

# **TEA PESTS AND THEIR MANAGEMENT WITH BIO-PESTICIDES**

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## **ABSTRACT**

*The increasing demand for higher productivity of tea results in its intensive cultivation, which increases the pressure from insect pests on this crop. Chemical pesticides, irrespective of their toxicity status, are being extensively applied. Their various detrimental effects become apparent in the ecosystem including residues in made tea. Bio-control agents such as parasites, predators, and fungal, bacterial and viral pathogens have strong potential to act as effective alternatives to chemical pesticides. In this paper, an attempt has been made to compile all available information on biocontrol research on tea around the world as well as in India. This information will not only help to focus the possibility of using these agents against tea pests, but also will identify the gap of biopesticidal research for designing the future thrusts. Department of Biotechnology Government of India has played a catalytic role and supported several projects on the management of tea pests and diseases in Indian tea.*

**Keywords:** India; tea productivity; pesticide residues; biocontrol agents; biocides

## **INTRODUCTION**

Tea (*Camellia sinensis* [L.] O. Kuntz) has a special place as export-oriented crop. Being a perennial grown as monoculture, tea provides a congenial permanent habitat to different pests (Chen and Chen, 1989; Muraleedharan, 1992; Hazarika *et al.*, 1994a, 2001). Insect pests attack all parts of tea plant viz. root, stem, leaf, flower and seed causing 10-15% loss in yield (Hazarika *et al.*, 2001). In order to ward off the severity of pests, chemical pesticides have been used extensively which also affect natural enemies, encourage development of resistant pests and secondary pest outbreaks, cause health hazards to applicators and leave undesirable residues in made tea (Hazarika *et al.*, 1994a). Pesticide residues in made tea seriously affect the exportability of Indian tea. Likewise health hazard to the consumers are also a matter of great concern. In this context the demand of biological control as a component of integrated pest management (IPM) along with need based

application of safer pesticides could lead to reduction of problems associated with pesticide application including residues and overall cost of made tea (Hazarika *et al.*, 1994a; Hazarika *et al.*, 2001).

## **SURVEY OF NATURAL ENEMIES OF TEA PESTS**

Survey and identification of natural enemies of tea pests were conducted by several workers from different parts of the world (Hazarika *et al.*, 2001). In Sri Lanka, Cranham (1966a) enlisted predators and parasites associated with tea pests, and Danthanarayana (1967) studied the interactions of parasitoids and pests. Identification and description of spider fauna associated with tea leafhoppers was reported from China (Zhang, 1993) and India (Hazarika *et al.*, 2001; Hazarika and Chakraborti, 1998).

Rao *et al.* (1970) catalogued predators, parasitoids and a few fungal pathogens of key pests of tea. Das (1974, 1979) prepared two directories of predators and parasitoids of pests of tea, shade trees and ancillary crops.

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Sarma (1979) reviewed extensively the literatures on biocontrol of tea pests from Indian sub continent. He catalogued a few parasitoids belonging to *Braconidae*, *Euplophidae* and *Tachinidae* as well as predators and pathogens of limacodids. Biology and distribution of predators and parasitoids of insect and mite pests of tea were studied by Muraleedharan *et al.* (1988) from south India. The problems and prospects of biocontrol as an alternative to pesticides in northeast Indian tea plantation were discussed by Borthakur *et al.* (1992) and Hazarika *et al.* (1994a). Somchoudhury *et al.* (1995) identified 38 species of predatory mites of red spider mite from northeast India. Several predatory mites belonging to Phytoseiidae (e.g. *Amblyseius spp.*, *Typhlodromalus spp.* and *Typhlodromips cumulus*) were recorded from tea areas in Kenya (Sudoj, V., 1989a, 1989b).

#### PARASITES OF TEA PESTS

Several workers like Cranham (1966a) and Muraleedharan and Selvasundaran, (1986) highlighted the importance of parasites against tea pests in Sri Lanka. A few species of egg parasitoids of leaf eating caterpillar (*Teleonomus euproctidis* - Scelionidae) on a lymantrid pest (*Euproctis pseudocaspersa*) were recorded in China (Wang, 1981). A few important tortricid species of tea and their larval parasitoids were described in Australia, India, Japan, Papua New Guinea and Sri Lanka by several researchers (Muraleedharan and Selvasundaram, 1986; Danthanarayana and Kathiravetpillai, 1969; Lu, 1993; Cranham, 1966a; Gadd, 1941; Evans, 1952; Takagi, 1978; Huddleston, 1983; Danthanarayana, 1967). Kodomari (1995) recorded *Trichogramma dendrolimi* as one of the common egg parasitoids of tortricids, cossids and tussock moths. The tea lasiocampid was parasitized by *Trichogramma chilonis* (Hazarika *et al.*, 1995a). *Apanteles* sp., an important larval parasitoid of the geometrid, was used to control looper caterpillar of tea in China (Ning *et al.*, 1995).

