

**INTEGRATED CONTROL OF TEA MOSQUITO BUG, *Helopeltis*
theivora Waterhouse, BY CULTURAL METHOD AND
RELEASE OF NATURAL ENEMIES**

A Thesis
Submitted to the
Bidhan Chandra Krishi Viswavidyalaya
for the award of the Degree of Doctor of Philosophy
in
AGRICULTURAL ENTOMOLOGY

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MARCH, 1998

Dedicated to
my
Parents



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CERTIFICATE

This is to certify that the work embodied in the thesis entitled " Integrated control of Tea Mosquito bug Helopeltis theivora Waterh., by cultural method and release of natural enemies", submitted by Sri Partha Protim Dhar for the award of the degree of Doctor of Philosophy in Agricultural Entomology of Bidhan Chandra Krishi Viswavidyalaya, is the faithful and bonafide research work carried out under my supervision and guidance. The results of the investigations reported in the thesis have not so far been submitted for any other Degree or Diploma. The help and assistance received during the course of investigation have been duly acknowledged.

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Partha Protim Dhar

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CHAPTER - I

I N T R O D U C T I O N

CHAPTER - I I N T R O D U C T I O N

In the long history of human civilization, man has selected and improved three important nonalcoholic beverages from nature's rich store house of plant resources - the extract of tea-leaves, the extract of coffee beans and the extract of cocoa-beans. Of the three beverage, tea is the oldest known and is now the most popular beverage. It is generally believed that tea originated somewhere in South-East-Asia. From this region tea has spread to different parts of the world. There are three distinct subspecies i.e. assamica, sinensis, and cambodia, on the basis of commonality in their morphological and biological features. The commercial success of initial plantations attracted a lot of public attention and there was a "tea mania" with plantations extending to Darjeeling, Cachar and Sylhet, Dooars and Terai, as well as Nilgiri Hills of South India and Kumaon (Barooah, 1993).

Tea is cultivated in our country in about 4,00,000 hectares. The consumption in India is the highest in the world even with a low per capita consumption of 600 gms (Roy, 1989). It is generally estimated that between Rs. 8,000 and Rs.10,000 per hectares is paid by the industry as government revenue in different forms. What is the most encouraging that in terms of productivity per hectare of land, tea ranks on the top, compared to the country's ranking of 35 in wheat and tobacco, 36 in rice, 43 in sugarcane, and 46 in pulses (Sarkar 1984).

As a long-lived woody perennial and monoculture, tea provides a stable microclimate and a continuous supply of food for rapid build up of phytophagous species. More than 300 species of insect, mite and eelworms are active, though not all at the same time (Banerjee, 1987). Among the group of insects, the tea mosquito bug has assumed the status of a major pest in recent years in several tea growing areas in West Bengal and Assam (Somchoudhury, 1993). Next to tea mosquito bug, mites, thrips and looper cause severe crop loss in tea. Out of different species of tea mosquito bug, Helopeltis theivora Waterh is endemic to the North-East India, (Watt and Mann, 1903; Hainsworth, 1952; Das 1965). In the year 1867, the crop loss was as high as 22,500 kgs in medium size tea garden in the district of Cachar, Assam (Watt and Mann, 1903). A severe outbreak of the pest occurred in the Dooars (Nagrakata-Sub-district) in 1958 inflicting a total loss of 7,50,000 kgs of made tea in eleven gardens (Das, 1965). Banerjee (1978) recorded the crop loss due to tea mosquito bug to a modest figure of 220 kgs of made tea per hectare. Beside tea, tea mosquito bug is known to attack cocoa, cashew, guava. Prior to the use of modern chemical pesticides, crop losses on tea plantation in India were sometimes, total under different situations (Muralioedharan, 1987).

The typical feeding injury of tea mosquito bug is always indicated by total blacking of the pluckable shoots and

in due course the shoots dries up. During the course of feeding the insect secret pectinase enzyme (Miles, 1987), as a result of its growth inhibitory action, the bush fails to produce subsequent two to three flushes.

Since early 1950s, the chemical insecticides are being used till today to combat the tea mosquito bug. During epidemic chemicals are the modern chemical insecticides, DDT was the first to be widely used to combat infestation of tea mosquito bug and remained as the standard chemical due to its long persistence, inspite of the development of resistance as early as 1961 (Tan, 1974). After the phasing out of DDT, short duration pesticides like endosulfan, phosalone, quinalphos, synthetic pyrethroids came into being in the control of the pest. The effectiveness of these chemicals remained obscure as these are mostly used after the damage was done by the pest. The typical dispersing nature of the pest, from the site of infestation, helps the pest to invade, by the contact of short persistent chemicals like organophosphorus and synthetic pyrethroid.

The repeated use of chemicals, on the other hand, invite contamination of made tea with toxic residue of chemicals.

The clonal resistance to tea mosquito bug has not been investigated in detail. No effective clones or seed stock of tea is available to contain the pest.

Under this situations the best possible ways are likely to be the monitoring of the pest to minimise the use of pesticides as well as to use the other methods of control like cultural and biological means to give a definite shape to 1PM concept against this pest.

Therefore, maximum emphasis was given to study the influence of abiotic and biotic factors in population of tea mosquito bug.

CHAPTER - II

REVIEW OF LITERATURE

CHAPTER - II REVIEW OF LITERATURE

2.1 Origin of Helopeltis spp. :

Plant bugs of the genus Helopeltis are serious pests of various cultivated plants in the old world tropics. The damaging effects of these insects on tea plants in India was documented over a century ago in reports by Peal (1873) and Wood-Mason (1884). It was in these early accounts that the common name 'tea-bug' and 'tea-mosquito' were established, as well as various names referring to the damage that results from feeding, including 'tea-blight', 'mosquito-blight' and 'spot-blight'. Since the late 1800s over 100 species of plants have been reported as hosts for Helopeltis spps. including a number of major cash crops such as black pepper (Piper nigrum), Cashew (Anacardium occidentale), cinchona (Cinchona spp.) Cocoa (Theobroma cocoa) and tea (Camellia sinensis). In tea it was first recorded in Java in the year 1847 (Rao, 1970). In India the pest was noticed in the year 1968 in Cachar (Watt and Mann, 1903).

2.2 Taxonomic characterisation of Helopeltis spp. :

Helopeltis belongs to the tribe Monalonini, which is distinguished from other groups of Bryocorinae by the elongate, cylindrical body form, the structure of the pretarsus, the reduced numbers of meso and metafemoral trichomae, the metathoracic scent efferent system lacking developed ostiole and evaporative area on metaepisternum and the eggs with respiratory horns (Schuh 1976).

Helopeltis is readily distinguished from other members of the tribe by the large, spine like process on the scutellum and by characteristics of the male and female genitalia, particularly of the genital chamber of the female.

Helopeltis theivora Waterhouse (Hemiptera :Miridae) , major pest of tea and cocoa in India and Asia, distinguished from other species of the subgenus by a combination of characters : base of antennal segment I narrowly pale, distal third of antennal Segment IIa and much of segment III of male with long, erect setae; head usually with broad, pale stripe laterally; pronotum usually with anterior half of collar and at least anterolateral margins of disc pale, or sometimes more broadly pale, leaving only posterior margin of disc infuscated abdominal sterna 1-V uniformly pale laterally (Stonedahl 1991).

2.3 Distribution of Helopeltis spp. :

The genus Helopeltis has a palaeotropical distribution extending from West Africa to New Guinea and northern Australia. It was first described by Waterhouse in the year 1886. Leefmans (1916) stated that four species of Helopeltis in Java. Two of these were H.antonii Sign. and H.cinchonae Mann. Beside the species, H.antonii was reported by him from the localities which is more than 4,300 feet above the sea level. Scientist Roepke (1916) has also given some account on its distribution in Java. According to Rao (1970), the tea mosquito bug was first recorded on tea in Java in the year 1847.

The island of Sri Lanka falls between 6° and 7°N latitude. The tea area occur mostly around 7°N latitude in the mountainous country on the South-Western part of the island. Occurrence of the different species of Helopeltis was reported by several authors on tea, cashew and cocoa cultivated in the island. Distant (1904) recorded two species viz. H.antonii Sign. and H.oryx sp. n on tea. Beside H.antonii, H.ceylonensis infesting cocoa from ceylon (Entwistle, 1965).

Danthanarayana (1967) reported from Ceylon (Sri Lanka) that the tea mosquito bug was a rare low country pest, largely confined to the Morawak-Korale district causing damage to tea. Other than tea and cocoa, cashew is cultivated in Sri Lanka and H.antonii was also found infesting cashew which was confirmed by Jeevaratnam and Rajapakse (1981).

In Indonesian tea also suffered from the damage of Helopeltis antonii Sign. (De Jong, 1934).

This genus was also reported from East Africa by Harris (1937).

Da Silva Barbosa (1958) mentioned that Helopeltis schoutedeni Reut is a major pest of cotton in Mozambique. Later this was confirmed by Neves Evaristo (1969).

In Malawi Sweeney (1965) could observed that H.schoutedeni and H.anacardii Miller infesting on tea, eucalyptus and many other hosts.

In Central African Republic the cocoa plants were infested by H.westwoodii (White) (Boulard, 1967). In the same year Lavabre and Boulard recorded the pepper shoots were severely damaged by the same species.

In Kenya and Tanzania the cashew plants were infested by the Helopeltis anacardii Miller (Nganga 1977; Intini and Sijioana 1983).

In Zambia the mango plants were found infested by the H.schoutedeni Reut observed by Javaid (1985).

In Malaysia three species of Helopeltis were recorded by several scientists in tea. Miller (1939) described the new species Helopeltis theobromae sp.n. But the other two species i.e. H.bradyi Waterh and H.cinchonae Mann were the most common insect pest of tea.

Different species of tea mosquito bug were also recorded from Nigeria infesting on cocoa, cotton crops. Golding (1941) reported that Helopeltis bugs infesting cocoa. Similarly Kay (1961) reported that among many other mirids, H.bergrothi Reut. caused damage to cocoa. On the other hand Hayward (1967) observed in cotton plants that Helopeltis was the major pest causing severe damage to the crop.

Distribution of the genus Helopeltis is also confirmed in the Cameron highland (Lever, 1949).

Two scientists namely Dun (1954) and Smith (1978) both observed in Papua New Guinea that only the tea mosquito bug H.clavifer (Wlk.) infesting cocoa plant. But cotton plant is attacked by the different species of Helopeltis.

In Ivory Coast H.schoutedeni Reut. was found to be a principal pest of cotton; (Angelinii and Vandamme 1965).

It is interesting to note that H.bergrothi Reut. has been found by Lodos (1969) as causing wilt of cherelles in Ghana. Leston and Gibbs (1971) stated Helopeltis species as a pod feeder of cocoa in Ghana.

In North East India Helopeltis theivora Waterhouse. was being an important pest so far as tea is concerned. Watt and Mann reported in 1903 that it was prevalent in many tea growing areas of India. Das (1965) reported that it was a major pest of tea in Darjeeling, Dooars, Cachar. Other than tea, this particular species was first recorded in Kerala infesting Cashew (Ambika and Abraham 1983). Helopeltis antobii Sign. was reported in India infesting cashew (Ambika and Abraham 1979 and Pillai 1979).

2.4 Nature and symptoms of damage of tea mosquito bug :

Among the tea growing countries in the world, different species of the mosquito bug infesting tea. Beside tea, their infestation was also noticed in cocoa, cashew, mango. But their nature and symptoms of damage differs within the tea plant and also among the other crops. In general the typical feeding damage by Helopeltis spp. appears as a discoloured necrotic area or lesion around the point of entry of the labial stylets into the plants tissue. The lesion may be elongate or spherical and become darker with age as the tissue around the stylet puncture dies, presumably in response to the enzymatic action of the insects salivary secretions.

Tan (1974) reported that cocoa pod wilt was mostly restricted to fruits when pods were less than 5 cm long, but larger damaged pods had reduced dry bean weight. He also found that both the nymphs and adult feeding on tea shoots. Males of H.theivora preferred the green shoots of older flushes, while the adult females preferred the reddish shoots of new flushes. In these feeding trials, the mean number of lesions per day ranged from one to 17. Das (1984) reported that a single late instar nymph of H.theivora could make as many as 80 feeding lesion in a 24 hour period. Affected leaves often curl and become deformed, sometimes dying from the tip or edges inward. Helopeltis antonii is the most serious pest of commercially grown cashew in India,

with crop losses sometimes reaching 30-40% (Devasahayam & Nair, 1986). The nymphs and adults feed on the leaves and stems of new shoots, the inflorescence panicles and on the developing nuts. In severe infestation the young shoots and panicles dry up, giving the infested trees a scorched appearance. Successive attacks on new growth results in stunting or death of the tree. Damage to the immature nuts cause them to shrivel, while older nuts develop a blistered or scabby appearance. Infestations during the early stages of fruit set often result in immature fruit drop. Miles (1987) reported the presence of a pectinase enzyme in the salivary glands of H.clavifer, and noted that the insect feeds by evacuating the contents of individual plant cells, leaving the cell walls intact and uncollapsed. The nature and extent of damage varies with the species. Feeding damage on pods provides an avenue for secondary invasion of micro-organisms, and also serves to attract other pests such as the cocoa pod borer, Conogethes punctiferalis (Guenee) (Lepidoptera : Pyralidae) (Chong, 1987, Fernando & Manickavasagar, 1956). Feeding on cocoa occurs primarily on the pods in all stages of development and on young shoots. Pod feeding is preferred by both nymphs and adults, with adult longevity and fecundity being much greater in pod reared individuals (Awang et al., 1988). In Africa H.bergrothi however doesn't confine its attack to leaves or young petioles, but traverses considerable length of green stem, in some instances making punctures every few millimeters. The necrosis caused by the salivary injection extends for some distance from the point of puncture and these dead areas of cortex

develop a severe canker especially when a series of them coalesce. The canker persists as the stems grow and mature, but the wound callus that is stimulated never entirely heals the lesion. The result is the gnarled stem canker of tea described by Leach & Smee. The condition of the attacked branches further deteriorates because of infection by fungi. Goodchild has isolated a *Phomopsis* and *Pestalotiopsis angusta* from old canker.

2.5 Assessment of damage of *Helopeltis* spp. :

Plant bugs of the genus *Helopeltis* is important polyphagous pest. Of many crops (e.g., tea, cotton, manogamy, quinine, fruit trees, but especially important on tea, cocoa and cashew. They damage the young tender parts of the plant, the insertion of the mouth-parts causing lesions which spread by necrosis and eventually lead to a drying up of the tissue. Very few studies on crop loss have been undertaken.

2.5.1 Tea -

It is evident from the work of Watt and Mann (1903) that the loss in production due to *Helopeltis theivora* was as high as 22,500 kgs made tea in the district of Cachar, Assam, in the year 1967. Similarly Das (1965) reported the crop loss of 7,50,000 kgs of made tea in eleven garden in the Dooars in the year 1958. The damage is caused by both adults and nymphs which usually feed in the morning and afternoon. Das (1984) reported that a single late

instar nymph can make as many as 80 feeding lesion in a 24 hours period. Banerjee (1978) after assessing different parameters of crop loss caused by the tea mosquito bug, the 220 kgs of made tea per hectare.

2.5.2 Cocoa -

Beside tea, tea mosquito bug Helopeltis spp, known to cause heavy damage to cocoa shoots and fruits. Tan (1974) reported that mean number of lesion caused by tea mosquito bug H.theivora, per day ranges from 1 to 17. Golding (1941) estimated 42.32% of cocoa pod damage by Helopeltis in Nigeria. Koy (1961) also recorded 20% crop loss in Gold Coast. Entwistle found that the loss ranges from 60-80% due to tea mosquito bug attack.

2.5.3. Cashew -

Among the major pests of cashew, tea mosquito bug Helopeltis antonii Signoret is the most serious one. Both adult and nymphs of the pest suck sap of tender shoots, inflorescences and immature fruits resulting in shoots and inflorescence blight immature fruit drop and shrivelling of nuts. Several workers have estimated the damage potential of this pest. Sathiamma (1977) reported that nymphs can produce 114 lesions, while adult female and male can produce 97 and 25 lesions per day on cashew. He also categorised that 14% shoot, 3% stems, 1% leaves, 10% stems and leaves and 48.5% panicles damaged by this pest. Sundararaju(1979..)

reported 30-40% cashew crops loss in Goa. Nambiar et al. (1980) has estimated that a total of 30% cashew crop loss by this single pest.

Similarly Devasahayam (1985) also reported the crop loss by tea mosquito bug.

Several workers also found the tea mosquito bug infesting guava, pepper, causing severe damage (Gopalan and Perumal, 1973; Blacklock, 1954; Pillai, 1978).

2.6 Mass rearing of tea mosquito bug :

Mass rearing of any insect is one of the most essential for detail studies like varietal screening, isolation of pheromone, chemical control, mass culturing of its natural enemies etc. Otherwise the pest can not be controlled properly. Extensive studies have been conducted on the biology of tea mosquito bug. (Anonymous, 1974; 1976; Amruth Sudhakar, 1975; Ambika and Abraham 1979; Das, 1965; Sathiamma, 1984). A viable mass rearing technique is not developed on tea mosquito bug.

Few workers developed mass rearing of mirid bug on artificial diet. Debott and Patana (1985) developed a rearing method of Lygus hesperus knight on artificial diet and reported that more than 60 percent nymphs survived.

