leucanii, Paecilomyces fumoroseus, P. tenuipes, P. carneus , P. lilacinus (Gurusubramanian, 2005), Hirsutella thompsonii (Debnath, 2004), Metarhizium anisopliae Bacillus thuringiensis, Bacillus sp. and NPV (Gurusubramanian et al., 1999; Debnath, 2004 and 2004a; Rahman et al., 2006; De et al., 2006) are effective and have been used widely especially in organic gardens of Darjeeling, Assam and West Bengal for 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). 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.

Table 10: Entomopathogens and their effect on different tea pests

Target pest	Stage	Entomopathogen	Concentration (%)	Per cent mortality
Helopeltis theivora	Nymphs and adults	*Beauveria bassiana*	0.75	34.86 – 58.45
			2.5	41.99 – 61.56
Microcerotermes sp.	Workers	*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	I - III	*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

....to be continued

Target pest	Stage	Entomopathogen	Concentration (%)	Per cent mortality
	I - III	*Bacillus* sp.	0.02	71.45 – 82.35
			0.01	60.00 – 67.46
			0.005	25.46 – 45.75
	I - III	*Buzura suppressaria* NPV 250 LE	0.1	37.29 – 43.11
			1.0	41.64 – 50.77
			10.0	56.79 – 63.43
	I - III	*Steinernematid* sp.	2600 IJ/ml	44.44 – 72.22
Andraca bipunctata	I - III	*Bacillus* sp.	0.02	75.45 – 78.40
			0.01	50.00 – 47.00
			0.005	35.55 – 40.75
		Steinernematid sp.	2600 IJ/ml	76.66 – 100.00
Scirtothrips dorsalis		*Bacillus* sp.	0.01	45.65 – 56.87
			0.005	18.54 – 36.45
Oligonychus coffeae	Larva, nymph and adult	*Hirsutella thompsonii*	0.01	23.68 – 44.67
			0.005	12.64 – 28.78
	Adult	*Metarhizium anisopliae* (Brown)	0.1	23.55 – 34.87
			0.5	31.00 – 38.83
			1.0	42.76 – 51.18
Eterusia magnifica	I - III	*Eterusia magnifica* NPV 250 LE	0.1	46.89 – 52.71
			1.0	49.73 – 58.89
			10.0	65.88 – 75.00

Biopesticide usage pattern

Quality of the biopesticides should be checked before spraying. Measures should be taken in pest 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. Any plant products should not be mixed with Neem formulations. After severe attack of pest imposes two rounds of applications must be followed at an interval of 7 15 days (H. theivora: May Sept 7 days; Oct-April 15 days; Red spider mite: April October 7 days and Nov-March 10 days). Mixing of biopesticides with other bioformulations should be avoided for retaining the toxicity of the biopesticides and better control. Thorough drenching of top, middle and bottom hamper of bushes with spray fluid is essential to kill the residual pest population. Fungal biocides need above 60% R.H. for sporulation and should not be used during hot summer season.

Based on our extensive laboratory and field observations, a biointensive package has been recommended for Northeast India especially for small holder growers (Table 11) to combat

Table 11: Biointensive package for tea gardens in North East Indian

Pest	Month	Biopesticides used	
		Assam and West Bengal tea gardens	Darjeeling tea gardens
Sucking pests (Tea mosquito bug, thrips, jassids)	Jan – Feb	Neem seed extract -5% @ 1:1500 *Beauveria bassiana* @3 kg/ha	Neem seed extract -5% @ 1:1500 *Beauveria bassiana* @3 kg/ha/ *Eupatorium glandulosum* @ 4 kg/ha
	Mar –Apr	*Clerodendron infortunatum* @ 4 kg/ha Neem seed extract -5% @ 1:1500	*Helianthus angustifolia* @ 1:400 Neem seed extract -5% @ 1:1500 *Verticilium leucanii* @1:200
	May –June	*Bacillus* sp. @ 1:1000 *Metarhizium anisopliae* @ 3 kg/ha *Acorus calamus* @ 4 kg/ha	*Bacillus* sp. @ 1:1000 *Metarhizium anisopliae* @ 3 kg/ha *Artimisia vulgaris* @ 4 kg/ha
	July –Aug	Neem seed extract –5% @ 1:1500 *Pogostemon paniflorus* @ 4 kg/ha *Artimisia vulgaris* @ 4 kg/ha	Neem seed extract –5% @ 1:1500 *Helianthus angustifolia* @ 1:400 *Acorus calamus* @ 4 kg/ha
	Sept –Oct	*Eupatorium glandulosum* @ 4 kg/ha *Metarhizium anisopliae* @ 3 kg/ha	Neem extract –5% @ 1:1500/ *Clerodendron infortunatum* @ 4 kg/ha
	Nov –Dec	*Clerodendron infortunatum* @ 4 kg/ha *Beauveria bassiana* @3 kg/ha	*Eupatorium glandulosum* @ 4 kg/ha *Beauveria bassiana* @3 kg/ha
Mite pests (red spider, pink, scarlet	Jan – Feb	*Acorus calamus* @ 4 kg/ha Neem seed extract -5% @ 1:1500 Sulfur @ 1:400/ 1:200	*Hirsutella thompsoni* @ 1:200 Neem seed extract -5% @ 1:1500 Sulfur @ 1:400/ 1:200