The red slug caterpillar (*Eterusia magnifica* - Zygaenidae) can be efficiently controlled by braconid, *Apanteles taprobanae* and *Exorista heteresia* (Cranham, 1966a; Ozawa, 1994). Takagi (1978) identified *Arrhenophagus chionaspidis*, *Archenomus bicolor* and *Thomsonisca typical* as parasitoids of white peach scale (*Pseudaaulacaspis pentagona*). *Arrhenophagus chionaspidis*, *Prospaltella (Encarcia) berlesesi* and *Mariella comesi* were also identified as parasitoids of same insects (Ozawa, 1994). A few hymenopteran wasp parasitoids of brown scale (*Saissetia coffeae*) and *Coccus viridis* were also identified from Sri Lanka (Cranham, 1966b).

The thought of biocontrol research on tea is not only confined on native parasitoids and predators, but also the probability of importing such agents and release after augmentation is getting attention. During 1935-36 a parasitoid *Macrocentrus homonae* was introduced from Java, Indonesia to bring complete suppression of the tortricid (*Homona coffearia*), a serious pest of tea in Sri Lanka (Evans, 1952; Gadd, 1941) and is regarded as a classical example of biological control of tea pest (Cranham, 1966b). Conservation of biocontrol agents is essential; however, mass production and release of effective biocontrol agents would bring more success for tea pest management. Attempts in this direction are not at all satisfactory.

#### PREDATORS OF TEA PESTS

The use of predators in controlling tea pests is also an effective method of plant protection. Mzhavanade (1984) released 500 adults of *Cryptolaemus montrouziere* per ha of tea which was sufficient for controlling *Camella* scale. Kokhreideze (1981) recorded predatory efficiency of common earwig adult, *Forficula auricularia*, as 40-75 aphids per day.

Natural enemies present in Kenya include *Scymnus moreletti* (Coccinellidae), *Xanthogramma aegyptium*

(Syrphidae) and *Aphytis* sp. (Aphelinidae), whereas *X. aegyptium* is found more efficient under green house condition (Sudoj *et al.*, 1996). Sudoj and Rotisch (1997) mass-reared *X. aegyptium* and observed that a larva consumed 10 aphids per day. In a survey on spiders in China, a few species of salticids and liocranids as predators of leaf hoppers were identified by Zhang (1993) and marked *Evancha albaria*, *Jotus minutus* and *Telamonia bifurcilinea* as dominant salticids, and *Clubiona corrugata*, *C. japonica* as dominant clubionids. Four anthocorids were identified to predate on thrips (Muraleedharan and Ananthakrishnan, 1978). Sudoj (1987) listed a few spiders, coccinellids and syrphids as predators of *Scirtothrips* sp. along with some entomogenous fungi. Two species of phytoseiid mites, that predate on *Ceroplastes cerifera*, were observed by Lai (1993). Some other predatory mites like *Amblyseius rhabdus*, *A. deleoni*, *Amblyseius* sp., *Tydeus* sp., *Acarus* sp. and an undescribed mite were also reported to predate upon *Acaphylla theae* and *Calcarus carinatus* (Muraleedharan and Chandrasekhar, 1981). Oomen (1982), while studying population dynamics of the scarlet mite in Indonesia, observed that there were two species of insects and 22 species of phytoseiid mites, which preyed upon other mites.