Sundararaju (1992) has been standardized a method for mass rearing of H. antonii in cashew under laboratory condition on

cashew shoots. According to his findings 50.9% to 93.9% of the nymphs attained adult stage during different months which is in concurrence with the findings of Smith (1973) who reported about 70% nymphs of H.clavifer Walker. reaching adult stage when reared on cocoa pods. Even though, Entwistle (1972) indicated that most of cocoa mirids are difficult to breed and maintain in laboratory.

2.7 Monitoring of tea mosquito bug :

Any ecological approach to pest control, survey and surveillance, monitoring are the first step of integrated pest management. Different type of traps are the major means of monitoring of pest, which causing severe damage at low population level. Few work has been^{done} regarding monitoring of tea mosquito bug.

Smith (1977) has indicated the presence of a sex attractant pheromone in female of Helopeltis clavifer. Sundararaju(1994) also found the presence of sex pheromone in tea mosquito bug and influence of age. According to his study, the 3 and 4 day old female attracting male, this results are in conformity with earlier studies on eight other species of mirids (Scales, 1968; Strong et al., 1970 King, 1973; Bovin & Stewart, 1982; Slaymaker & Tugwell, 1984; Graham, 1987; Thristlewood et al., 1989). Sex pheromones are helpful in the early detection of pests and their timely control.

Rattan (1984) worked out a method of monitoring tea mosquito bug H. schoutedeni by counting the number of damaged and healthy shoots on a number of randomly selected bushes for timely application of pesticides.

Azhar (1983) worked out a forecasting on H. theobromae Miller in cocoa. The tea mosquito bug was more active in the evening after the onset of the rainy season and their population density was high in October to February.

2.8 Factors influencing tea mosquito bug population :

2.8.1 Abiotic factors -

Insect pests being poikilothermic, the climatic factors exercise a dominating influence on their development, longevity, reproduction and fecundity. It is well known that densities of pest populations fluctuate with the prevailing weather conditions such as temperature, moisture, light and wind.

The typical tea ecosystem is formed due to the changed natural shape of the tea bush by pruning and plucking into a flat "plucking table". The ecological studies of Helopeltis with respect to the tea ecosystem not yet done extensively. Some scientists reported the response of temperature, relative humidity separately during the life cycle study.

2.8.1.1 Temperature and relative humidity -

Devasahayam (1986) reported that the population development was negatively correlated with minimum temperature, maximum temperature, relative humidity. He also stated that at a temperature range of 24°C - 32°C and relative humidity of 47 to 100 percent, the incubation period of tea mosquito bug H. antonii lasted for 6-7 days and nymphal period for 10 days.

Ambika and Abraham (1979) reported that $25 \pm 0.5^\circ\text{C}$ was the most suitable for fertilization and oviposition and $2.8 \pm 0.5^\circ\text{C}$ ideal for embryonic development and progeny production. Sundararaju (1992) gives an indication that H. antonii can be reared throughout the year in the prevailing room temperature of 26.5 to 32.0°C and relative humidity of 79.2 to 97.2 %.

2.8.1.2 Rainfall and light intensity -

There are some evidences indicating that tea mosquito bug population fluctuate in response to more localised and less regular climatic events, tending not to do well under conditions of heavy rains, high winds or low relative humidity (Lever, 1949; Miller, 1941; Betrem, 1950; Pillai et al., 1976). Lever (1949) noted that feeding caused by H. bradyi and H. cinchonae on tea in the Cameron Highlands (Malayasia) was the most severe during the period of dull, calm, misty weather, the insect being much less active under conditions of heavy rains, wind and or bright sunshine.

Azhar (1983) done some preliminary observation on the ecology of selected cocoa pest in West Malayasia. The mirid H. theivora Waterhouse was more active in the evening than by day, actively remained high during the night.

Das (1984) reported in India that the feeding activity of tea mosquito bug (H. theivora) on tea is highest in the early morning and late afternoon, and that the adults prefer shaded, more humid position near the centre of the plant.

Similar observation made by Smith et al. (1985) regarding the activity of H. clavifer on tea in New Guinea.

2.8.2 Biotic factors -

Besides the abiotic component of the environment, insect life is also influenced by the biotic factors such as food and natural enemies, and they are important components of the concerned life-system. It is not only the individuals of the subject species that are influenced by the abiotic environment but also the biotic factors.

2.8.2.1 Alternate host -

Fletcher (1914) reported the occurrence of Helopeltis antonii on tea, mahogany, neem, cocoa, cinchona and - annatto (Bixa orellana). The pest has been recorded on redgram in South

Kerala (Rau, 1937) and guava in South India (Cherian, 1937). All the eleven varieties of guava in an orchard in Tamil Nadu were found susceptible to the pest (Gopalan and Perumal, 1973). The biology of the pest has been studied on guava at Bangalore (Sudhakar, 1975).

H.antonii has been recorded on apple and grape vines in Mysore. On the apple, the feeding activity of the bugs caused the flowers to dry up and young fruits to develop a scabby appearance. On grapevines, tender leaves and developing fruits were attacked resulting in the drying up of the affected tissues (Puttardiah and Appanna, 1955).

Pillai, Saradamma and Nair (1979) observed the pest on Moringa oleifera in Trivandrum and Quilon districts of Kerala. The pest was observed to complete its life cycle on the tree and its infestation resulted in withering and die back of terminal shoots, drying up of inflorescences and incomplete development of fruits.

At Vittal, H.antonii was recorded on tender shoots of mango, neem, Syzygium sp. and on cocoa (Anonymous, 1983). The pest infestation on mango and neem resulted in the drying up of the entire shoot; on Syzygium sp. necrotic spots were seen on the tender leaf lamina. On cocoa the damage was seen on the pod in the form of scabby spots; when cherelles were infested they dried up completely.

Helopeltis antonii has been observed to damage tender shoots and leaves of black pepper, allspice and Eugenia jambos in some tracts of Calicut district in Kerala (Debasahayam, Abdulla Koya and Prem Kumar, unpublished) Sundararaju (1984) has recorded the pest damaging Lawsonia alba in Goa.

Helopeltis theivora attack a number of plants, especially in the jungle. Melastoma malabathricum L.; Maesa ramentacea A.D.C.; Eurya acuminata D.O. and Jasminum sandens Vahl. have recorded as common alternative host, (Das, 1965). According to his observation Mikania micrantha, a creeper, which grows abundantly in and around tea gardens found to be another host plant in which the insect breeds.

2.8.2.2 Natural enemies -

Biological control programme against Helopeltis spp. have not been attempted, but the high level of parasitism provided by some egg and nymphal parasitoids certainly warrant further investigation. In most instance, it appears that natural enemies, which playing an important role in control, can not maintain populations of Helopeltis spp. below economic thresholds.

A great number of natural enemies of Helopeltis spp. have been reported by several authors. In 1985 a species of Reduviid bug was found by Watt (Watt & Man, 1903). Later this author recorded Sycanus sp. and Melamphaus sp. feeding on tea mosquito bug. In

Darjeeling they also recorded a spider feeding on H.theivora.

In Indonesia some species of Mautids and a Reduviid bug Sycanus collaris F recorded feeding on tea mosquito bug but they had no practical importance Leefman (1916). It was found in Assam that a mermithid worm and an ichneumon fly were two parasites on tea mosquito bug. The parasitisation by the worm was only 2% of the population (Anonymous, 1920). In Malaysia, Erythmelus helopeltidis has been reported to parasitize up to 36% of the fertile eggs of H.cinchonae on tea (Lever, 1949). Dun (1954).has stated that predators like Pristhesanctus sp. (Reduviidae), an attid spider and an ant Cecophylla smaragdina were active on cocoa capsid. De Silva (1962) reported from SriLanka that Sycanus collaris (F) was present on Helopeltis ceylonensis a pest of cocoa. There was no parasite recorded other than predator. Lodos (1968) reported a Telenonus sp. parasitising eggs of various mirids. Rates of parasitism varied from 10-17% for H.bergrothi, 25-66% for Bryocoropsis laticollis Schum. and less than 10% for S.singularis & D.theobroma. Simmonds (1970) listed the recorded natural enemies of Helopeltis spp. from Africa and Asia, and of other cocoa mirids from West Africa and Collingwood (1977) discussed the effectiveness of those that have been studied.

Simmonds (1970) listed the recorded natural enemies of Helopeltis spp. from Africa and Asia, and of other cocoa mirids from West Africa, and Collingwood (1977) discusses the effectiveness of those that have been studied (Table 2.1).

Table 2.1 Recorded natural enemies of Helopeltis spp. and other mirids (modified from Simmonds (1970) and Collingwood (1977)* marks species considered to be of some value

Parasites	Locality	Host
Hymenoptera:		
Braconidae		
<u>Leiothorax anates</u> (Nixon)	Ghana, Nigeria	<u>Helopeltis</u> sp.
* <u>L. helopeltidis</u> (Ferriere)	Java, Sri Lanka	<u>H. antonii</u> Sign. <u>H. thelvora</u> Waterh.
<u>L. nigricarpus</u> (Szépl.)	Nigeria	<u>H. bergrothi</u> Reut. <u>H. schoutedeni</u> Reut.
* <u>L. sahlbergellae</u> (Walkn.)	Ghana, Nigeria	<u>Sahlbergella</u> <u>singularis</u> Hagi.
Encyrtidae		
<u>Encyrtus cotterelli</u> Wtstn.	Ghana	<u>Distantiella</u> <u>theobroma</u> (Dist.)
Mymaridae		
* <u>Erythmelus helopeltidis</u> Gah.	Malaysia	<u>H. cinchonae</u> Mann.
Scelionidae		
* <u>Telenomus</u> sp.	Ghana	<u>H. bergrothi</u> , <u>Bryocrotopsis</u> <u>laticollis</u> Schum,
<u>Telenomus</u> sp.	India	<u>H. cinchonae</u>
Trichogrammatidae		
<u>Trichogramma minutum</u> Ril.	Sri Lanka	<u>H. antonii</u> .
Predators		
Dictyoptera :		
Mantidae		
<u>Micromantis formosa</u> Shir.	Taiwan	<u>H. fasciaticollis</u> Popp.
* <u>Panurgica compressi-</u> <u>collis</u> (Sauss.)	Ghana	<u>D. theobroma</u>
<u>Pseudocreobotra ocellata</u> (P. de B.)	Ghana	<u>D. theobroma</u>
<u>Tenodera aridifolia</u> (Stoll.)	Taiwan	<u>H. fasciaticollis</u>
<u>T. sinensis</u> (Sauss.)	Taiwan	<u>H. fasciaticollis</u>

(Contd..)

Hemiptera:

Pentatomidae

<u>Amyotea reciprocas</u> Szent-Ivany	Papua New Guinea	<u>H.clavifer</u> (Wlk.)
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Reduviidae

<u>Carcinomma astrologus</u> Bergr.	Congo	<u>S.singularis</u>
* <u>Cosmolestes picticeps</u> Stal.	Malaysia	<u>H.bradyi</u> Waterh. <u>H.cinchonae</u>
<u>Endochus africanus</u> (Bergr.)	Ghana	<u>D.theobroma</u>
<u>E.cameronicus</u> Miller	Malaysia	<u>H.bradyi</u> , <u>H.cinchonae</u>
<u>Euagorus plagiatus</u> Burm.	Malaysia	<u>H.bradyi</u> , <u>H.cinchonae</u>
* <u>Isyndus heros</u> F.	Malaysia	<u>H.bradyi</u> , <u>H.cinchonae</u>
<u>Rhinocoris carmelita</u> Stal.	Ghana	<u>D.theobroma</u>
<u>R.marginellus</u> Thnb.	Malaysia	<u>H.bradyi</u> , <u>H.cinchonae</u>
* <u>R.obtusius</u> (P.de B.)	Ghana	<u>D.theobroma</u>
<u>Sycanus collaris</u> (F.)	Sri Lanka	<u>H.ceylonicus</u> De Silva
	Indonesia	<u>Helopeltis</u> spp.
* <u>S.leucomesus</u> Wlk.	Malaysia	<u>H.bradyi</u> , <u>H.cinchonae</u>

Diptera :

Asilidae

<u>Maira</u> sp.	Papua New Guinea	<u>H.clavifer</u>
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Syrphidae

* <u>Allograpta</u> (Xanthogramma) <u>pfeifferi</u> Big.)	Nigeria	<u>Helopeltis</u> sp.
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Hymenoptera :

Formicidae

<u>Crematogaster wroughtonii</u> Forel	India, Sri Lanka	<u>H.antonii</u>
* <u>Dolichoderus bituberculatus</u> (Mayr.)	Java	<u>Helopeltis</u> spp.
* <u>Oecophylla longinoda</u> (Latr.)	West Africa	<u>D.theobroma</u> , <u>S.singularis</u> .

(Contd..)

Table 2.1 (Contd.)

<u>O.smaragdina</u> (F.)	Papua New Guinea	<u>H.clavifer</u> , <u>Pseudodoniella</u> <u>typica</u> (China & Carvalho)
<u>pheidole megacephala</u> (F.)	Ghana	<u>D.theobroma</u>
* <u>tetramorium</u> (<u>Macromischoides</u>) <u>aculeatum</u> (Mayr.)	Ghana	<u>D.theobroma</u>
3.Nematodes		
<u>Agamermis paracaudata</u> Steiner	Java, India	<u>H.antonii</u> , <u>H.theivora</u>
<u>Hexamermis microamphibidis</u> Steiner	Java	<u>H.antonii</u>
4. Fungi		
<u>Beauveria</u> sp.	West Africa	<u>D.theobroma</u>
<u>Hirsutella</u> sp.	Ghana, Nigeria	<u>S.singularis</u>

Rao et al. (1971) has listed many Reduviid predator which have been released in Malaysia against H.bradyi Waterh. and H.cinchonae Mann. The predators were Rhinocoris marginallus Thub., Sycanus leucomesus Wlk., Euagorus plagiatus Mann., Isyndus heros F. Cosmolestes picticeps stal. Among these S.leucomesus Wlk., I.heros F., and C.picticeps Stal, have established on the host. The other spp. of Reduviid, namely, Endochus cameronicus Miller. Isyndus sp. and Euagorus sp. were also recorded as indigenous to tea mosquito bug in Malaysia . Ambika and Abraham (1979) reported that an ant Crematogaster wroughtonii Forel, as a predator of Helopeltis antonii nymphs infesting cashew . Similarly Jeevaratnam and Rajapakse (1981)

have found C.wroughtonii Forel, and Cecophylla sp. as a predator of H.antonii in Sri Lanka . Other than the nymphal parasite, eggs of H.antonii were parasitised by Trichogramma spp., especially T.minutum Ril, in Sri Lanka but the mean level of parasitism was low in October and January, when populations of the pest were high Sivaram (1982) found a parasite Erythmelus helopeltidis Gah. on H.bradyi Waterh. and H.cinchonae Mann in Malaysia. Leiophron helopeltidis (Ferriere), a parasite of H.theivora Waterh. in Java but it was hyperparasitised by Stictopisthus javensis (CIBC 1983). In digest, presented by CIBC (1983) regarding the possibilities for the use of natural enemies in the control of Helopeltis spp. More natural enemies of the mirids were known from West Africa than other areas. Egg parasite and nymphal parasites of the genus Leiophron appeared to be promising.

Sundararaju (1984) stated that a spider, Hyllus sp., (Salticidae) and five species of Reduviids, S.collaris (Fab.), Sphecanoletes signatus Dist., Irantha arnispes stal., Occamus typicus Dist. and Endochus inornatus Stal. were found as predators of H.antonii in Goa. Devasahayam and Nair (1986) further added three types of spiders namely. Oxyopes schireta, Phidippus patch and Matidia sp. predator of H.antonii in India . Ibrahim (1989) recorded Erythmelus helopeltidis Gah. and two species of Telenomus sp. parasitizing the eggs of Helopeltis theobromae in Malaysia. Lim et al. (1989) have found that the fungus Beauveria bassiana is highly pathogenic to the adults of H.theobromae. Graham (1991) worked on the

biological control of Helopeltis spp. in mature cocoa by black ant Dolichoderus bituberculatus. It was found from his investigation that the nymphs of Helopeltis spp. could not tolerate the presence of the ant as a result very few puncture wounds by the pest species was observed on the cocoa pod. Heirbamt et al. (1992) studied the biological control of H.theobromae by using artificial nest of black cocoa ant, Dolichoderus thoracicus Smith in Malaysia. Six different types of artificial nests were established in cocoa plantation. A large polythene bag filled with cocoa leaves gave the best result per unit investment.

Sundararaju (1993) studied on the parasitoids of H.antonii Sign. of cashew in South India. Three species of Hymenoptera endoparasitoids, viz., Telenomus sp. (Hymenoptera, Scelionidae), Chaetostricha sp. (Trichogrammatidae) and Erythmelus helopeltidis Gah. (Mymaridae) were recorded on the eggs. Bochartia sp. (Acarina : Erythroridae) was recorded as an ectoparasite on nymphs and adults. Telenomus sp. was observed almost throughout the year with a range of 1.8 to 45.5% parasitism, where as Chaetostricha sp. was noted mostly during cropping season (Nov-May) with relatively low level of parasitization of 0.7% to 4.3% .

2.9 Cultural Control :

Agricultural operations like plucking, pruning and manuring can be manipulated to reduce the incidence of pest on tea. It is an important component of integrated pest management. Much

information is not available regarding the control of Helopeltis by using cultural practises. Few workers reported that the cultural practices like pruning, plucking, weeding, and proper shading schemes were employed to assist in the control of tea mosquito bug (Das, 1984; Fernando & Manickavasagar, 1956).

Muraleedharan (1987) says, while plucking, tea shoots infested with tea mosquito bug can be removed by the pluckers. The periodical pruning operation removes a large number of eggs containing infested shoots. Das (1981).