....to be continued Overleaf

Biointensive Integrated Management of Tea Pests

....to be continued from 55

Pest	Month	Biopesticides used	
and purple)	Mar –Apr	*Metarhizium anisopliae* @ 3 kg/ha *Hirsutella thompsoni* @ 1:200 *Clerodendron infortunatum* @ 4 kg/ha	*Helianthus angustifolia* @ 1:400 *Metarhizium anisopliae* @ 3 kg/ha *Eupatorium glandulosum* @ 4 kg/ha
	May –June	*Xanthium strumarium* @ 4 kg/ha *Artimisia vulgaris* @ 4 kg/ha *Polygonum hydropiper* @ 3 kg/ha	*Polygonum hydropiper* @ 3 kg/ha *Xanthium strumarium* @ 4 kg/ha
	July –Aug	*Verticillium leucanii* @ 1:200 Neem seed extract -5% @ 1:1500	*Acorus calamus* @ 4 kg/ha Neem seed extract -5% @ 1:1500
	Sept –Oct	*Clerodendron infortunatum* @ 4 kg/ha Neem seed extract -5% @ 1:1500 *Acorus calamus* @ 4 kg/ha	*Verticillium leucanii* @ 1:200 Neem seed extract -5% @ 1:1500 *Artimisia vulgaris* @ 4 kg/ha
	Nov –Dec	*Artimisia vulgaris* @ 4 kg/ha Sulfur @ 1:400/ 1:200 *Polygonum hydropiper* @ 3 kg/ha	*Metarhizium anisopliae* @ 1:200 / Sulfur @ 1:400/ 1:200
Caterpillar pests (Red slug, looper,	Mar –Apr	B.t. formulations @ 1:1500 *Clerodendron infortunatum* @ 4 kg/ha *Bacillus* sp. @ 1:1000 *Eupatorium glandulosum* @ 4 kg/ha	B.t. formulations @ 1:1500 *Artimisia vulgaris* @ 4 kg/ha *Clerodendron infortunatum* @ 4 kg/ha *Eupatorium glandulosum* @ 4 kg/ha
bunch, psychids, flush worm, leaf roller and nettle grub)	May –June	Neem seed extract -5% @ 1:1500 B.t. formulations @ 1:1500 *Artimisia vulgaris* @ 4 kg/ha *Polygonum hydropiper* @ 3 kg/ha	Neem seed extract -5% @ 1:1500 B.t. formulations @1: 1500/ *Bacillus* sp. @ 1:1000 *Artimisia vulgaris* @ 4 kg/ha
	July –Aug	B.t. formulations @ 1:1500 Neem seed extract -5% @ 1:1500	B.t. formulations @ 1:1500 Neem seed extract -5% @ 1:1500
	Sept –Oct	B.t. formulations @ 1:1500 *Clerodendron infortunatum* @ 4 kg/ha Neem seed extract -5% @ 1:1500	B.t. formulations @ 1:1500 *Artimisia vulgaris* @ 4 kg/ha Neem seed extract -5% @ 1:1500
Termites and weevils	Dec –Feb May - July	*Beauveria bassiana* @1:300 *Metarhizium anisopliae* @ 1:300	*Beauveria bassiana* @1:300 *Metarhizium anisopliae* @ 1:300

different pests. 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. But, it is practically feasible in small holder growers because of smaller area, better scouting and adoption of the technology in a successful manner.

6) Future strategies

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 biointensive IPM strategies to produce residue free tea, increase the exports and meet the consumers' demand.

At this juncture diverse novel approaches as a) push and pull strategy relies on enriching the diversity of plants and natural enemies in and around the cropping environment, b) infochemicals elicit attraction from the natural enemy being specific indicators of insect identity, c) precision agriculture for monitoring pests and plant protection, d) genetic engineering technology to increase the efficiency of biocontrol agents and develop tea crop resistance, f) crop management tactics enhancing biological control in tea system, 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. 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 biopesticides commonly used on tea crop 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 viz. researchers, extension workers, 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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