Das (1974) recorded 11 species of Coccinellid predators, six species of syrphid predators and one species of antlion that feed on active form of tea aphid. Many predators and parasitoids were recorded on the nymphs and adults of *Helopeltis theivora* Waterhouse (Miridae), which is a very notorious pest of tea in northeast India. Among these predators a spider, *Oxyopes* sp., preying mantids and reduviids was dominant (Barbora and Singh, 1994). Hazarika and Chakraborti (1998) forwarded opinion about the probable utilization of spiders for controlling jassids and thrips – two common pests of tea. Three coccinellids and three predatory mite species were found to feed on red spider mite and scarlet mite (Borthakur, 1981;

Borthakur and Das, 1987). *Amblyseius giganticus* and *A. rhabdus* are good predators of phytophagous mite (Gupta, 1980; Ray and Gupta, 1983). Predatory mite fauna and prey-predator relationship were studied by Somchoudhury *et al.* (1995). The green lacewing is an important predator of all stages of soft bodied insects. Its predatory efficacy on tea aphid (*Toxoptera aurantii*), red spider mite (*Oligonychus coffae*) and tea mosquito bug (*Helopeltis theivora*) were observed by Hazarika *et al.* (1996).

### MYCOPATHOGENS FOR TEA PESTS

The fungal infection is often observed on tea pests. The basic requirements for fungal growth are high humidity, rainfall and moderate temperature. A few mycoparasites are abundantly found on scale insects, such as *Aschersonia* sp. on *Fiorina theae*, *Saissetia coffeae*, *S. formicarii*, *Duarium* sp. and *Fusarium* sp. on *F. theae*, and *Septobasidium* sp. on *Velataspis sernulata*. *Verticillium lecanii* was considered as an important pathogen of *Coccus viridis* in Sri Lanka (Cranham, 1966a).

In China, *Beauveria bassiana* was used to control a few pests of tea successfully. *B. bassiana* (strain 871) when used @ 100-200 million spores/l at 7.5 to 15.0 Kg/ha gave more than 95% mortality of the brown weevil (*Myloccerus aurolineatus*) on 10<sup>th</sup> day of spraying (Wu and Sun, 1994). Wu *et al.* (1995) sprayed 15-30 kg of the fungus @ 1-2 X 10<sup>8</sup> spores/ml suspension and had about 80% control of the weevil in the field. In China, formulation of this fungus was prepared in order to apply it in combination with synthetic pyrethroid and organophosphorous insecticides in the soil for controlling *M. aurolineatus* during October – December, a period when adults emerge from the soil (Sun *et al.*, 1993).

The role of another pathogen, *Entomophthora* sp. in natural control of *Cerace tetraonis* was established by Debnath and Das (1995). Likewise,

*Poecilomyces carneus* caused 37% mortality to the field population of the mole cricket (*Gryllotalpa africana*), a minor pest of tea in the nurseries (Hazarika *et al.*, 1994b).

Barua (1983) reported the occurrence of *Aspergillus* sp. on dead aphids. The potentiality of utilizing *Verticillium lecanii*, *Beauveria bassiana*, *Aegeria weberri* and *Entomophthora* sp. against scale insects were reported by Barua (1983) and Hazarika *et al.* (1994b). Water suspensions of some plant products and *Verticillium lecanii* containing 3% Sandovit E were sprayed in field and gave marginal control of red spider mite (Hazarika *et al.*, 1995b).

### **VIRAL PATHOGENS FOR TEA PESTS**

The potency of polyhedral virus in controlling lepidopterous insect of tea is countable. Spraying of polyhedral suspensions on the field resulted 98% mortality of the caterpillars, which also contributed toward possible infection to the next generation (Gan, 1981). Shi (1985) and Qi *et al.* (1985) had not only confirmed pathogenicity of BsNPV on *Bazura suppressaria* but also the protection of large area of tea from its attack in Jiangxi, China. NPV was reported earlier from the tea geometrid (*Ectropis oblique*) by Zhu *et al.* (1981) who also contributed towards its histopathology and mode of action. Hu *et al.* (1997) managed *E. obliqua* by spraying  $7.25 \times 10^9 - 1.5 \times 10^{10}$  PIB/mm in the field. In Argentina, Sosa-Gomez *et al.* (1994) created artificial epizootics on a field population of a sphingid (*Penagonia lucasilus*) by applying NPV. The virus also caused severe infection to *Adoxophyes privatana* (Tortricidae) and could kill larvae up to 80-93% within 15-40 days (Liang *et al.*, 1981). Kodomari (1993) reported effectiveness of GV on tea tortrix in Japan, which was originally collected from an oriental species (*Homona magnanima*) by Sato *et al.* (1980). A highly infectious and specific to tea limacodid, *Darna trima* GV (DtGV) was identified from China. The baculovirus was of  $281 \times 73.5$  nm in size; spraying

a suspension containing  $10^6$  granular bodies/ml, controlled 90% of the 4<sup>th</sup> instar larvae of the species with LD<sub>50</sub> as  $2.63 \times 10^4$  GB (Yang *et al.*, 1994). Earlier, Cranham (1966b) checked outbreak of nettle grubs by spraying GV and *Bacillus thuringiensis* in Sri Lanka.