Peregrine (1992) reported that Annatto (Bixa orellana) - a possible trap crop, may be suitable to assist the control of the tea mosquito bug H. schouledeni in tea in Malawi.

2.10 Integrated Pest Management (IPM) : of tea mosquito bug

The original concept of integrated control was developed to stress the need for understanding the complicated and antagonistic relationship between biological control and the use of chemical pesticides (Hill, 1993). In 1967 the FAO panel of experts on integrated control defined as " a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in a compatible a manner as possible and maintains the pest population at levels below those causing economic injury ".

Decazy and Essono (1979) studied in Cameroun to compare blanket spraying of the whole cocoa growing area twice with a system recommended by the SODECAD which consisted of treatments applied only after preliminary investigations of the pest population and ecological conditions. The SODECAD programme gave adequate control and used less insecticide, as a single treatment during the build up of the mirid population protected 73% of the trees for the year.

In India, IPM packages have been developed for some of the important pests like the American bollworm - Helicoverpa armigera and other cotton bollworms, sugarcane borers, mealybugs, scale insects, coconut black-headed caterpillar - Opisina arenosella diamond-back moth - Plutella xylostella, tobacco caterpillar - Spodoptera litura, house fly etc. Some of the biological control agents used in such IPM programmes include Trichogramma, Chrysopa - erla, Goniozus, Bracon, ladybird beetles, NPV, Bacillus thuringiensis, Trichoderma etc. Insect sex pheromones are also used as a major component in IPM.

Chakraborty and Singh (1994) worked on IPM in tea in Darjeeling. They described the tools of IPM, like cultural control e.g. bush sanitation, improvement in growing conditions, agronomic adjustments; mechanical control e.g. light trapping of moths, hand collection of caterpillars and chrysalids; chemical control e.g. use of pesticides with established MRL's; alternate host and resistant planting materials; biological control e.g. parasites, predators

and pathogens; antifeedants and repellents; hormones, e.g., pheromones, juvenile hormones, IGR's.

2.11 Use of microbial pesticide against tea mosquito bug :

Control of insects by pathogens is sometimes referred to as microbial control. There are three main groups concerned; bacteria, fungi and viruses.

Fungi are responsible for producing antibiotics and apparently about 3000 antibiotics, do show some promise as pesticide; these act directly as killing agents or inhibitors of growth or reproduction (Hill, 1993). Beauveria, Metarrhizium, Verticillium, Spicaria, Aspergillus, Isaria and Hirsutella of Deuteromycetes are the important insect pathogen (Jayaraj, 1986).

Several studies have been undertaken using the entomogenous fungi for the control of insect pest since 1950. The pests belonging to insect orders, viz. Lepidoptera, Coleoptera, Homoptera, Hymenoptera and Diptera are susceptible to different fungal pathogens. Several fungi are known to produce toxin which are lethal to insects. Sharma et al. (1994) reported that the toxin of Bauveria bassiana destroy natural physiological balance in Helicoverpa armigera. Reduction of respiratory efficiency may lead to the accumulation of carbohydrate in the noctuid. Toxic metabolites of the pathogen play an important role in the decrease of total proteins, amino acids and nucleic acids.

Prasad et al. (1990) reported that Beauveria bassiana was found to be the most virulent on second instar larvae of Helicoverpa armigera at the lowest LC_{50} of 2.17×10^5 conidia/ml.

Pathogens have been found infecting cocoa mirids from time to time. Fungi are dependent on wet conditions. Collingwood (1977) reports on trials with a highly lethal bacterial disease in West Africa, which was pathogenic to Helopeltis spp.

Lim et al. (1989) reported from Malaysia that B.bassiana was found in cocoa mirid, H.theobromae. This entomogenous grew and sporulated best at 25°C. It was highly pathogenic to adult H.theobromae that were sprayed or dusted with fungal spore.

CHAPTER - III

MATERIALS AND METHODS

CHAPTER - III MATERIALS AND METHODS

Studies were undertaken on an important pest - the commonly known as mosquito bug i.e. Helopeltis theivora Waterhouse found in association with tea plantation of North East India in Terai, Dooars. The site of investigation was spread over a few selected areas in the Central (Nagrakata), Eastern and Western Dooars in the district of Jalpaiguri, West Bengal.

Investigations were carried out on the bio-ecology of the tea mosquito bug with special reference to the cultural and biological control of the pest.

The materials used and various methods followed are as follows :

MATERIALS

i) Plant Species :

Out of two widely used spp. of tea Camellia sinensis (L.) o.kuntze and C. assamica (Master weight) grown in foot hills and plains of West Bengal, the later being the preferred host plant of mosquito bug, was the obvious choice for the experimental purpose. As assam type of tea exists in different vegetative clones and seed stocks, the most widely used clones like TV (Tocklai vegetative) - 1, TV-9, TV-11, TV-12, TV-14, TV-16, TV-17, TV-18 and ST (Seed stock) - 378, ST-449, ST-460, ST-461, ST-463, ST-464 along with some garden selection clones were used. Most of the tea



1. First instar nymph of Helopeltis theivora .



2. Second instar nymph of H.theivora.

bushes were planted in standard single hedge or in double hedges. The spacing of 120cm x 90 cm as single hedge and 120 cm x 90 cm x 90 cm as double hedge are two distinct types of plantation followed in N.E. India.

ii) Insect Species :

The 'D-Vac' (Suction trap) was used to collect different mosquito bugs at different stages during the course of experiment and identified as Helopeltis theivora based on Stonedal (1991). The test specimen was cross examined and was compared with the specimen maintained at TRA, Jorhat, and then further reconfirmed as Helopeltis theivora (Heteroptera : Miridae).

iii) Chemicals :

The following insecticides were used to study their adverse effect, if any, on an insect predator Chrysoperla sp. found in association with tea mosquito bug.

Insecticide	Trade Name	Concentration % a.i.	Source
Endosulfan	ENDOCEL-35EC	0.05	Excel Industry Ltd., Bombay.
Quinalphos	EKALUX-25EC	0.03	Sandoz (I) Ltd., Bombay
Monocrotophos	MONOCIL-36SL	0.03	NOCIL, Bombay.
Cypermethrin	RIPCORD-10EC	0.005	NOCIL, Bombay.

iv) Site of investigation :

Most of the scheduled experiments were conducted in the Experimental Plot of TRA, Nagrakata Sub-station, Jalpaiguri, West Bengal. In addition, several tea estates, such as, Jiti, Karbala, Chalouni, Nagaisurce, Dalgaon, were also selected to suit the need of the experiments.

3.2 METHODS

3.2.1 Nature of feeding of tea mosquito bug :

Ten normal tea shoots with 2 mm diameter bearing five leaves and a bud, on an average, were exposed to a newly emerged nymph in a specially designed rearing chamber to follow the course of development till adult. The tea shoots were changed periodically to count the number of necrotic spots on each of the five leaves in their respective positions from first to fifth place in descending order on the twig. The twig remained fresh for 5 days on an average and the withered shoot was replaced by fresh shoots as and when required. The number of necrotic spots produced on the bud was also recorded. There were ten such sets in each large group, each consisting of one nymph and ten shoots. The studies were conducted in laboratory condition in a room temperature ranges from $27 \pm 1^{\circ}\text{C}$ and relative humidity - $80 \pm 5\%$.

3.2.2 Distribution of ten mosquito bug in the infested area :

Rapid roving survey was undertaken to study the distribution pattern of mosquito bug at weekly interval. The 'D-Vac' suction trap was operated for 5 minutes per sample on tea bush canopy to



3. Third instar nymph of H.theivora .



4. Fourth instar nymph of H.theivora .

catch the mosquito bugs at different stages. Five samples were taken from each estate. So, a total of 25 samples drawn from five estates. The tea estates located in the Central Dooars were selected randomly to draw the samples (mosquito bug catch) during June to August, 1991). The findings are presented based on Morista's Index and so on.

3.2.3 Assessment of damage potential of nymph and adult of tea mosquito bug under field caged condition, at Nagrakata, Dooars, Jalpaiguri, West Bengal during August, 1993 :

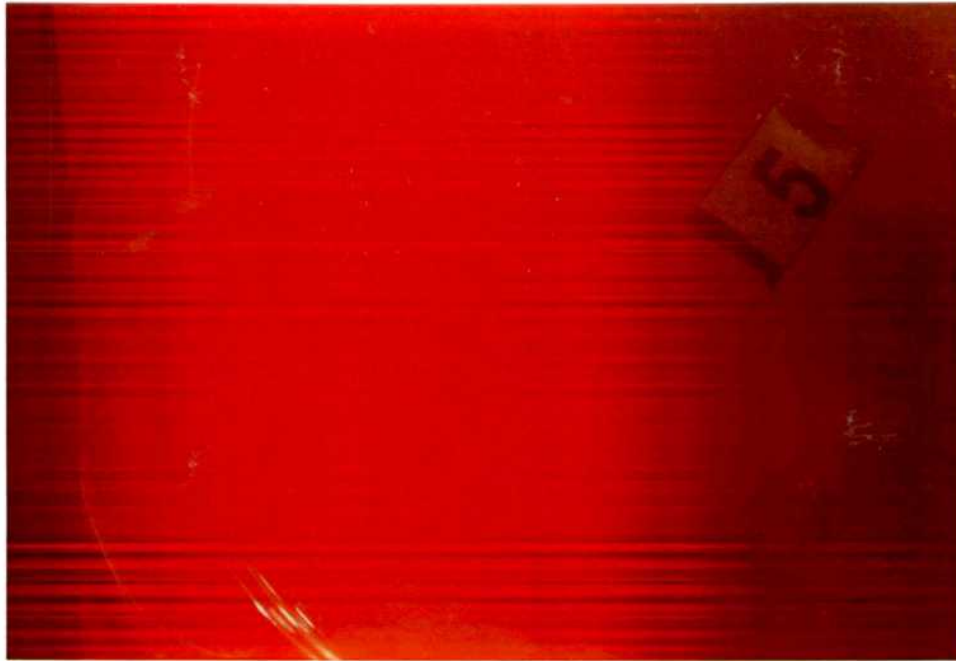
To work out the damage potential, experiment was conducted under field caged condition (3m x 1.5m x 1.5m) during August, 1993 at the TRA Experimental Station, Nagrakata. Helopeltis nymphs (4th instar) were released in the field cages in three various densities i.e., five, ten and fifteen per cage. The tea bushes used in the investigation were conditioned accordingly to provide sufficient shoots for the mosquito bug. The fresh shoots and damage shoots were counted at 7th day, 14th day and and the experiment was repeated seven times. Finally, infested shoots were expressed in percentage. Due to severe damage of shoots, the bushes were plucked (standard plucking) for further uniform flushing.

Similarly, another experiment was set up taking adult stage of tea mosquito bug at four density levels i.e. one, five, ten and fifteen pairs (male and female) per cage. The experiment was repeated five times. The fresh shoots and infested shoots were counted at 7th day and 14th day. The infested shoots were expressed in percentage.

The assessment of damage potential was estimated by analysis of variance.

3.2.4 Mass multiplication of tea mosquito bug under field caged condition :

Attempts were made to rear the pest in large number under field condition in specially designed cages (3m x 3m x 1.5m) made of slotted angles with adjustable frames to suit the conditions required during different months of a year. Each cage was covered with fine nylon net on all side with adjustable opening to allow the insects to migrate in the adjacent cages in a sequence. Whole field was divided into a give sectors taken as five replications. Only the severely infested shoots without eggs from different sectors containing 10 bushes (clone TV-1) were plucked and the infested shoots containing eggs were kept for hatching. The age of the bushes were 5 years. Fixed density levels of male and female mosquito bugs (15:15) were released in the cage to standardize the technique and the course of development of the population was studied on ten enclosed bushes. Various manipulation practices were adopted to provide suitable ecological niche to the pests for their rapid multiplication. Each cage was dismantled (reused in a sequence) after shifting the population of tea mosquito bug in the adjacent cage. Tea shoots severely damaged during the course of feeding by the insects were plucked after 14 days to avoid growth inhibitory action and the same bushes were reused in a sequence to multiply the pests.



5. Fifth instar nymph of H. theivora .



6. Suction trap 'D-Vac' used for catching insect.

The mass multiplication of tea mosquito bug was started in the month of March, 1993 and continued till December, 1993. Mean number of nymphs reared per cage, the percent nymph reached adult stage and the sex ratio were counted from each of the five replications in every month.

The correlation studies were worked out between percent nymph reached adult stage and weather parameters to see the feasibility of the rearing technique in the field.

3.2.5 Monitoring of tea mosquito bug and population prediction :

a) Use of sticky traps :

To develop reliable system for monitoring and assessment of pest populations, the traps, made of yellow rectangular galvanized sheets, plastic jars and tin boxes were suspended from or held by a support. A sticky adhesive was used for trapping the insects. Traps were placed at 1.0 - 1.5 meters above the ground in the fields. Thus a total of ten traps, at 10 m distance, were fixed at TRA Experimental Plot.

The observations were taken during the peak periods (July, August, September, 1991) of infestation, to study their migration. The insects were grouped according to their order, and the number of Helopeltis, if any.

b) Use of light traps :

Bulbs of 40 and 60 watt covered with different colours of celofen papers fitted with sticks were fixed at 1 to 1.5 meter height at the ground level, at five different places in the TRA Experimental Plot during the period of the tea mosquito bug infestation (May - November) in the years 1991, 1992, 1993. The insects collected in the traps were grouped according to their orders.

c) Pheromone studies of tea mosquito bug :

Preliminary studies were undertaken to reveal the presence of sex pheromones, if any, in any one of the sex, with the help of modified wind tunnel technique with an olfactometer. The olfactometer consists of two cubic chambers (30 x 30 x 30 cm) made up of transparent acrylic sheet (3mm in thickness); one chamber is named as bait and other as test chamber. Each chamber has a removable lid at the top and two protruding circular holes (8 cm in diameter) on opposite sides. These two holes are connected by a transparent tube (80 cm length and 8 cm diameter). The opposite hole of each cube is covered with the wire net to allow wind movement. The mouth of the tube at bait chamber end is covered with muslin cloth to confine the insects to the bait chamber. Five tea shoots containing ten leaves and five buds in glass vials filled with water, as a source of food for the insects, kept in each of the test and bait chambers.



7. Temperature gradient apparatus .



8. Relative humidity gradient apparatus.

A mini table fan (30 cm diameter) was stationed in front of the sieve hole of the bait chamber so that the wind passed through the bait chamber and test chamber.

All time the components of the apparatus were washed by 80 % alcohol followed by soap water and distilled water and also sun drying before starting next experiment.

The insects were allowed to acclimatize for one hour in the respective chamber before the experiment.

The adult tea mosquito bugs after final moulting (as '0' day old) were collected from laboratory culture.

A preliminary experiment was conducted for presence of sex pheromone with virgin female and unmated males comprising 10 individuals each of 1,2,3 and 4 day old. The behaviour of female and male was studied by keeping them separately in the test and bait chamber. The experiment was repeated with opposite sexes in test and bait chamber and the number of adults reaching in bait chamber was counted in one hour, by blowing air and without air blow.

An indication of the presence of sex pheromone was found in this experiment with 3 and 4 day old adults.

Similarly another experiment was conducted with 3 and 4 day old age group adults and repeated five times.

The data were transformed to $\sqrt{0.5 + X}$ and analysed in completely randomized design (Gomez & Gomez, 1984).

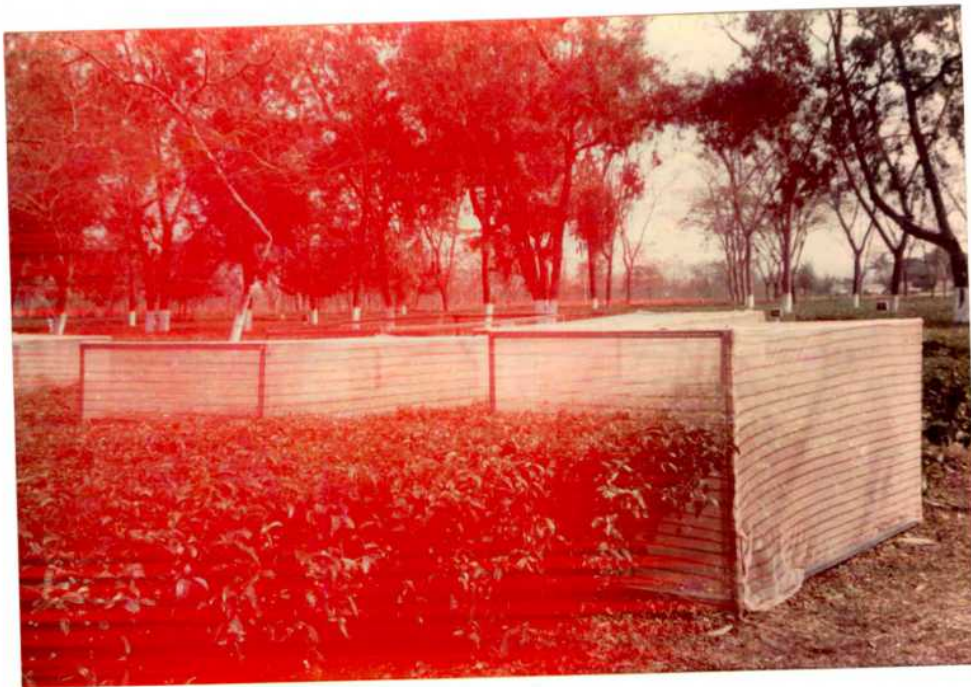
d) Use of suction trap ('D'-vac) :

Suction trap ('D'-Vac) was used to catch the different stages of tea mosquito bugs at weekly interval. A total of forty-eight operations (each of five minutes duration) was considered to sample the population levels of the insects. The site of investigation was Dalagaon T.E. (organic tea area) at Birpara Sub-District. The period of observation was from January 1993 to December, 1993. Meteorological data (temperature, relative humidity, rainfall) pertaining to the period of observation were recorded to study their influence on the population dynamics of the pests.