NPV occurrence on the 5<sup>th</sup> instar larvae of bunch caterpillar (*Andraca bipunctata*) as well as on looper caterpillar (*Bazura suppressaria*) in northeast India was reported by Hazarika *et al.* (1995c). NPV, a potent source of biopesticide, has tremendous scope in controlling lepidopteran tea pests. Hazarika *et al.* (1995c) reported for the first time that the NPV efficiently controlled the bunch caterpillar (*Andraca bipunctata*) in field condition. Hazarika and Puzari (2001) observed 80-100% control of pest population by using *B. bassiana* in *H. theivora*, *V. lecanii* in *O. coffeae* and NPV in *Bazura suppressaria*.

### **BACTERIAL PATHOGENS FOR TEA PESTS**

The epizootics potency of pathogens on tea pests is not yet exploited fully (Barua, 1983). However, a few bacterial disease outbreaks were reported in lepidopteran pests (Hazarika *et al.*, 1994a). Commercial formulation of *B. thuringiensis* like Dipel was used for the control of tortricid caterpillar in tea field of Japan. (Kodomari, 1993). He also prepared a suspension by mixing GV and NPV for controlling the pest.

### **EFFORTS MADE BY DEPARTMENT OF BIOTECHNOLOGY (DBT), THE GOVERNEMENT OF INDIA TOWARDS MANAGEMENT OF TEA PESTS**

Biotechnology has great potential in biocontrol. Taking cognizance of need to take the technology of biocontrol from lab to land, DBT has supported a major programme to study the biological control of crop pests, disease and weeds. Under this major programme a national R & D network programme was established in 1989 with the main objectives

of developing better product formulations as well as to develop cost effective, commercially viable mass production technologies of various biocontrol agents. This R & D network programme is a continued activity of the DBT. Besides, this DBT has also launched several other programmes for large scale adaptation of biocontrol based IPM technologies and their adoption by the farmers. During 1994-95 a goal oriented time bound Mission Mode programme was launched on development, production and efficacy demonstration of biocontrol agents. Subsequently, during 1998-99, a major R & D programme on INM/IPM was launched in the country on the use of biological resources for INPM for increasing the agricultural productivity in the existing crop ecosystem of different states representing various agroclimatic zones. Due to pesticide residues, Indian consignments of plantation crops were not accepted outside the country and this has affected the export of this agricultural commodity drastically. Keeping in view the export potential of plantation crops (tea, coffee and rubber) and other crops like cotton, basmati rice, fruits (mango, apple, citrus) spices (ginger, turmeric, black pepper and cardamom) etc. several projects were generated and supported under various programmes by DBT. The main aim is to develop/ generate the technology packages/ capable modules, which are cost effective, sustainable and eco-friendly in different ecosystem.

DBT has played an important role in supporting several projects on pest and disease management of tea crop. The projects are already underway on the development of microbials and plant based pesticides for controlling various pests of tea at Assam Agricultural University (AAU), Tocklai Experimental Station (TES), Regional Research Laboratory (RRL), Jorhat and many other organizations. AAU is situated in the major tea belts of India; it has the distinction of not only offering graduate and post graduate degrees, but it has been also involved in pursuing research and

development activities on tea. This centre has sufficient infrastructure facilities for conducting research on various fields of plant protection including IPM and biocontrol. Considerable progress has been made for the control of pests and diseases of tea at AAU and TES, Jorhat which are highlighted hereunder by citing a few examples.