The data were statistically analysed by path coefficient analysis and population prediction model was prepared with the help of weather parameters.

3.2.6 Behaviour of tea mosquito bug in a linear temperature gradient :

The reaction of Helopeltis theivora Waterhouse to temperature was studied by using linear temperature gradient apparatus (Fig.3A), as described by Youdeowei (1968) and Nwana (1975). The experimental chamber was made of clear paper box with internal dimensions of 44.3 cm x 3.8 cm x 2.6 cm; its top consisted of two layers of perplex, 1.9 cm apart such that they enclosed an insulating layer



9. Cages used for mass rearing of tea mosquito bug.



10. Wild plant, Phlogocanthus rubinervius host of H. theivora .

over the chamber. The top also carried ten 30 cms long thermometers, each placed in 10 equally spaced holes (0.6 cm diameter) made through it to the centre of each of the 10 sectors of the chamber. The floor of the chamber was formed by a 63.3 cm x 5.4 cm x 0.6 cm copper bar covered with a thin layer of absorbent paper and at each end, 7.7 cm of the copper bar was projected into a well insulated copper box (10.2 cm x 10.2 cm x 10.2 cm) covered with an insulated wooden lid. The entire experimental chamber was well insulated by 2.5 cm thick expanded polystyrene.

The thermometers for recording the temperature were, therefore, placed half way (1.3 cm) from the top of the chamber in order to record the mid temperature of the chamber because most of the insects were on the side walls and roof of the chamber. A temperature gradient of 18.24° to 38.80° was established within the chamber by use of ice-cold water and hot water in the right and left copper boxes respectively. The established temperatures in sector one on the left, to sector 10 on the right of the apparatus were 38.80; 35.05; 31.86; 29.57; 28.34; 25.78; 24.58; 20.68; 20.13; and 18.24 degree celsius respectively. The desired temperatures were maintained, thereafter, by draining the water in the boxes through taps and replacing with water at the appropriate temperature.

Twenty insects were introduced into the chamber through the central hole which was then plugged with cotton wool. The dis-

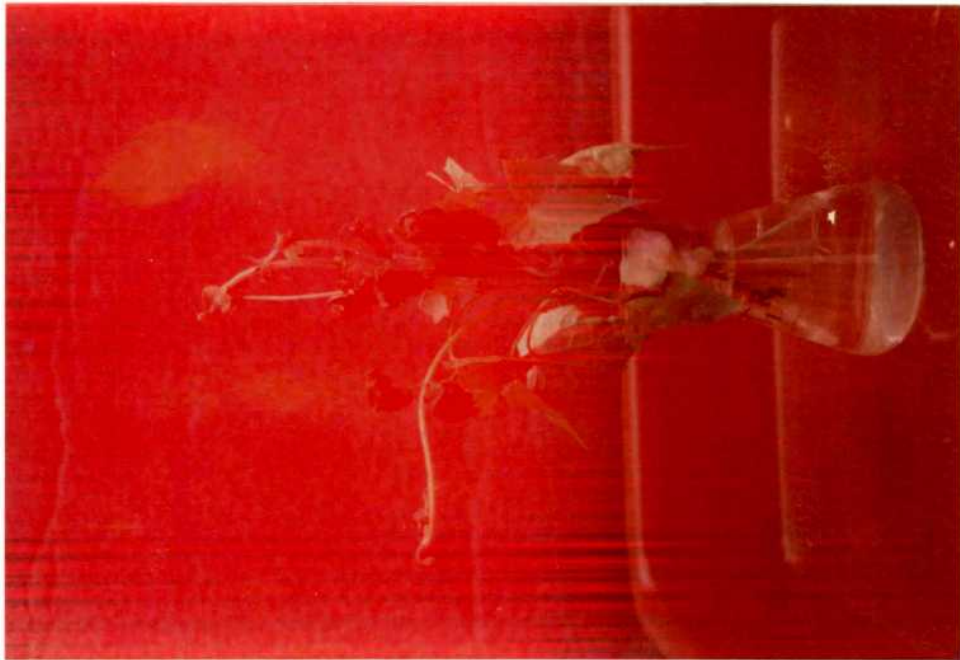
distribution of the insects within the chamber was recorded thirty minutes afterwards. Immediately after each record, the insects were redistributed within the chamber by trapping the top and sides of the apparatus, and rotating it through 108°.

A control experiment in which the temperature gradient in the chamber was replaced with a uniform temperature of 26.6 ± 0.5 by use of tap water in the boxes of the apparatus was also carried out. Both the experiments were replicated 10 times with fresh batches of 20 insects of H.theivora.

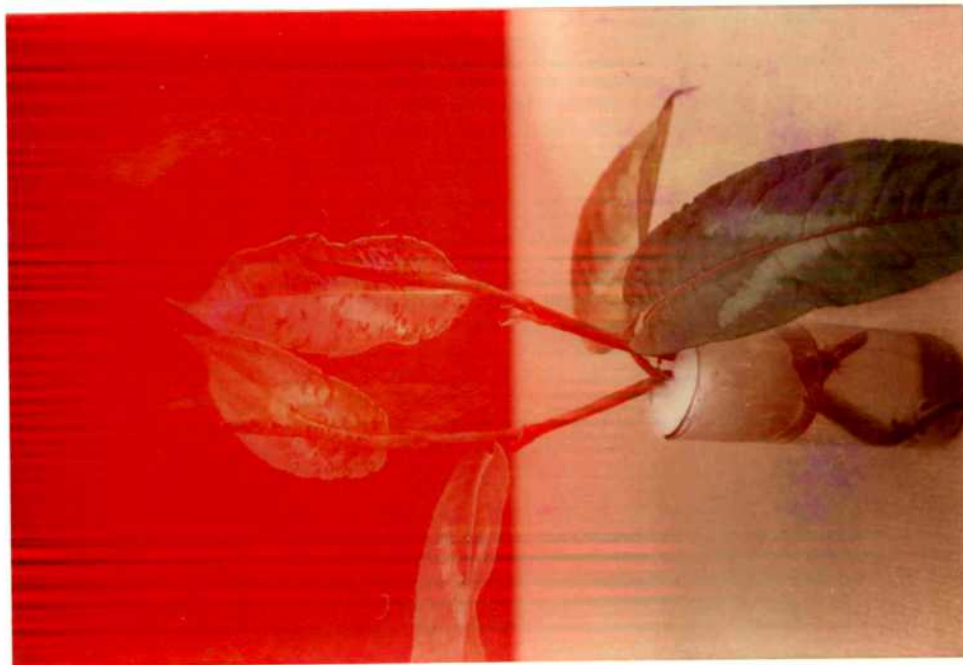
The data were transformed to arcsine and were analysed in randomised block design.

3.2.7 Behaviour of tea mosquito bug in a linear humidity gradient :

The reaction of H.theivora to moisture was also studied by using a linear relative humidity gradient apparatus (Fig. 3B), described by Youdeowei (1967). It was a rectangular perplex box with a removable top and a wooden bottom. The internal dimensions were 41.2 cm x 8.8 cm x 2.0 cm. The apparatus was usually made air-tight by sealing all the corners and the central hole with sellotape. It was divided into 5 sectors and a glass dish of 15 cm deep and internal circumference of 20.8 cm was placed in each sector to make contact with the false floor. Each dish contained graded aqueous solutions of sodium hydroxide prepared according to the method of Madge (1961 a), to produce a relative humidity gradient



11. Wild plant, Mikania micrantha, host of H.theivora.



12. wild plant, Polygonum chinensis, host of H.theivora.

of 20; 40; 60; 80; and 95 percent in the chamber. The gradient of humidity in the chamber was indicated by the graded change in the colour of strips of thiocyanate paper (Solomon, 1945) placed on the false floor, directly above each dish.

One hour after setting up the apparatus, ten adult males, females and different stages of nymphs of H.theivora were quickly placed into the chamber through the central hole. The record of the distribution of the insects in each sector was taken after twenty minutes. Immediately after taking the record, the insects were redistributed within the chamber. The same experimental procedure was used for the control experiment in which a uniform humidity was achieved in the experiment chamber by replacing the graded sodium hydroxide solutions in the dishes with distilled water. Both the experiments were replicated 10 times with fresh batches of 20 insects of H.theivora. Fresh humidity solutions were used for each replicate.

The data were transformed to arcsine and analysed in randomized block design.

3.2.8 Distribution of tea mosquito bug (adult and nymph) at different regions of light intensity in tea bushes :

Attempt was taken to study the effect of light intensity on the distribution pattern of tea mosquito bug in tea bushes, both at shaded and unshaded sections during August to September, 1993. One hectare area with moderately shaded by Albizzia spp. and one hectare, unshaded were selected for the site of investigation at

Banarhat Sub-district. The number of nymphs and adults were counted from top and middle portion of the bush at the same time and corresponding light prevailing at the top and middle portion of bush was measured by lux meter.

Thus, a total of 20 observations were taken at randomly selected spots from both shaded and unshaded areas at weekly interval.

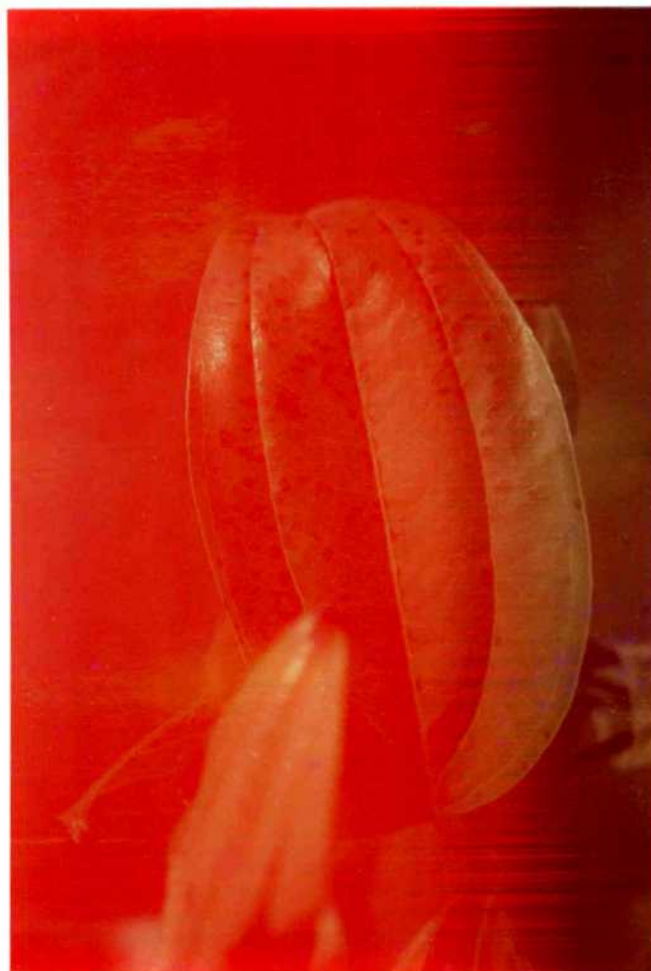
Later on the different light intensities were grouped and arranged against the percent of adults and nymphs with the corresponding ranges of light intensities.

Data were transformed to arc sine and statistical correlation was worked out.

3.2.9 Distribution of tea mosquito bug in three segments of tea bushes at Nagrakata, Jalpaiguri, West Bengal :

The purpose of investigation was to identify the preferred ecological niche of tea mosquito bug. So an experiment was conducted in young tea bushes to study the population build up of Helopeltis theivora Waterhouse, from nymphs to adults on the basis of damage caused by different stages of the insect with respect to pluckable shoots available in different regions of each bush.

Young leaves and buds are preferred by nymphs and adults. According to the distribution of these shoots, a bush was divided into three parts.



13. Wild plant, Similax sp., host of H.theivora.

- a) Shoots above the plucking table which are ready to harvest - TOP (90 cm from ground level).
- b) Shoots at the plucking table which will be plucked after attaining maturity - MIDDLE (76 cm from ground level).
- c) Shoots below the plucking table within the maintenance leaves (i.e. shoots of few primary suckers and dormant buds) - BOTTOM (Below 76 cm).

The field was observed for a month to follow up the pattern of symptoms produced during the course of feeding from the initiation of infestation by the insects. The infested shoots were recorded at seven days interval from the above three regions in randomly selected 10 bushes. The diameters of the puncturing spots produced along with the percent of infested shoots were recorded at first day, seventh day and fourteenth day of the experiment.

At fourteenth day more than 50 percent of the shoots were found infested and block die back symptoms were appeared at the top hamper of the bush.

In this way the experiment was repeated at 10 times.

Data were transformed to arc sine and analysed by randomised block design.

3.2.10 Feasibility of wild plants as host of Helopeltis theivora at Jiti Tea Estate, Dooars, Jalpaiguri, West Bengal during December to March in 1991 and 1992 :

To identify the host plants other than tea, sequential sampling was undertaken near the endemic area of tea mosquito bug i.e., Jiti Tea Estate and border of Bhutan hills. The entire vegetation of these areas containing wild plants, were thoroughly scanned with the help of suction trap ('D'-vac) at weekly interval during the dormant season of tea (December to March, 1991 and 1992). Around 500 plants of each species were examined to find the infestation marks of the pest at weekly interval. The plants having the damage marks were kept under constant observation by fixing the tags to study the course of development of the pest.

3.2.11 Rearing of tea mosquito bug Helopeltis theivora Waterhouse. on the wild plants under laboratory condition at temperature $27 \pm 1^{\circ}\text{C}$ and relative humidity $80 \pm 5\%$:

To study the life cycle of tea mosquito bug the twigs of different wild plants like Similax spp., Solanum spp. Eupetorium odoratum, Polygonum chinensis, Phlogocanthus pubinervius and Mikania micrantha were taken into glass vial and were kept inside the wooden cage (0.6 m x 0.6 m x 0.6 m) covered with mosquito nets at laboratory condition at temperature $27 \pm 1^{\circ}\text{C}$ and relative humidity $80 \pm 5\%$. A pair of 3 day old adult (male & female) released separately to each species of plant and parameters like incubation period, number of spots produced per instars

etc. were studied. The experiment was repeated 5 times. The data were analysed by randomized design. Twigs were changed at an interval of 24 hours and the insects were transferred to fresh twigs with the help of a camel hair brush in order to avoid any injury to the insects.

3.2.12 Presence of tea mosquito bug in tea clones during the dormant season at Nagrakata Tea Estate, Dooars, Jalpaiguri, West Bengal during December to February, 1992 :

Sequential samplings were undertaken by suction trap ('D'-Vac) in the clones like TV-9, TV-10, TV-14, which give little flush during dormant season by a total of 13 samples (5 operations each of 5 minutes duration) from each clone at weekly interval were taken. Other parameters like percent infested shoots and the number of eggs per shoots were also studied. So, a total of 500 shoots, randomly plucked from each clone (100 bushes), was examined for working out the percent infested shoot and the number of eggs per shoot.

The data were transformed to arc sine and analysed by factorial randomised block design (3 x 3).

3.2.13 Cultural control of tea mosquito bug by light skiffing, and black plucking in the clone TV-1 during July-August, 1993 at Karbala Tea Estate, Dooars, Jalpaiguri, West Bengal:

Experiment was conducted to evaluate the effect of light skiffing and black plucking against control on tea mosquito bug during July-August, 1993 at Karbala Tea Estate, Jalpaiguri Tea

field was of single hedge plantation, moderately shaded by Albizzia spp.

The cultural practices (treatments) were light skiffing by knife i.e. cutting of top hamper of the bush at 2" depth; black plucking by hand i.e. plucking of shoots include 4 leaves and a bud; and standard plucking i.e. two leaves and a bud.

The experiment was laid out in randomised block design with 3 treatments and seven replications. Each treatment contained 100 bushes.

The treatments were imposed after more or less 50% infestation of tea mosquito bug in the field.

The number of infested and uninfested shoots were counted from 5 bushes. Thus, a total of 10 random samplings were taken from each treatment at one day before and 21 days, 28 days and 35 days after application of treatment. The cumulative infestation was expressed as percentage.

The treatments where skiffing and black plucking were done the bushes started normal flushing at 21 days, whereas the standard plucked bushes continued flushing at 7 days after plucking. So, the plucking operation was carried on the standard plucking plots to maintain the usual shoots growth.

It was found that the number of pluckable shoots were more in black plucked plots than skiffed plots at first round after the operations.

3.2.14 Incidence of tea mosquito bug, thrips and their predator Chrysoperla sp. in tea bushes (TV-18) during February to May 1992 at Nagrakata, Dooars, West Bengal.:

Attempts were made to record the incidence of tea mosquito bug, thrips, and the predatory insects at weekly interval and period of infestation of the pest during February to May 1992 at Nagrakata Tea Estate, Dooars, Jalpaiguri, West Bengal. An area containing 100 bushes of TV-18 was selected as a site of investigation. Total number of predators per bush, percent bush infested by tea mosquito bug and number of thrips from 10 shoots per bush were recorded on 20 randomly selected bush at weekly intervals throughout the studies.

3.2.15 Occurrence of egg parasitism in tea mosquito bug eggs under natural condition at Dalgaon Tea Estate, Dalgaon, Jalpaiguri, West Bengal, during 1992 :

Studies were undertaken to find out the occurrence of any egg parasites of tea mosquito bug available in organic tea at Dalgaon Tea Estate Jalpaiguri, West Bengal. Tea shoots containing tea mosquito bug eggs were collected at 15 days interval throughout the year. A total of eggs were collected during the course of investigation. The shoots dipped in a small glass vial (10 ml) filled with water were kept under laboratory condition ($27^{\circ}\text{C} \pm 1^{\circ}\text{C}$ and $80 \pm 5\%$ r.h.) covered by jars made up of transparent acrylic sheet

(3 mm in thickness). The shoots were checked regularly until the eggs hatched. The unhatched eggs were examined thoroughly under binocular for the presence of any parasite.

3.2.16 Effect of insecticides on the predator
Chrysoperla sp. under laboratory condition :

Experiment was undertaken to find out the relative toxicity of insecticides recommended for control of tea mosquito bug like endosulfan (0.05%), quinalphos (0.03%), monocrotophos (0.03%) and cypermethrin (0.005%) on the newly hatched larvae of predator C. scelestes.

Four samples of Corcyra eggs were treated with the above said insecticides at their respective dosages and one sample was kept as untreated control. All the five treatments (including control) were given to 20 Chrysoperla larvae for 24 hours. The set was replicated three times. The predatory larvae survived after 24 hours were removed and reared on untreated Corcyra eggs. The mortality percent of the larvae was worked out on 3 days after treatment. The experiment was conducted under laboratory condition at $27^{\circ}\text{C} \pm 1^{\circ}\text{C}$ and 80 ± 5 % relative humidity.

3.2.17 Mass rearing and evaluation of Chrysoperla sp. as bio-control agent under field caged condition to control of tea mosquito bug at TRA Nagrakata, Jalpaiguri, West Bengal during June 1992 :

Attempts were made to rear the predator on alternate host consisting of frozen Corcyra eggs for larval rearing and

artificial diet for adults. Wooden cage measuring about 70 x 30 x 30 cm with sides and lined with smooth, nylon wire mesh and the sliding top cover fitted with black cloth for harvesting predator eggs was used for 3000 adult insect. The adult diet was consisting of protinex 40 gms + fructose 70 gms dissolved in 250 ml of drinking water along with castor pollen. The larvae of the predator were kept individually in 2.5 cm cubical cells of plastic leavers with Corcyra eggs as food. Five thousand cubical cells provided around 4000 cocoons of the predators. The rearing units were kept at 27°C and 80% r.h. 2-3 day old predator larvae were released in field cage mixed with saw dust. TRA experimental plot, Nagrakata was selected for the purpose of investigation.

Iron cages measuring about (3 x 3 x 1.5 m) covered with nylon nets were used. There were four replications in each experiment. Each cage of TV-1 was fumigated overnight with DDVP to kill active stages of all insects and mites, if any. The experiments were laid out thereafter by inoculating tea mosquito bug nymphs of second instar at various densities and an insect predator, Chrysoperla sp. , was released in given number to maintain 1:1, 1:2, 1:3, 1:4 (prey : predator) ratio. A control set was maintained where the pest was released alone to review the extent of damage done by it in absence of the predator. The percent shoots damaged on 3 day, 5 day, 7 day and 14 days after inoculation was

The data were subjected to analysis of variance after making necessary transformation.

3.2.18 Use of microbial pesticide against tea mosquito bug :

Availability of formulated biological insect control product is poor under Indian conditions. However, DISPEL^(R) was received through Pesticide India Ltd. to undertake the efficacy studies against tea mosquito bug. It is registered in U.S.A. in the name of NATURALLIS, and was found to be effective against certain Lepidopterous, Coleopterous, Hemipterous and Homopterous pests.

DISPEL^(R) is a formulated product, contains active ingredient Beauveria bassiana (2.3×10^7 conidia per mili litre of product) which belongs to the class fungi imperfecti. It is a naturally occurring fungal strain and is not genetically altered. DISPEL is a contact bio-insecticide, not absorbed by the plants, residues degrade rapidly and are not persistent.

Spot trial was undertaken at Debpara T.E. , Central Dooars, Jalpaiguri, West Bengal during Sept. - Oct. 1993 being the peak period of tea mosquito bug infestation. This estate is an endemic pocket of tea mosquito bug of Central Dooars.

An area of young tea (10 years) of TV-1 was selected and it was divided into nine segments, each segment consisting of 50 bushes of TV-1 clone. Two different dosages of DISPEL i.e. 2 ml/lit, 4ml/lit. and a control set was taken. Preparing the solution in water (@ 400lit of water/ha), the each dose of DISPEL were sprayed in 3 segments, 3 times at 15 days interval. The percent shoot infested was considered for the efficacy of the product and ultimately the percent control was calculated at 15 days interval.

CHAPTER - IV

RESULTS AND DISCUSSION

CHAPTER- IV RESULTS AND DISCUSSION

4.1 Distribution, nature and symptoms of damage caused by Helopeltis theivora Waterhouse :

4.1.1 Distribution :

The tea mosquito bug Helopeltis theivora Waterh. was distributed in South and North East India, Sri Lanka, South East Asia, Malaysia, Indonesia (Stonedahl, 1991). It is a major pest of tea and cocoa in Asia. Its importance as a pest of tea was first recorded in 1865 in Cashar, Assam. Since then its importance as pest k growing over the years mainly due to its destructive nature, typical mode of feeding, behaviour and periodic outbreak after a gap of around 11 years. It has established itself as an important pest of Assam, Darjeeling since 1869. Severe outbreak of the pest occurred in Dooars (Nagrakata sub-district in 1965, Das, 1965). From early 80's regular incidence of Helopeltis has been reported in the eastern central as well as western Dooars. Of late it has assumed an important pest status in most of the tea growing estates in Assam and West Bengal.

Incidentally no attempts so far been made in the study of population distribution of Helopeltis in tea. It was therefore necessary to initiate to undertake studies on the pattern of distribution of Helopeltis in the endemic pocket of mosquito bug comprising of eastern, central and western Dooars.

Rapid roving survey was undertaken to study the distribution pattern of tea mosquito bug. Sampling data obtained from field studies on the catches of tea mosquito bug by 'D'-Vac (suction trap) were used to calculate Morista's Index to determine the pattern of distribution of the pest.

$$\text{Morista's Index : } I_s = \frac{N \sum X^2 - \sum X}{(\sum X)^2 - \sum X}$$

$$N = 7$$

The clumped or aggregated distribution of a pest was in this case is expressed by the negative binomial. The negative binomial distribution is described by two parameters, the mean ($\bar{X}$) and the exponent ('K') which is a measure of the amount of clumping.

$$k = \frac{\bar{X}^2}{s^2 - \bar{X}}$$

This provide a rough estimate of 'K' for substituting it in the maximum likelihood method suggested by Shenton (1958). The date confirms to the negative binomial model based on the formula.

$$U = s^2 - \left(\bar{X} - \frac{\bar{X}^2}{K} \right)$$

The smaller the value of 'K' means greater extent of aggregation while larger values (above 8) indicate that the distribution is random (Southwood, 1978). The aggregation indicated by 'K' may be due to either the behaviour of the pest or to the environmental factors. If the average size of λ is less than 2, then the aggregation/clumping may be considered to be due to environmental

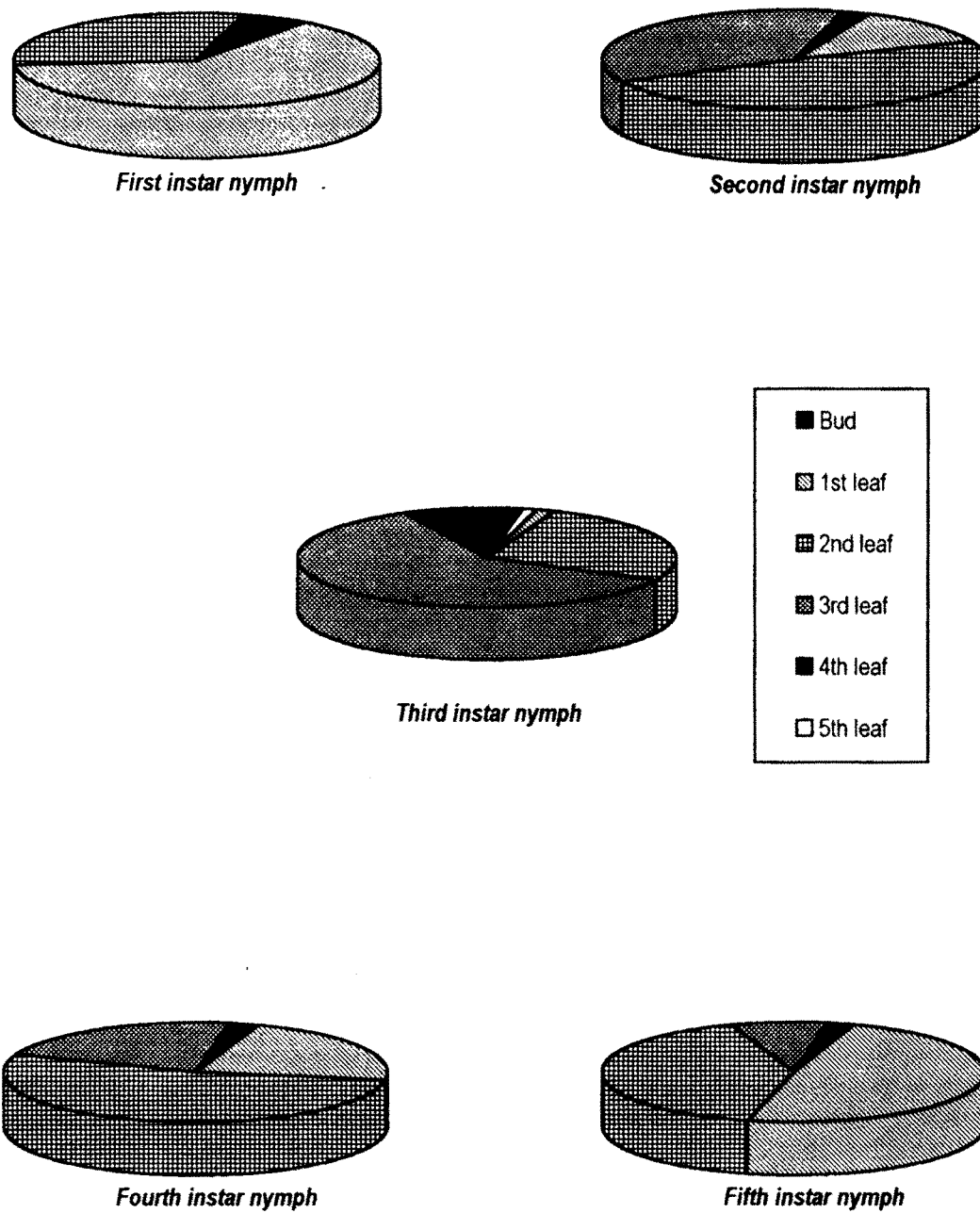


Fig. No.1 Pattern and assessment of damage percentage caused by the nymphal stages of tea mosquito bug under laboratory condition

factors and clumping/aggregation (λ) of more than 2 could probably be caused by the behaviour of the pest.

In the present investigation the value of the index was more than one, indicating clumped distribution of the pest population (Table 4.1). It means that Helopeltis remains in group and were rarely seen individually spaced apart. Pattern of distribution are characteristics feature of each pest. Very often it is possible to detect the causative factors for a particular pattern of distribution. The calculated value of λ was well above 2. It may therefore, be said that the clumping pattern of distribution of Helopeltis probably caused due to the behaviour of the pest and not by the environmental factors (Arbous and Kerrich, 1951).

4.1.2 Nature and symptoms of damage :

Typical feeding marks of tea mosquito bug is always indicated by a discolor necrotic lesion around the point of injury of the labial stylete into the plant tissue. The lesion often assume elongated or special shape and turns into darker spot with age as the tissue around the stylete puncture dies, probably due to the action of pectinase enzyme secretion of the salivary gland of the insect (Miles 1987). It has been reported that single adult could make as many as 100-150 feeding spots within a span of 24 hours while the corresponding number of such spots would be around 80 in the case of late instar nymph (Hainsworth 1952; Das, 1984; Singh and Kakoty, 1993).

Table 4.1 : Suction trap [D'-Vac] catches of tea mosquito bug in different tea estates in Doars, Jalpaiguri, during June - August, 1991.

Period of observation	Number of tea mosquito bug / operation (Average of 5 operations of 5 minutes duration				Morista's Index	'K' value	Number of individuals in aggregation	
	Lanka-para T.E.	Surendra-nagar T.E.	Birpara T.E.	Nagaisuree T.E.				
4th week, June '91	7.8	6.2	3.4	7.4	4.0	4.77	-8.32	5.32
1st week, Jul '91	9.2	5.8	7.4	6.0	5.2	4.65	-8.54	6.45
2nd week, Jul '91	6.4	9.2	3.8	3.6	7.6	4.97	-9.47	5.64
3rd week, Jul '91	4.0	4.4	6.2	2.8	4.8	4.38	-5.91	4.25
4th week, Jul '91	6.8	9.2	7.6	6.4	6.0	4.55	-8.54	6.88
1st week, Aug '91	7.0	4.8	5.8	9.8	8.4	4.74	-9.53	6.89
2nd week, Aug '91	8.6	6.0	9.0	3.6	6.8	4.81	-9.52	6.54
3rd week, Aug '91	10.4	7.4	6.2	5.8	7.4	4.68	-9.49	7.18
4th week, Aug '91	8.2	10.0	8.6	7.6	8.2	4.52	-9.39	8.27

Almost similar results were obtained when the nature of feeding of tea mosquito bug studied under laboratory condition ($26^{\circ}\text{C} \pm 1^{\circ}\text{C}$ and $80 \pm 5\%$ r.h., Table 4.2).

First instar nymph was almost restricted upto second leaf and young bud from the canopy were found to produce injury marks on first, second and young bud from the canopy. The number of necrotic spot produced per day 13. The maximum percent of spots (63.24) were located on the first leaf. On the other hand second instar nymph were found to feed upto third leaf from the canopy but the maximum feeding activity was noticed on second leaf resulting in 48.69% spots on the leaf. Intensity of feeding of second instar was considerably higher order and 47 spots were produced per day.

Third instar nymph on the other hand was recorded to produce feeding marks upto fifth leaf from the canopy but the maximum intensity (60.33) of necrotic spot was recorded on third leaf but the posts per day - 36 compare to second instar of nymph.

Maximum feeding activity (53.28) of forth instar nymph was restricted to second leaf and it was found to feed upto forth leaf from the canopy. The maximum feeding intensity was noticed in this case 126 spots per day.

In case of fifth instar nymph a sharp decline in feeding activity was observed. Only 45 spot were recorded per day.

Table 4.2 : Pattern and assessment of damage caused by the nymphal stages of tea mosquito bug on tea shoot (mean of ten replications) under laboratory condition during August, 1991.

Nymphal stages	Duration of instar (days)	% necrotic spot recorded on the apical bud/ leaves according to their position from the tip					No. of spots produced / day
		Bud	1st leaf	2nd leaf	3rd leaf	4th leaf	5th leaf
First instar	3	5.88	63.24	30.88	0	0	13
Second instar	4	2.09	12.57	48.69	36.65	0	47
Third instar	3	0	1.63	26.63	60.33	10.33	36
Fourth instar	5	1.24	22.06	53.28	21.95	1.47	126
Fifth instar	2	0.73	48.90	40.83	8.07	1.47	45

The maximum feeding intensity (48.9%) of this stage was located on the youngest leaf.

Incidentally all the instar should have least preference to feed on bud as evidence from many of the percent of necrotic spots located here.

It revealed from available literature that feeding activity are primarily restricted to the young leaf and a lesser degree in buds and stems (Das 1965). However, considerable variation was recorded in this regard during the course of present investigation. A differential response was recorded in fifth instar of tea mosquito bug viz. first instar nymph prepared the most youngest leaf while third instar nymph preferred little matured leaf and so in the case of forth instar.

In general tea mosquito bug showed its preference more for younger leaf than older one and in the buds are least preferred one compare to the younger leaf.

4.2 Assessment of damage potential of nymphs and adult of tea mosquito bug under field caged condition at Nagrakata, Jalpaiguri, W.Bengal :

Experiment was laid out under the field condition to assess the damage potential of nymph and adult stage of tea mosquito bug over a period of 14 days sincronising with a weekly interval of observation. Three levels of nymphal densities (5,10, 15 nymphs/cage) were used.

It is evident from the table 4.3 that at the lowest and the highest density level the percent of shoot damage is highest. The differences were statistically significant when the three densities and the two periods (7th day and 14th day) of observations were taken in consideration. However, in the lowest level of pest density the rate of increase in damaged shoots was very high (71.20) during the second quarter of observation. Again, in the highest density level the rate of increase in damaged shoots was the lowest (13.48).

On the otherhand, at the increasing density level of nymph, the rate of increase in damage shoot decreases beyond 10 pairs of nymphs/cage at 7th and 14th days of observation.

It can be said from both the cases due to intraspecific competition for limited food, the rate of increase in damaged shoots decreased when their density level increases. Intraspecific competition is a common phenomena in insect when the density increases at certain level as reported by several workers (Verhulst, 1838; Pearl and Reed, 1920; Crombie, 1945). However, in caged condition the tendency of dispersion is limited due to cover and space & food is limited so it is likely to occur.

Similarly damage potential of adult tea mosquito bug was assessed under field condition over a period of 14 days with weeking interval (Table 4.4). Here four density (1,5,10,15 pairs

Table 4.3 : Assessment of damage potential of tea mosquito bug nymphs under field caged condition at Nagrakata, Dooars, Jalpaiguri, W.Bengal during August, 1993.