- (i) A new improved medium for mass production of *Beauveria bassiana* has been developed which is of great significance. The medium is designed to produce  $39.33 \times 10^7$  spores/ml and showed high pathogenicity to insects (85% mortality).
- (ii) 80-100% control of pest population was observed by using *B. bassiana* in *Helopeltis theivora*, *Verticillium lecanii* in *Oligonychus coffeae* and NPV in *Buzura suppressaria*.
- (iii) Infection of NPVs (AbNPV and BsNPV) was detected for the first time in the bunch caterpillar (*Andraca bipunctata*) and looper caterpillar (*Buzura suppressaria*) in tea. *Cryosperla carnea* and *Trichogramma chilonis* were also identified as potential predator and parasitoid of soft-bodied pests and eggs of several lepidopteran pests of tea crop.
- (iv) A few entomopathogens namely *Beauveria bassiana*, *Verticillium lecanii* and *Paecilomyces sp.* were also isolated from tea pests. The feasibility of *B. bassiana* and *V. lecanii* in controlling tea insect pests was established by field application and demonstration. It was recorded that *V. lecanii* could kill 70-80% tea aphid and 70% tea coccid, and thus could protect 83% of the infested tea seedlings.
- (v) TV clones released by TES were screened against *O. coffeae* and *H. theivora* and resistant clones were identified.
- (vi) Aqueous and solvent extracts of various plants were also tested against tea pests. Extracts of *Linostoma decundrum* and *Phlogacanthas sp.* were found to show prominent insecticidal activity against *O.*

*coffea*. Further, characterization and structure-activity determination of its bioactive molecule is being continued for bringing the active molecule to pesticidal formulation in commercial scale.

- (vii) For the first time 28 species of spiders were recognized as potential naturally occurring biocontrol agents against several pests of tea crop and a booklet of "*Spider Complex Of Tea Ecosystem*" was prepared. The spider fauna from tea ecosystem was surveyed and identified subsequently which have potentiality for use as predators of tea pests.
- (viii) Scientists of different centres were also provided several training cum demonstration programmes on the potentiality and usefulness of biopesticides in tea crop protection for the purpose of popularization of the biopesticides application in tea garden. The concept of 'Biological control' among the tea growers of Assam and West Bengal was popularized. The endeavor of the research team of AAU is quite appreciable for its outstanding contribution in development of biopesticides in the context of present-day anti pesticidal campaign.
- (ix) BIOCON (*Trichoderma* biocide) and BIOTOK (*Bacillus* biocide), two biopesticide formulations, were developed at TES, Jorhat. Tea growers of north east India are using these biocides successfully for controlling certain root, stem and black rot diseases of tea crop.
- (x) *Trichoderma* biocide (BIOCON) was provided to 74 member gardens of Tea Research Association from the production unit of TES established under these projects, along with its application technology.
- (xi) TES covered 24 tea estates throughout Assam for assessing biological control of stem and root diseases of tea. Success has been achieved in reducing the rehabilitation period of tea from 2 years to 3-6 months for

replanting purpose through control of root diseases.

- (xii) Besides, several demonstration camps were organized in different tea estates located throughout northeast India and a technical brochure on the use of biopesticides in tea crop for diseases management has been brought out.

## CONCLUSIONS

Among plantation crops, tea has dominance on international export market. Lots of innovative researches are needed to accelerate its production with 100% safety assurance. Pesticide load in tea production is too high, which gives to several problems like residues, health hazards, insect resistance, increase in cost of production etc. Presence of residues in made tea at above MRL results in rejection of Indian tea in international market.

Agricultural pests are developing resistance to many synthetic agrochemicals, and new synthetic chemicals are being registered at a slower rate than in the past. This situation has helped open the market for a new generation of microbial pesticides. Bacterial and viral pathogens need to be exploited in the future. Similarly, pesticide resistant strains of predators and parasitoids have also great potential in this ecosystem where pesticides are applied extensively. Genetic engineering can be exploited for developing tea clones resistant to pests.

Therefore, to reduce the pesticide load and thereby minimizing residue problem, the use of biopesticides may play a crucial role as a component of IPM of tea crop. The work on biological control of tea pests is still in its infancy in India; its success will create a long lasting impact on the commercial tea cultivation. The priority/ thrust areas of biocontrol/ biopesticides were already identified by DBT. There is an urgent need for undertaking basic and applied research in respect

of mass multiplication of biopesticides, product development, and also the introduction, conservation and augmentation of biocontrol agents.

Petch's experience in Sri Lanka left with a somewhat pessimistic view of biological control (Petch, 1925). According to him, "No fungus disease has ever exterminated an insect or prevented an epidemic (outbreak). That such diseases do kill off large numbers of insects periodically and so exercise a considerable natural control is undoubted but it has not yet been possible to improve on nature in this respect". Perhaps the situation has not much changed since then. Therefore, detailed investigations, which require both time and money, are necessary to interpret the complex host-pathogen interactions and to develop appropriate technology to overcome the well-documented constraints to successful implementation in the field as compared to the laboratory situation so that a viable alternative to conventional chemical control can be worked out.

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#### REFERENCES

- Barbora, B. C. and Singh, K. (1994). All about *Helopeltis theivora* : a serious pest of tea. Two and a Bud 41 (2): 2-4.
- Barua, G. C. S. (1983). Fungi in biological control of tea pest and disease in northeast India. Two and a Bud 30 (1/2): 5-7.
- Borthakur, M. (1981). Biological notes on a mite predator of the scarlet mite *Brevipalpis phoenicis* (Geijsken). Two and a Bud 28 (1): 18-19.
- Borthakur, M.; Borthakur, M. C.; Kakaty, N. N. and Das, S. C. (1992). Prospects of biocontrol of tea pests. In " Proc. 31<sup>st</sup> Tocklai Conf.", TRA, Tocklai Experimental Station, Jorhat, pp. 118-130.
- Borthakur, M. and Das, S. C. (1987). Studies on acarine predator of phytophagous mite on tea in North East India. Two and a Bud 34 (1&2): 21-24.
- Chen, Z and Chen, X. (1989). An analysis of the world tea fauna. J. Tea Sci. 9 (1): 13-22.
- Cranham, J. E. (1966a). Monographs Of Tea Production In Ceylon : Insect And Mite Pests Of Tea In Ceylon And Their Control. Tea Research Institute of Ceylon, Talawaklle.
- Cranham, J. E. (1966b). Tea pests and their control. Ann. Rev. Entomol. 11: 491-514.
- Danthanarayana, W. (1967). Tea entomology in perspective. Tea Quart. 38 (2): 153-177.
- Danthanarayana, W. and Kathiravetpillai, A. (1969). Studies on the ecology and causes of outbreaks of *Ectopis bhurmitra* Wlk. (Geometridae), the twig caterpillar of tea in Ceylon. J. Appl. Ecol. 6 (2): 311-322.
- Das, S. C. (1974). Parasites and predators of pests of tea, shade trees and ancillary crops in Jorhat circle in North East India. Two and a Bud 21: 17-21.
- Das, S. C. (1979). Parasites and predators of tea pests. Two and a Bud 26 (2): 72-73.
- Debnath, S. and Das, S. C. (1995). Outbreak of *Cerace tetraonis* Butl., a new record of tea pest from Northeast India. Two and a Bud 42 (1): 37-39.
- Evans, J. W. (1952). The injurious insects of the Commonwealth Institute of Entomology, London.
- Gadd, C. H. (1941). The control of tea totrix by its parasite, *Macrocentrus homonae* Nixon. Tea Quart. 14: 93-97.
- Gan, Y. K. (1981). Studies on the NPV of *Buzura suppressaria*. Acta Entomol. Sinica 24 (4): 372-378.
- Gupta, S. K. (1980). Phytoseiidae (Acari : Mesostigmata) from J & K, India with description of 5 new spp. Ind. J. Acarology 5 (1/2): 32-36.