Sl.No.	Density	Percent shoot damaged/cage at 7 days af- ter release (Mean of sev- en replicati- ons)	Rate of increase in dama- ged shoo- ts	Percent shoot damaged/cage at 14 days after release (Mean of sev- en replicat- ions)	Rate of increase in dama- ged shoo- ts	Rate of in- crease in damaged shoots
1.	5 nymphs/cage	12.50 (20.70)		21.40 (27.55)		71.20
2.	10 nymphs/cage	32.67 (34.86)	161.36	53.12 (46.78)	148.22	62.59
3.	15 nymphs/cage	48.14 (43.93)	47.35	54.63 (47.65)	2.84	13.48
	C.D.at 5% level	(1.29)		(1.10)		

Figures in parenthesis are angular transformed values.

Table 4.4 : Assessment of damage potential of tea mosquito bug adults under field caged condition at Nagrakata, Dooars, Jalpaiguri, W.B. during August, 1993.

Sl.No.	Density	Percent shoot damaged/cage at 7 days after release(Mean of five replicat- ions)	Rate of increase in dama- ged shoo- ts	Percent shoot damaged/cage at 14 days after release(Mean of five replications)	Rate of increase in damaged shoots	Rate of increase indamaged shoots
1.	1 pair of adult i.e. male and female/cage	4.81 (12.66)		18.46 (25.44)		283.78
2.	5 pairs of adults i.e. male and fe- male/cage	20.54 (26.94)	327.02	81.87 (64.79)	343.49	298.58
3.	10 pairs of adults i.e. male and fem- ale/cage	33.45 (35.33)	62.85	88.64 (70.30)	8.26	164.99
4.	15 pairs of adults i.e. male and fem- ale/cage	35.97 (36.85)	7.53	94.16 (76.01)	6.22	161.77
	C.D. at 5% level	(1.55)		(2.09)		

Figures in parenthesis are angular transformed values.

adult/cage) levels were used. Again the similar pattern of shoot damage was observed. With the increment of pest density level the percent shoot damage also increased. The rate of increase in damaged shoots was the highest (298.58) in second quarter of observation when the pest density level was five pairs of adult and the lowest (161.77) at the highest density level (15 pairs of adult).

The rate of increase in damaged shoot decreases beyond 5 pairs of adult with the increase of density level at 7th and 14 days of observation.

Again the same intraspecific competition is responsible for reducing rate of shoot damage with increasing density level.

It reveals from the tables (4.3 and 4.4) that the percent of damaged shoots caused by adults is more than the nymphs. This is due to the ovipositional instinct of adult as the adults have dispersing tendency and they don't attack the same shoot for egg laying where eggs were already laid. But in case of nymphs, devoid of wings, no dispersing tendency, they repeatedly feed the same shoots as observed in laboratory condition (Samanta, 1995).

4.3 Mass multiplication of tea mosquito bug under field caged condition during 1993 at Nagrakata, Dooars, Jalpaiguri, West Bengal. :

The tea mosquito bug Helopeltis theivora Waterhouse is the most important pest of tea. Studies have been conducted on the

biology but available mass rearing technique is not yet developed. Since a large number of nymphs of particular instar as well as adults are required for undertaking studies on different aspects of this pest. So attempts have been made to rear the tea mosquito bug under field caged condition. Considering the dormant period of tea in North East India, i.e. no vegetative growth of tea during end of December to February, mass rearing of tea mosquito bug undertaken from March. 15 pairs of adult (male and female) were released/cage as it has been found in earlier studies (4.2 Assessment of damage by nymphs and adults) that 15 pairs of adult is optimum in the cage (10' x 10' x 5').

It is evident from the findings (Table 4.5) that in the month of March the mean number of nymphs obtained/cage was 845.71 and 60.82 % of nymph reached adult stage and the sex ratio of the population was 2:1 . The number of mass reared nymphs declined slightly during the month of April but the percent of nymphs reached adult stage increased considerably. There was slight increase in the sex ratio of the population (2.1:1). Thereafter, the number of nymphs reared/cage increased gradually reaching the peak during the month of September. Simultaneously the percent of nymph reached adult stage also increased progressively. It was further observed that the population sex ratio also increased considerably. From the month of October a declined trend in number of nymphs reared/cage was observed. The percent of nymph obtained/cage during October-November almost equal to what was observed during that of June and

Table 4.5: Mass multiplication of tea mosquito bug under field caged (3mx3mx1.5m) condition at Nagrakata, Dooars, Jalpaiguri, West Bengal (mean of five cages).

Period	Number of adult pairs released/cage	Mean number of nymphs reared/cage	% nymph reached adult stage	Sex ratio ♀ : ♂
<u>March, 93</u>				
1st - 31st	15	845.71	60.82	2:1
<u>April, 93</u>				
1st - 30th	15	785.36	68.15	2.1:1
<u>May, 93</u>				
1st - 31st	15	1009.29	79.99	2.02:1
<u>June, 93</u>				
1st - 30th	15	1107.54	80.66	2.4:1
<u>July, 93</u>				
1st - 31st	15	1549.15	86.05	2.74:1
<u>August, 93</u>				
1st - 31st	15	2321.30	91.31	2.31:1
<u>September, 93</u>				
1st - 30th	15	2897.62	97.92	1.25:1
<u>October, 93</u>				
1st - 31st	15	1537.44	90.72	1.1:1
<u>November, 93</u>				
1st - 30th	15	1676.83	81.35	1:1
<u>December, 93</u>				
1st - 31st	15	737.98	51.23	1:0.8

Table 4.6 Correlation of rainfall, temperature (minimum and maximum) relative humidity (morning and afternoon) with percent nymph reached adult stage.

	Rainfall	Minimum temp.	Maximum temp.	Morning r.h.	Afternoon r.h.
Percent nymph reached adult stage	0.645*	0.739*	1.04*	0.399	0.866*

* Significant at 0.05% level .

July. December was the worst month of mass rearing of Helopeltis theivora when 51.23% nymph reached adult stage and the sex ratio was also adversely affected (1:0.8).

Attempt was made to find out the effect of climatological factors (Table 4.7) on the production of adult stage of tea mosquito bug. Correlation studies were undertaken to find out the parameters affecting the life cycle of Helopeltis theivora. Correlation in development of nymphal stage to adult stage with the most optimum temperature (maximum and minimum) relative humidity (morning & afternoon) and rainfall was recorded. During the month of August and September the mean number of nymphs reared/cage were highest when the maximum temperatures (30.5°C and 31.2°C) and the minimum temperature (23.7°C and 20.1°C) favoured the nymph to reach adult stage at the peak. The morning relative humidity (98 and 98), afternoon relative humidity (84% and 75%) and the rainfall (706.8 mm and 413.4 mm) also favoured the development of the population.

Rainfall, temperature and humidity were correlated with percent of nymph reached adult stage. As seen from the table 4.6, the significant correlations was found.

A perusal of available literature revealed that most of the mass rearing attempts of Helopeltis confined to the laboratory condition. The percent of nymphs reaching adult stage was considered the index of success in all the earlier works (Cope and Handique, 1991;

Table 4.7 : Meteorological data pertaining to the period of experiment (January to December, 1993).

Month	Rainfall mm	Temperature °C		Humidity %	
		Minimum	Maximum	Morning	Afternoon
January'93	25.0	10.7	20.7	97	67
February'93	18.0	13.4	25.0	94	51
March'93	16.4	14.6	28.3	86	42
April'93	146.2	19.0	30.1	84	50
May'93	420.0	21.0	30.2	93	71
June'93	669.2	24.0	31.0	90	76
July'93	988.8	24.7	30.1	98	85
August'93	706.8	24.8	30.5	98	84
September'93	413.4	23.7	31.2	98	75
October'93	436.6	20.1	30.1	98	73
November'93	38.8	16.6	27.5	80	64
December'93	15.4	12.4	26.5	96	49

Sundararaju and John, 1992). The rate of survival of nymphs varied depending on the species, food etc. was used. Smith(1973) recorded about 70% nymphs of H.clavifer walker reached adult stage when reared on cocoa pods. While Sundararaju and John (1992) reported 50.9% to 93.9% of nymphs attained adult stage of H.antonii reared on cashew plant. He reported the maximum survival of nymphs reached adult stage during May, December and January. A significant changing sex ratio was reported during March to August.

In the present study when mass rearing was attempted in the field condition, almost similar picture was observed. In this case around 98% nymph reached adultstage during August-September with a very high favoural sex ratio indicating the suitability of this method in mass rearing of H.theivora on tea. Most of the previous workers faced grear hardle in mass rearing of Helopeltis spp. under laboratory condition. However, they were able to produce a small number of Helopeltis adults, adopting various techniques so the mass rearing of Helopeltis spp. remained the far cry.

On the other hand the present investigation has paved the way for mass multiplication of Helopeltis species by field cage technique which was otherwise difficult to perform under laboratory conditions.

4.4 Monitoring of tea mosquito bug (H.theivora waterh.) and population prediction model of tea mosquito bug :

To develop a reliable system for monitoring and assessment of tea mosquito bug population to forwarn the tea estate managers, change in population abundance, egg laying of the pest, different studies were undertaken.

Different sizes of yellow sticky traps were fixed in TRA Experimental Station at 1-1.5 meters above the ground level during July to September, 1991 (Table -4.8). As previously reported by

Table 4.8 : Mean percent of major orders of insect caught/
sticky trap in three months (July - Sept.,91).

Orders	Mean percent of insects		
	July	August	September
Lepidoptera	3.5	1.9	2.5
Coleoptera	2	0	4.1
Hemiptera(aphid,jassids thrips)	82.8	87.5	89.3
Hymenoptera	1.6	1.4	0.3
Diptera	10.1	9.2	3.8
<u>Helopeltis theivora</u> Water	0	0	0

Prokopy and Owens (1983) that the yellow color attracts a wide range of insects, so yellow color sticky traps were tested for trapping the tea mosquito bug during their peak period of activity.

It is envisaged from the table that maximum percent of insect were caught during the three months under the order hemiptera (82.8, 87.5, 89.3). The lowest percent of insects were under hymenoptera (1.6, 1.4, 0.3). Under the order hemiptera, the insects were mostly jassids, thrips, aphid, no tea mosquito bug was found in this yellow sticky trap. It can be clearly said from the present study that the traps were not effective to catch the tea mosquito bug.

Similarly light traps was also fitted to study the possibility of light trap catch during May to November for three years ('91, '92, '93). Maximum trap catches were hemipteran insect (57.8, 46.1, 41.8) followed by lepidopteran insect (20.6, 35.7, 28.8) (Table - 4.9). Other insects under order coleoptera,

Table 4.9 : Light trap catches for Helopeltis at Nagrakata, Jalpaiguri.

Orders	Mean percent of major orders of insects caught/light trap during May - Nov., at '91, '92, '93		
	1991	1992	1993
Lepidoptera	20.6	35.7	28.8
Coleoptera	8.9	10.3	8.4
Hemiptera	57.8	46.1	41.8
Hymenoptera	3.5	5.2	12.3
Diptera	9.2	2.7	6.7
<u>Helopeltis theivora</u> Water	0	0	0

hymenoptera and diptera were in small number. Among hemipteran insects no tea mosquito bug was found in the trap. So again it is clear that tea mosquito is not attracted by light. No such literature was available regarding the attractive^{nchb} of tea mosquito-bug to light. Stonedahl 1993 (personal communications) reports that the tea mosquito bug is not attracted by light. Sex pheromones are one of the recent tools employed in insect pest management. Earlier reports have indicated that the presence of a sex attractant pheromone in female of Helopeltis clavifer (Smith 1977) congeneric species of H. antonii. However, very little information is available on the existence of sex pheromone in the tea mosquito bug. The study was undertaken to reveal the presence of sex pheromone in tea mosquito bug (H. theivora) and influence of age with the help of modified wind tunnel method.

In the present investigation the female of H. theivora attracted the males only when an air current was generated through wind tunnel apparatus. It is evident that the air female that resulted in attraction of males, in effect, the possibility of a sex pheromones. The behavioural responses of males noticed that antennal movement, rapid walking, chasing and mounting on other males. These behavioural responses were not noticed in either females in the test chamber. This observation confirmed by Sundararaju (1994). The present results are in confirmity with earlier studies on eight other species of mirids (Scales, 1968; Strong, et al. 1970; King, 1973; Smith 1977; Boivin & Stewart 1982;

Slaymaker and Tugwell, 1984; Graham 1987; Thristlewood et al. 1989). Different age group were kept 10 unmated male tea mosquito bug in bait chamber and 10 female in test chamber. Air blown through bait chamber to test chamber, no adult male reach the bait chamber in one hour when position of male and female changed 10 female bait chamber and 10 male test chamber, the number of 2, 3, 4 day old male adults reached the bait chamber were 2, 5, 7 respectively (Table 4.10). It was found that the female attracting more males when 4 day old. For the confirmation of sex attraction in 4 day old tea mosquito bug, the experiment was repeated five times with only this age group (Table 4.11).

Table 4.10 : Sex attraction in one to four days old tea mosquito bug through wind tunnel trap.

Treatment	Age of newly emerged adult (days)	No. of adults reaching bait chamber in one hour	
		No. of air blows through bait chamber to test chamber	Air blown through bait chamber to test chamber
i) 10 ♀ in bait chamber & 10 ♀ in test chamber	1	0(0.7071)	0(0.7071)
	2	0(0.7071)	0(0.7071)
	3	0(0.7071)	0(0.7071)
	4	1(1.2247)	0(0.7071)
ii) 10 ♀ in bait chamber & 0 ♀ in test chamber	1	0(0.7071)	0(0.7071)
	2	0(0.7071)	2(1.5811)
	3	1(1.2247)	5(2.3452)
	4	0(0.7071)	7(2.7386)
C.D. at P=0.05		0.325	

Figure in parenthesis are root transformed values.

Table 4.11: Sex attraction in four days old tea mosquito bug through wind tunnel trap.

Treatment	Replication	No. of adults reaching bait chamber in one hour	
		No Air blown	Air blown
i) 10 σ in bait chamber & 10 σ in test chamber	1	0(0.7071)	1(1.2247)
	2	1(1.2247)	0(0.7071)
	3	0(0.7071)	0(0.7071)
	4	0(0.7071)	2(1.5811)
	5	0(0.7071)	1(1.2247)
ii) 10 σ in bait chamber & 10 σ in test chamber	1	0(0.7071)	4(2.1213)
	2	0(0.7071)	3(1.8708)
	3	2(1.5811)	6(2.5495)
	4	3(1.8708)	4(2.1213)
	5	2(1.5811)	5(2.3452)
C.D. at $P = 0.05$			0.514

Figure in parenthesis are root transformed values.

So it is evident from the observation (Table 4.10, 4.11) that the three and four days old adult females attracted the males indicating the probable presence of sex pheromone. Strong et al. (1970) suspected that the mirids reproductive organs particularly spermatheca secretes sex pheromones.

It is evident from the Table 4.12 that the peak population of the pest was recorded during September to October while it was minimum during December to April. The population build up of the pest started from April reaching its zenith in October. The mean temperature recorded during September to October (peak period of incidence) ranged

between 28-31°C. While the mean relative humidity was around 80% .
The mean rainfall during the peak period of incidence was around
12 cm.

Table 4.12 : Population dynamics of tea mosquito bug during
January - December'93 at Birpara sub-district.

Period of observa- tion (1)	Mean No. adult/op- eration (2)	Temperature °C		Relative humidity.....		Rainfall (cm) (7)
		Max. (3)	Min. (4)	Morning (5)	Afternoon (6)	
<u>January</u>						
1st week	3.0	19.57	11.28	99.14	73.14	0.08
2nd week	3.2	16.71	10.87	100.00	87.28	4.72
3rd week	3.8	19.14	10.71	99.71	52.00	0.08
4th week	3.0	19.71	10.14	99.28	54.85	0.00
<u>February</u>						
1st week	3.4	24.71	13.57	90.28	38.14	0.00
2nd week	3.0	24.71	18.28	95.71	63.57	3.56
3rd week	2.0	23.85	17.71	97.28	59.00	5.08
4th week	4.2	24.00	14.14	91.28	42.28	0.00
<u>March</u>						
1st week	5.6	27.14	17.42	92.57	48.42	0.00
2nd week	3.2	30.14	19.71	83.57	31.57	0.00
3rd week	1.6	28.85	18.00	77.00	34.71	0.00
4th week	2.2	27.57	18.71	90.42	56.28	0.63
<u>April</u>						
1st week	2.0	31.28	25.71	77.00	28.42	0.00
2nd week	2.0	28.71	24.71	84.42	55.28	0.69
3rd week	3.2	28.14	23.28	89.14	64.00	9.52
4th week	3.8	30.28	23.00	87.85	58.28	5.05
<u>May</u>						
1st week	4.2	29.28	21.28	97.14	77.14	16.12
2nd week	5.0	31.57	24.57	90.42	68.00	17.80
3rd week	3.4	31.00	24.14	95.57	74.14	21.60
4th week	4.4	31.14	24.57	93.14	65.14	10.19

(Contd..)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
<u>June</u>						
1st week	9.0	31.85	26.14	97.85	77.57	13.90
2nd week	5.8	33.14	27.00	94.57	74.57	6.28
3rd week	4.8	32.42	27.28	95.42	81.85	6.35
4th week	6.4	33.71	25.05	96.57	81.14	45.06
<u>July</u>						
1st week	6.2	31.57	26.42	86.71	84.28	24.20
2nd week	3.8	33.71	29.42	79.00	67.85	1.78
3rd week	5.2	31.28	27.14	86.00	74.14	10.27
4th week	7.6	34.14	28.42	86.85	77.85	14.73
<u>August</u>						
1st week	6.8	33.97	27.42	81.00	71.85	12.98
2nd week	7.4	33.85	29.71	86.00	81.14	7.64
3rd week	8.4	35.28	30.42	84.14	78.00	7.29
4th week	7.6	31.42	26.57	82.28	71.00	14.09
<u>September</u>						
1st week	8.4	34.14	27.71	85.85	80.57	2.54
2nd week	7.4	35.85	29.28	85.14	80.00	8.25
3rd week	9.2	35.28	28.42	89.00	76.71	6.35
4th week	7.6	31.42	26.71	86.85	79.42	11.20
<u>October</u>						
1st week	10.0	33.28	26.00	90.00	76.00	7.97
2nd week	8.4	33.14	25.28	86.71	71.00	24.05
3rd week	9.2	32.85	25.57	87.42	70.57	21.59
4th week	6.2	29.72	25.71	87.57	78.85	0.00
<u>November</u>						
1st week	6.2	29.00	21.57	85.85	65.28	0.00
2nd week	5.2	29.57	20.28	85.28	77.85	0.00
3rd week	5.4	27.57	19.14	77.28	52.14	0.00
4th week	6.2	27.28	17.28	75.14	65.00	0.00
<u>December</u>						
1st week	3.4	26.85	16.71	81.00	53.00	0.00
2nd week	5.0	26.42	15.71	86.14	46.00	0.00
3rd week	4.2	24.42	14.42	81.85	59.00	0.00
4th week	3.6	24.14	13.57	85.28	48.00	0.00

Attempts were made to develop population prediction model based on suction trap catches as dependent variable (Y) and weather parameters as independent variables (X₁, X₂ and So on). The correlation matrix showing the relationship between the suction trap catches and weather factors at weekly intervals are presented in table 4.13.

The number of tea mosquito bugs caught in the suction trap had a negative association with morning relative humidity and a positive association with maximum temperature, minimum temperature, afternoon relative humidity and rainfall. But the association were significant with maximum temperature ($r = 0.728$), minimum temperature ($r = 0.701$), afternoon) relative humidity ($r = 0.827$) and rainfall($r=0.393$).

Table 4.13 :Correlation matrix of relationship between suction trap catches (Y) and weather parameters (n = 44). Data were computed at weekly intervals.

Variables	X ₂	X ₃	X ₄	X ₅	Y
X ₁ = Maximum temp.(°C)	0.981**	-0.328	0.726**	0.621**	0.728**
X ₂ = Minimum temp.(°C)		-0.239	0.772**	0.685**	0.701**
X ₃ = Morning R.H.(%)			0.056	0.082	-0.233
X ₄ = Afternoon R.H.(%)				0.681**	0.827**
X ₅ = Rainfall (Cm)					0.393**

* Significant P = 0.05, ** Significant at P = 0.01

The meteorological factors studied were found to be positively correlated among themselves ranging between 0.621 to 0.685 and most of the associations were significant except with the morning relative humidity.

The results of the multiple regression analysis (Table-4.14) of different weather factors on the suction trap catches depict that the factors studied (maximum and minimum temperature, morning and afternoon relative humidity and rainfall) produced combined interaction ($R^2 = 0.923$ at $P = 0.01$) of the total variation of the population of tea mosquito bug in the trap.

As the meteorological factors (temperature, relative humidity, rainfall) are dependent among themselves, the cumulative interaction of their association influenced the total variation of population of tea mosquito bug.

Table 4.14 : Multiple regression analysis of suction trap catches (Y) and weather factors (n=44). Data were computed at 2 weekly interval. Constant term a = -9.441, $R^2 = 0.923$, Significant at $P = 0.01$

Variables	Mean	Partial regression coefficient (b)
X_1 = Maximum temp.(°C)	29.945	0.651
X_2 = Minimum temp.(°C)	22.845	-0.438
X_3 = Morning R.H.(%)	88.070	-0.052
X_4 = Afternoon R.H. (%)	65.610	0.158
X_5 = Rainfall (Cm)	9.743	-0.054

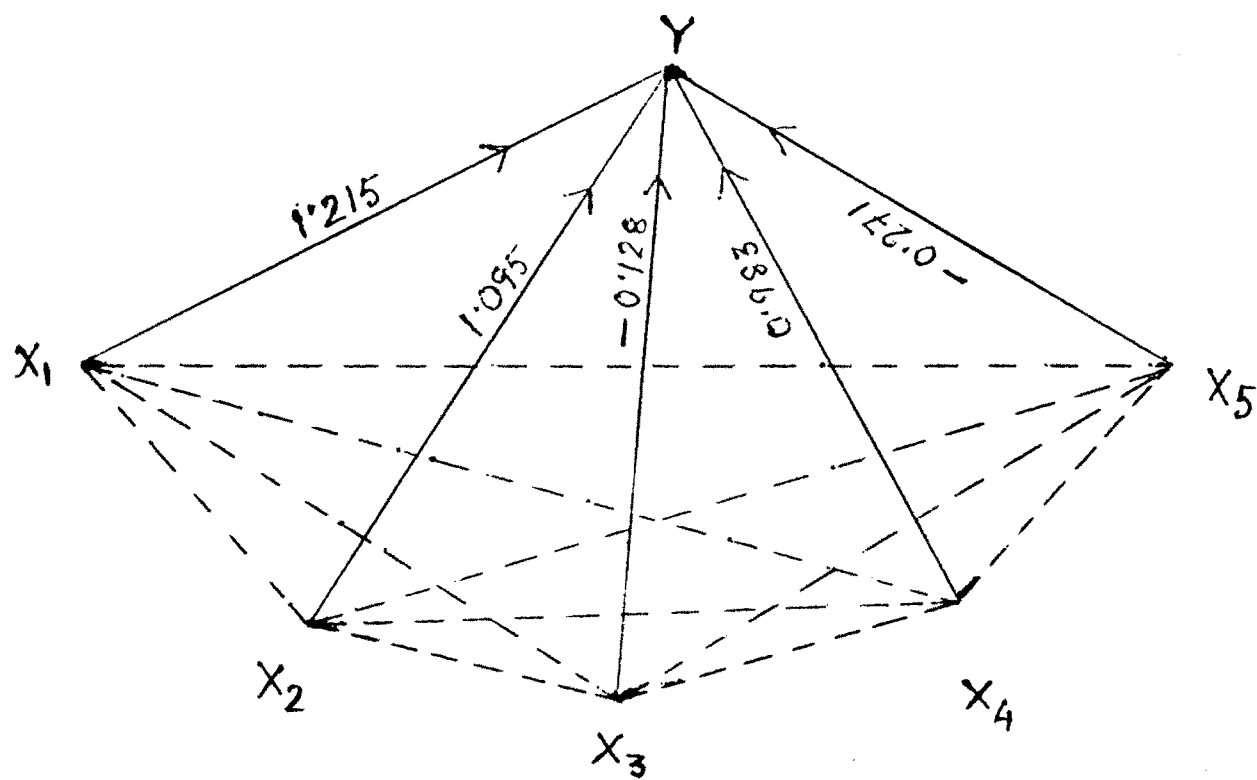


Fig. 2. Schematic representation of path co-efficient analysis.

It is evident from the path co-efficient analysis (Fig.2) that the direct effect of maximum temperature on population was high when the maximum temperature increased. But high temperature reduced the insect population indirectly through its correlated variables. The sum total indirect effect of maximum temperature (X1), through minimum temperature (X2), morning relative humidity (X3), afternoon relative humidity (X4) and rainfall (X5) is -0.486. Hence the total effect of maximum temperature (X1) on population reduces to 0.728, table-4.15.

Table 4.15: Total effect of X_1, X_2, X_3, X_4, X_5 on population dynamics of Helopeltis during the year 1993.

Weather parameters	Direct effect	Indirect effect	Total effect
X_1 = Maximum temp. (°C)	1.215	-0.486	0.728
X_2 = Minimum temp.(°C)	-1.095	1.794	0.699
X_3 = Morning R.H.(%)	-0.128	-0.103	-0.231
X_4 = Afternoon R.H.(%)	0.983	-0.154	0.829
X_5 = Rainfall (cm)	-0.271	0.663	0.392

The direct effect of minimum temperature and rainfall were negative but both the parameters increased the population level indirectly. The total direct and indirect effect of minimum temperature and rainfall reduced to 0.699 and 0.392 respectively.

The afternoon relative humidity had direct influence in increasing the insect population but in association with other parameters responded indirectly amounting to negative effect of Helopeltis population. The total effect (both direct and indirect) of the afternoon

relative humidity showed positive correlation with the mosquito bug population (0.829).

The multiple regression equation fitted with weather factors to predict the number of tea mosquito bug caught in suction trap.

$$Y = -9.441 + 0.651 X_1 - 0.438 X_2 - 0.052 X_3 + 0.158 X_4 - 0.054 X_5$$

The ultimate goal of pest control programme is the accurate forecasting of pest attacks before they actually take place, so that the control measure can be planned with maximum efficiency (Hilli, 1993). Singh et al. (1996) prepared a prediction model on serpentine leafminer Lirionomyza trifolii Burges based on weather parameters. According to his findings, the population of L.trifolii was immensely influenced by sunshine and rainfall and it was observed that the development of this pest was faster during bright and humid period (September - October).

4.5 Response of tea mosquito bug to temperature by Linear temperature Gradient apparatus :

Environmental factors such as relatively cool temperatures and high relative humidity that prevail in the field during the rainy season are probably within ranges that the preferred by tea mosquito bug for survival and reproduction and subsequent population build up.

Laboratory studies on the behaviour of tea mosquito bug in a linear temperature and humidity gradients were therefore, carried out, in order to obtain information on its temperature and moisture reaction.

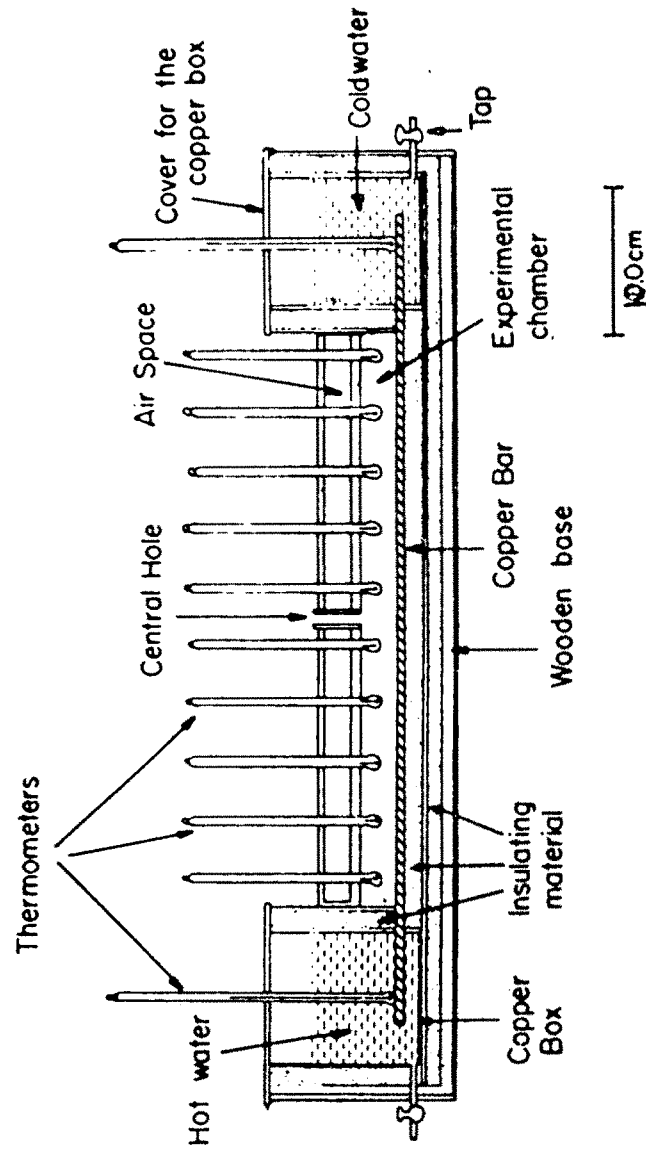


Fig. 3A A Section of the temperature gradient apparatus.

Such information could be used as a basis for partial explanation of the occurrence of high population of Helopeltis in the field during the rainy season.

The reaction of different stages of Helopeltis theivora to temperature was studied by use of linear temperature gradient apparatus (Fig. 3A), described by Youdeowei (1968) and Nwana (1975). The thermometers for recording the temperature were, therefore, placed half way from the top of the chamber in order to record the mid temperature of the chamber because most of the insects were on the side walls and roof of the chamber. Deal (1941) had pointed out the differences between floor, mid or roof temperature in an experimental chamber, and significantly different from either the floor or roof temperature.

First and Second instar nymph - A temperature gradient of 22.06°C to 38.80°C was established within the chamber by use of ice cold water and hot water in the right and left copper boxes respectively. The established temperature in sector one on the left to sector on the right of the apparatus were 38.80, 35.23, 34.93; 32.87; 31.35, 28.62; 26.43; 26.16; 25.37 and 22.06 degree celsius respectively. The desired temperatures were maintained thereafter by draining the water in the boxes through taps and replacing with water at the appropriate temperature.

The frequency distribution of first and second instar nymphs of tea mosquito bug in a linear temperature gradient (22.06°C - 38.80 °C) and under a uniform temperature ($26.76 \pm 0.26^\circ\text{C}$) are presented in

Table 4.16, 4.17; Fig. 4,5. The insects were observed to be very active at the hot sectors (31.5° - 38.80°) and often avoided that end with higher temperature. The avoidance of the hot sectors of the apparatus and the higher number of first and second instar nymphs recorded at the cool sectors (22.06° - 28.62°). The nymphs were uniformly distributed in the chamber under a uniform temperature of $26.76 \pm 0.26^{\circ}\text{C}$.

Table 4.16: Distribution of First and Second instar Helopeltis nymph in a linear temperature gradient.

Mean temperature °C	Frequency in percent of nymphs
22.06	13.75 (21.76)
25.37	6.25(14.47)
26.16	16.25(23.77)
26.43	8.75(17.20)
28.62	12.50(20.70)
31.35	7.50(15.89)
32.87	6.25(14.47)
34.93	8.75(17.20)
35.23	7.50(15.89)
38.80	12.50(20.70)

N.S.

Figure in parenthesis are angular transformed values.

Table 4.17: Distribution of First and Second instar Helopeltis theivora nymph in a uniform temperature gradient.

Mean temperature °C	Frequency in percent of nymphs
26.58	9.33 (17.78)
26.63	11.43 (19.76)
26.66	10.12 (18.54)
26.64	9.54 (17.99)
26.68	11.42 (19.75)
26.65	9.30 (17.75)
26.67	10.56 (18.96)
26.59	10.21 (18.63)
26.66	8.34 (16.78)
26.65	9.75 (18.19)

Figure in parenthesis are angular transformed values.

The mode of distribution of the insect in the temperature gradient apparatus was at a temperature of 26.16°C. It thus appears that the higher frequency distribution of the nymphs (16.25%) at the cool end was not due to the end effect but due to preference of the lower temperature ranges (22.06 - 28.62°C).

The higher numbers observed in the cooler zone could, however, be partially accounted for by the aggregating tendency of insects under cold temperature in the gradient apparatus (Youndeowei, 1968).

Third instar nymph - Another temperature gradient of 23.45°C to 37.54°C was established within the chamber. The established temperature were 37.54; 37; 34.78; 33.55; 32.20; 27.78; 27.91; 25.60; 24.47 and 23.45 degree celsius. The frequency distribution of third instar nymph of tea mosquito bug in a linear temperature gradient (23.45° - 37.54°) and under a uniform temperature 26.54 are presented in Table 4.18, 4.19 and in Fig.6,7. The higher number insects recorded at the cooler sector (23.45 - 27.98) and the mode of distribution was at a temperature of 25.60. It is observed that with the advancement of stages (then tendency of aggregation towards cooler sectors.

Table 4.18: Distribution of third instar Helopeltis nymph in a linear temperature gradient.

Mean temperature °C	Frequency in percent of nymph
23.45	12.78(20.94)
24.47	8.52(16.97)
25.60	14.20(22.13)
27.91	11.10(19.46)
27.98	7.10(15.45)
32.20	8.10(15.45)
33.55	8.52(16.97)
34.78	8.78(17.23)
37.00	9.94(18.37)
37.54	7.10(15.45)
C.D. at 5% level	(27.09)

Figure in parenthesis are angular transformed values.