- Hazarika, L. K.; Borthakur, M.; Singh, K. and Sannigrahi, S. (1994a). Present status and future prospects of biological control of tea pests in North East India, In "Proc. 32<sup>nd</sup> Tocklai Conference", Tea Research Association, Tocklai Experimental Station, Jorhat, pp. 169-177.
- Hazarika, L. K.; Puzari, K. C. and Barua, G. (1994b). Fungi as microbial insecticides on mole cricket. *Two and a Bud* 41 (2): 22-25.
- Hazarika, L. K.; Borthakur, B. K. and Singh, K. (1995c). A new pathogen of tea bunch caterpillar. *Two and a Bud* 42 (1): 40-41.
- Hazarika, L. K. and Chakraborty, S. K. (1998). Spider complex of tea ecosystem in Assam. Res. Bull. No. AAU/DA/E1, Assam Agricultural University, Jorhat.
- Hazarika, L. K.; Saikia, M.; Sarma, M. K. and Borthakur, M. (1995a). Parasitization by *Trichogramma chilonis* on tea lasiocampid. *Two and a Bud*, 42 (1): 32-34.
- Hazarika, L. K.; Sarma, M.; Saikia, M. K. and Borthakur, M. (1995b). Biochemical basis of mite resistance in tea. Nat. Conf. on Ins. Biochem. Mole. Biol., Trivandrum.
- Hazarika, L. K.; Sarmah, M. K.; Borthakur, M. and Singh, K. (1996). Evaluation of green lacewing as a predator of tea pests. *Two and a Bud*, 43 (1): 37-39.
- Hazarika, L. K. and Puzari, K. C. (2001). Microbials in tea pest management. In "Microbials In Insect Pest Management", (eds. S. Ignacimuthu and A. Sen), Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, pp. 99-104.
- Hazarika, L. K.; Puzari, K. C. and Wahab, S. (2001). Biological control of tea pests. In "Biocontrol Potential And Its Exploitation In Sustainable Agriculture", (eds. R. K. Upadhyay, K. G. Mukerji and B. P. Chamola), Kluwer Academic / Plenum Publishers, New York, pp. 159-180.
- Hu, C.; Ye, G. Y.; Zhu, J. and Shang, J. N. (1997). Studies on the application on the nuclear polyhedrosis virus in the tea garden for controlling *Ectropis obliqua* Prout (Lepidoptera : Geometridae). *Wuyi Sci. J.* 13: 215-220.
- Huddleston, T. (1983). *Meteorus* (Hymenoptera : Braconidae) of Australia and New Guinea. *Syst Entomon.* 8 (4): 339-420.
- Kodomari, S. (1993). Microbial control of insect pests of tea in Japan. In "Proc. Internat. Symp.", Tea Tech., Tea Research Association, Calcutta.
- Kodomari, S. (1995). Ecology of *Trichogramma dendrolimi* on tea fields in Japan. In "Proc. 1995 Internat. Tea Quart. – Human Health Symposium", Shanghai, China.
- Kokhreideze, G. G. (1981). The earwig a predator of aphids. *Zaschita Rastenii* 8: 50.
- Lai, C. B. (1993). Study on the bionomics of *Ceroplastes ceriferus* Anderson in tea garden and its control. *Entomol. Know* 30 (6): 337-338.
- Liang, D. R.; Zhang, Q. L.; Guang, D. M.; Gan, Z. Y. and Lin, M. Y. (1981). A study of the granulosis virus of *Adoxophyes privatana* experiment on isolation, identification and infection. *Hubei Nongye Kexue* 8: 19-23.
- Lu, W. M. (1993). Population dynamics of the geometrid and its forecasting. *China Tea* 15 (4): 26-28.
- Muraleedharan, N. (1992). Pest control in Asia. In "Tea Cultivation to Consumption", (eds. K. C. Wilson and M. N. Clifford), Chapman and Hall, London, pp. 375-411.
- Muraleedharan, N. and Anantakrishnan, T. N. (1978). Bioecology of four species of *Antnocooridae* (Hemiptera : Insecta) predaceous on thrips, with key to genera of Anthocorids from India. Occasional Paper, Records of the Zoological Survey of India 11: 1-32.



- Muraleedharan, N. and Chandrasekharan, R. (1981). Observation of the seasonal variation of *Acaphylla theae* Keifer and *Calacarus carinatus* (Green) (Acarina : Eriophyidae) in a tea field at Annamalais. *Pestology* 5 (6): 11-15.
- Muraleedharan, N. and Selvasundaran, R. (1986). New records of parasites of flushworm and leafroller of tea. *Entomon.* 11 (4): 262-263.
- Muraleedharan, N.; Selvasundaran, R. and Radhakrishnan, B. (1988). Natural enemies of certain tea pests occurring in southern India. *Ins. Sci. Appl.* 5: 647-654.
- Mzhavanade, V. I. (1984). *Cryptoleamus* against *Camellia* scale. *Zashchita Rastenii* 7: 26.
- Ning, X.; Zongmao, O.; Kunshan, Y.; Hufau, W. and Xiaqing, Y. (1995). Induction of volatile parasitoid attracting synomone in tea plants by feeding of tea geometrid (*Ectropis obliquahypulina* Wehali) larvae and behavioural response of *Apanteles* sp. to different odors. In "Proc. 1995 Internat. Tea Quality Human Health Symposium", Shanghai, China.
- Oomen, P. A. (1982). Studies on population dynamics of the scarlet mite, *Brevipalpus phoenicis*, a pest of tea in Indonesia. *Medelingen Landbouwhogeschool, Wageningen* 82 (1): 1-88.
- Ozawa, A. (1994). The occurrence of the white peach scale *Pseudaulacaspis pentagona* (Targioni) in tea fields and its control. III. Effects of various pesticides in the control of the scale. In "Proc. Kanta. Plant Protection Society", No. 41, pp. 257-259.
- Petch, T. (1925). Entomogenous fungi and their use in controlling insect pests. Department of Agriculture Ceylon, Bulletin No. 71, pp. 1-40.
- Qi, Y. P.; Ye, L. B.; Yin, Y. N.; Liu, N. C.; Zhang, Y. C. and Yu, Y. Z. (1985). Field trial of BsNPV against tung oil tree loopers. *Chinese J. Biol. Con.* No 3, pp. 19.
- Rao, G. N.; Dutta, B. and Ramashiah, G. (1970). Natural enemy complex of flushworm and phytophagous mites on tea in India. *Tea Board, Calcutta*, pp. 53.
- Ray, S. and Gupta, S. K. (1983). Some new records of phytoseiidae from India (Acarina : Mesostigmata). *Records of Zoological Survey of India* 80 (3/4): 301-307.
- Sarma, P. V. (1979). Possibilities of integrated control of major pests of tea in India. *PANS* 24: 237-245.
- Sato, T.; Oho, N. and Kodomari, S. (1980). A granulosis virus of the tea tortrix, *Hormona magnanima* : its pathogenicity and mass production method. *Appl. Entomol. Zool.* 15: 409-415.
- Shi, Y. E. (1985). The economical effect of large area control of *Buzura suppressaria* with BsNPV. *Chinese J. Biol. Con.* 3: 46.
- Somchoudhary, A. K.; Saha, K.; Sarcar, P. K.; Choudhary, A. and Bhattacharyya, A. (1995). Approaches to integrated control of red spider mite, *Oligonychus coffeae* (Nietner) on tea. In "Proc. 1995 Int. Tea Quality Human Health Symposium", Shanghai, China.
- Sosa-Gomez, D. R.; Kitajima, E. W. and Rolan, M. E. (1994). First record of entomopathogenic disease in Paraguay tea agroecosystem in Argentina. *Flor. Entomol.* 77 (3): 378-382.
- Sudo, V. (1987). Thrips, their identification, spatial distribution and biocontrol agent with special reference to genus *Scirtothrips* Shull – a review. *Tea* 8 (1): 33-36.
- Sudo, V.; Mwangi, J. M. and Kipsang, D. (1996). Preliminary survey of natural enemies of citrus aphid, *Toxoptera aurantii* (Homoptera : Aphidae) in tea at Timbilil estate, Kericho. *Tea*, 17 (2): 50-52.
- Sudo, V. and Rotisch, F. (1997). The rearing of hoverfly, *Xanthogramma aegyptium* (Diptera : Syrphidae) for use as a biological agent in controlling citrus aphid, *Toxoptera aurantii*

- (Homoptera : Aphidoidea) in tea. Tea 18 (1): 42-44.
- Sun, J. D.; Wu, G. Y.; Lin, A.; Zeng, M. S.; Wang, Q. S. and Xu, D. Y. (1993). Investigation and demonstration of the integrated control of the tea weevil by a mixture of pesticides and microbes. Tea Sci. Tech. Bull. 3: 32-34.
- Takagi, K. (1978). Trap for monitoring adult parasites of tea pests. JARQ 12 (2): 99-103.
- Wang, W. X. (1981). Biology of *Telenomus euproctidis* Wilcox (Hymenoptera : Scelionidae) an egg parasite of the tea lymantrid, *Euproctis pseudocospersa* (Lepidoptera : Lymantridae). Acta. Entomologica Sinica 24 (4): 384-389.
- Wu, G. Y. and Sun, J. D. (1994). A study and application of *Beauveria bassiana* (Bals. Vuill. in the control of the tea brown weevil. China Tea 16 (1): 30-31.
- Wu, G. Y.; De, S. J.; Shen, Z. M. Aug, L. A.; Yean, X. D. and Shen, W. Q. (1995). Application of *Beauveria bassiana* strain 871 in controlling tea weevil (*Mylloceris aurolineatus*). J. Fujian Acad. Agri. Sci. 10 (2): 39-43.
- Zhang, J. W. (1993). Dominant population and species of spiders preying on leafhoppers in tea plantation. Tea Commun. No. 1, pp. 17-19.
- Zhu, G. K.; Hon, J. W.; Zhao, H. F.; Yao, Y. E.; Lin, X. Q. and Zhau, X. D. (1981). Identification of a nuclear polyhedrosis virus in tea geometrid, *Ectropis obliqua* Warren. Weishengyue Tongba 8 (3): 102-103.