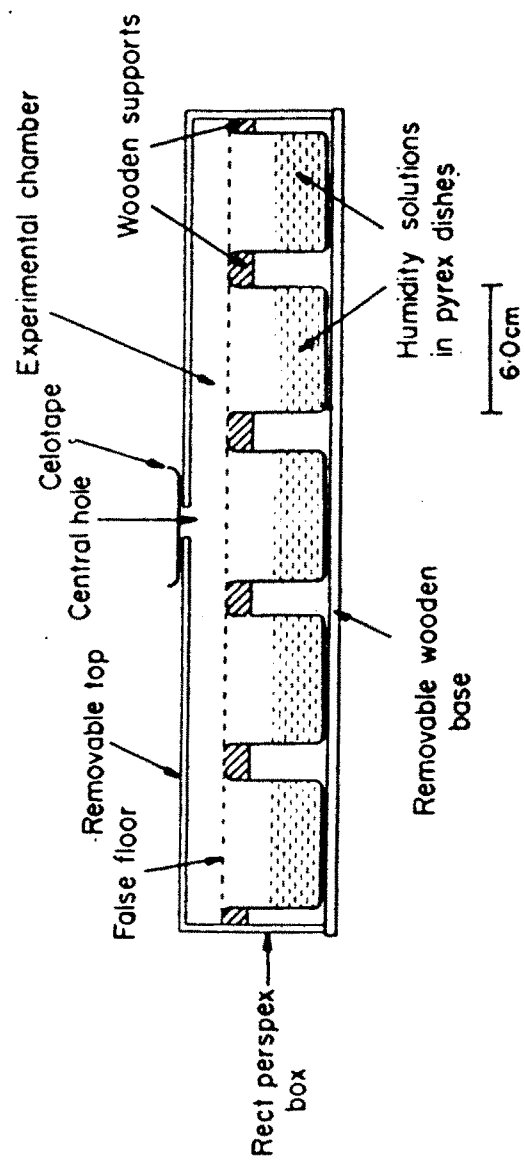


Fig 3 B A Section of the relative humidity gradient apparatus

Table 4.19: Distribution of third instar H.theivora nymph in a uniform temperature gradient.

Mean temperature °C	Frequency in percent of nymph
26.58	10.32(18.73)
26.63	9.49(17.94)
26.66	10.11(18.53)
26.64	9.44(17.89)
26.68	11.45(19.77)
26.65	10.31(18.72)
26.67	10.13(18.55)
26.59	9.87(18.31)
26.66	9.48(17.93)
26.65	9.4 (17.85)

Figure in parenthesis are angular transformed values.

Fourth instar nymph - Similarly the response of fourth instar nymph to the temperature gradient of 20.37°C to 39.37°C was observed in the linear temperature gradient apparatus. The temperatures were 39.37; 34.75; 33.56; 31.31; 30.25; 27.75, 25.75, 23.50; 22.25; and 20.37 degree celsius. The higher number of insect observed at the cooler sector (20.37° - 27.75°), though the mode of distribution of fourth instar nymph observed at 27.75°C but they are uniformly distributed at the uniform temperature (26.12) Table 4.20, 4.21, Fig. 8, 9.

Table 4.20 : Distribution of Fourth instar Helopeltis nymph in a linear temperature gradient.

Mean temperature °C	Frequency in percent of nymph
20.37	11.00(19.36)
22.25	9.75(18.19)
23.50	11.25(19.59)
25.75	10.25(18.67)
27.75	12.50(20.70)
30.25	8.75(17.20)
31.31	8.75(17.20)
33.56	7.75(16.16)
34.75	8.75(17.20)
39.37	11.50(19.82)
C.D. at 5% level	(15.21)

Figure in parenthesis are angular transformed values.

Table 4.21: Distribution of Fourth instar H. theivora nymph in a uniform temperature gradient.

Mean temperature °C	Frequency in percent of nymph
26.58	10.11(18.53)
26.63	9.58(18.03)
26.66	9.67(18.11)
26.64	11.47(19.79)
26.68	10.32(18.73)
26.65	9.56(18.01)
26.67	10.11(18.53)
26.59	9.89(18.32)
26.66	9.34(17.79)
26.65	9.95(18.38)

Figure in parenthesis are angular transformed values

Fifth instar nymphs - Again in case of fifth instar nymphs the established temperature were 36.94, 36; 33.50; 32.53; 30.89, 29.55; 26.61; 24.38; 23.44 and 22.44 degree celsius. The higher number of nymphs observed at the cooler sectors (22.44°C to 29.55°C). The mode of distribution of fifth instar nymph was at 24.38°, but they were uniformly distributed at temperature 26.76°C (Table 4.22, 4.23, Fig. 10,11).

The results of the nymphs conform with those of Nielsen and Nielsen (1959), Youdeowei (1968) and Daramola (1976), who showed independently that insects are not necessarily normally distributed in a linear temperature gradient.

Male - The frequency distribution of male of H.theivora in a linear temperature gradient (18.24° - 38.12°C) and under uniform temperature (27.34) are presented in Table . 4.26, 4.27, Fig.12,13. The established temperatures were 38.12, 35.02, 31.86; 29.57, 28.34; 25.78, 24.56, 20.68; 20.13 and 18.24 degree celsius. The frequency distribution of male was significantly higher at the cool (18.24°C to 25.78°C) than at the hot (28.34°C - 38.12°C) region of chamber. The mode of distribution of temperature gradient apparatus was at a temperature as obtained from the point of intersection of the linear temperature graph and the position along the temperature gradient with the mode of the distribution (Okwankpan, 1978), was 20.13. It thus appears that the higher frequency distribution of male at the coolend was not due to end effect but to preference of lower temperature ranges of 18.24° - 25.78°C.

Table 4.22: Distribution of Fifth instar Helopeltis nymph in a linear temperature gradient.

Mean temperature °C	Frequency in percent of nymph
22.44	8.88(17.33)
23.44	5.55(13.62)
24.38	23.31(28.86)
26.61	12.16(20.40)
29.55	8.88(17.33)
30.88	8.88(17.33)
32.53	11.11(19.47)
33.50	5.55(13.62)
36.00	7.77(16.11)
36.94	15.54(23.21)
C.D. at 5% level	(15.60)

Figure in parenthesis are angular transformed values.

Table 4.23 : Distribution of Fifth instar H.theivora nymph in a uniform temperature gradient.

Mean temperature °C	Frequency in percent of nymph
26.58	8.34(16.78)
26.63	9.56(18.01)
26.66	10.78(19.16)
26.64	11.43(19.76)
26.63	12.41(20.62)
26.65	8.37(16.81)
26.67	10.44(18.85)
26.59	8.39(16.83)
26.66	10.38(18.79)
26.65	9.9(18.33)

Figure in parenthesis are angular transformed values.

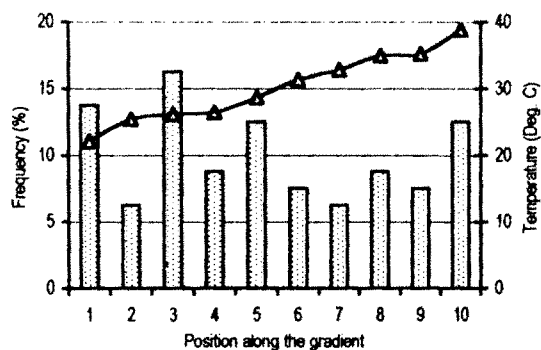


Fig. 4 1st and 2nd instar nymph

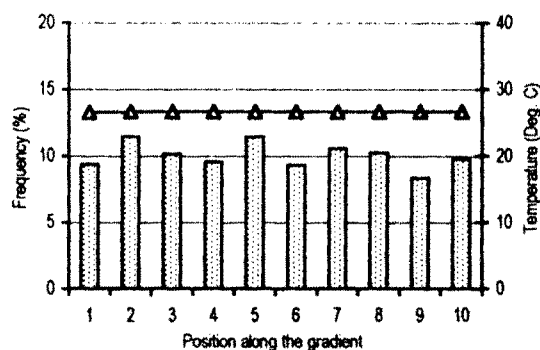


Fig. 5 Control

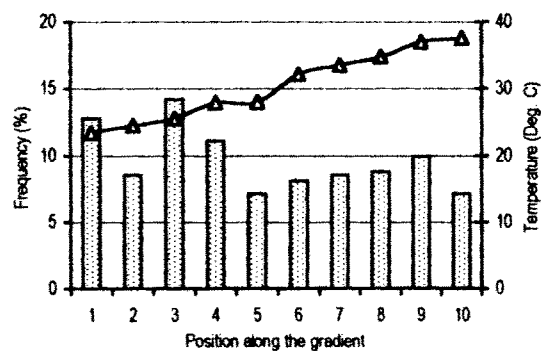


Fig. 6 3rd instar nymph

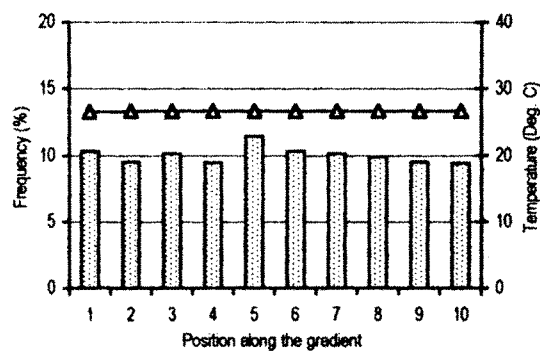


Fig. 7 Control

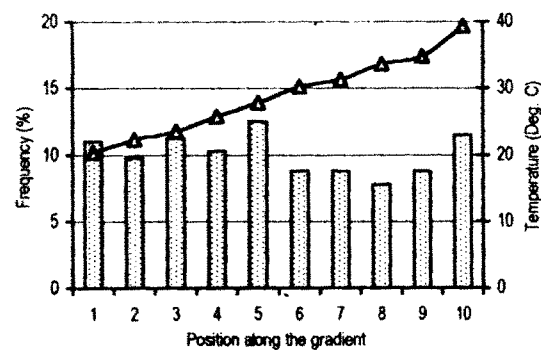


Fig. 8 4th instar nymph

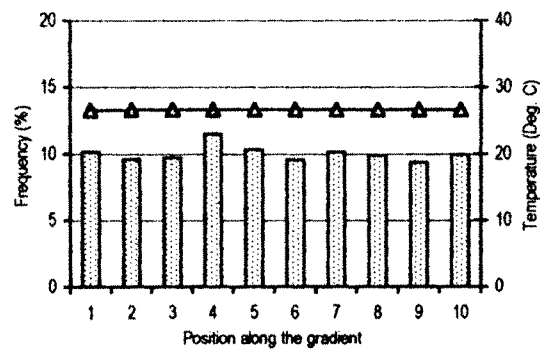


Fig. 9 Control

Distribution of *Helopeltis theivora* in linear temperature gradient

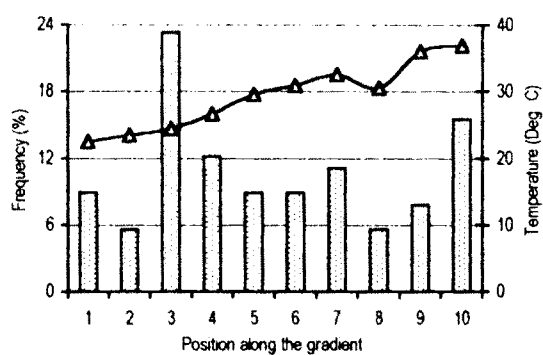


Fig. 10 5th instar nymph

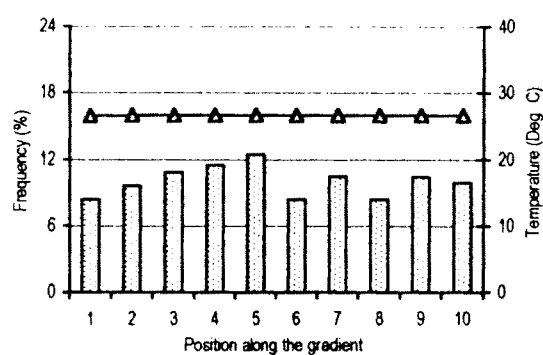


Fig. 11 Control

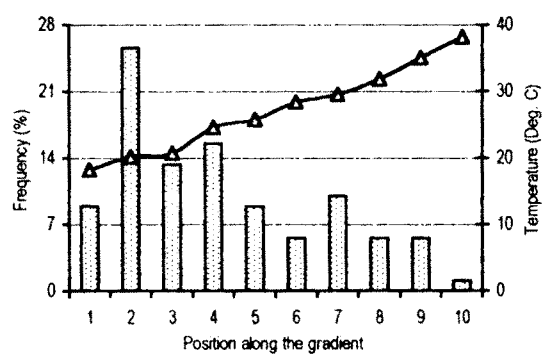


Fig. 12 Male

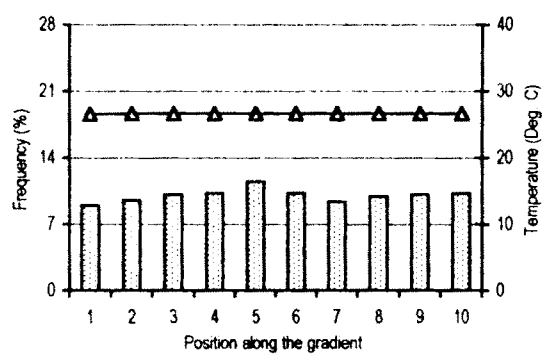


Fig. 13 Control

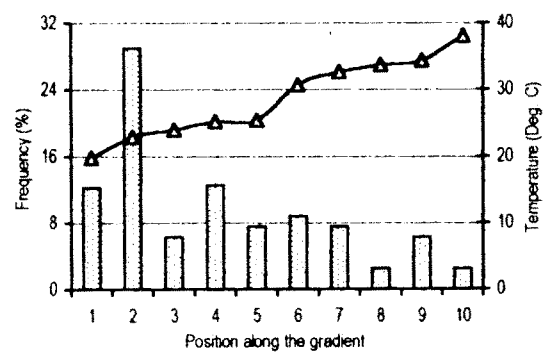


Fig. 14 Female

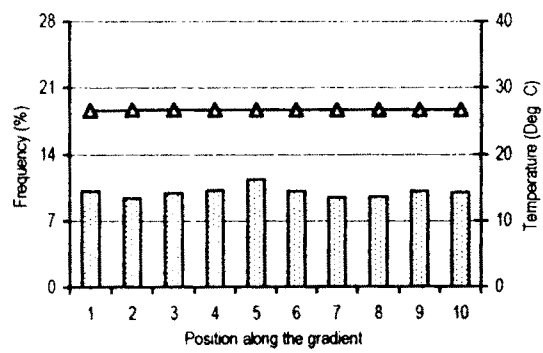


Fig. 15 Control

Distribution of *Helopeltis theivora* in linear temperature gradient

Table 4.24: Distribution of Helopeltis female in a linear temperature gradient.

Mean temperature °C	Frequency in percent of female
19.80	12.20 (20.44)
22.81	29 (32.58)
23.90	6.25 (14.47)
25.16	12.5 (20.70)
25.41	7.5 (15.89)
30.73	8.75 (17.20)
32.62	7.5 (15.89)
33.67	2.5 (9.09)
34.40	6.25 (14.47)
38.06	2.5 (9.09)
C.D. at 5% level	(9.12)

Figure in parenthesis are angular transformed values.

Table 4.25 : Distribution of H.theivora female in a uniform temperature gradient.

Mean temperature °C	Frequency in percent of female
26.58	10.12 (18.54)
26.63	9.34 (17.79)
26.66	9.87 (18.31)
26.64	10.16 (18.58)
26.68	11.34 (19.67)
26.65	10.11 (18.53)
26.67	9.44 (17.89)
26.59	9.52 (17.97)
26.66	10.11 (18.53)
26.64	9.99 (18.42)

Figure in parenthesis are angular transformed values.

Female - Again in case of female the established temperature gradient in linear of temperature gradient apparatus were 38.06; 34.40; 33.67; 32.62; 30.73; 25.41; 25.16; 23.90; 22.81 and 19.80 and under a uniform temperature (26.44) presented in Table-4.24, 4.25, Fig. 14, 15. The frequency distribution of female was significantly higher at the cool (19.80 - 25.41°C) than at the hot (30.73° - 38.06°C) region of chamber. The insects showed no significant end effect recorded for other insects such as Dermestes maculatus bug.(Toye 1970), Bathycoetis thalassina H-S. (Nwana 1975) and Sophrorhinus gbanjaensis Daramola and Taylor (Daramola, 1976).

The mode of distribution in the Temperature Gradient Apparatus was at a temperature 19.80°C. The preferred temperature as obtained from the point of intersection of the linear temperature graph and the position along the temperature gradient with the mode of the distribution (Okwankoam 1978) was 19.80°. It again appears in case of female that the higher frequency distribution at the cool end was not due to end effect but to preference of lower temperature ranges of 19.80°C - 25.41°C.

Temperature is the single most important factor controlling insect development and hence population number. A simple method using mean temperatures for two months has been developed to predict the date of emergence of the adult of the rice stem borer in Japan (Hill, 1993).

Table 4.26: Distribution of Helopeltis male in a linear temperature gradient.

Mean temperature °C	Frequency in percent of male
18.24	8.88(17.33)
20.13	25.53(30.34)
20.68	13.32(21.40)
24.58	15.54(23.21)
25.78	8.88(17.33)
28.34	5.55(13.62)
29.57	9.99(18.42)
31.86	5.55(13.62)
35.05	5.55(13.62)
38.12	1.11(6.04)
C.D. at 5% level	(12.76)

Figure in parenthesis are transformed values.

Table 4.27: Distribution of H.theivora male in a uniform temperature gradient.

Mean temperature °C	Frequency in percent of male
26.58	8.93(17.38)
26.63	9.49(17.94)
26.66	10.12(18.54)
26.64	10.23(18.65)
26.68	11.46(19.78)
26.65	10.21(18.63)
26.67	9.33(17.78)
26.59	9.88(18.32)
26.66	10.13(18.55)
26.65	10.22(18.64)

Figure in parenthesis are transformed values.

4.6 Response of tea mosquito bug to humidity by Linear Humidity Gradient Apparatus :

The reaction of different stages of H. theivora to moisture was also studied by use of a linear relative humidity gradient apparatus (Fig.) described by Youdeowei (1967). It was a rectangular perplex box with a removable top, and a wooden bottom. It was divided into 5 sectors. Each dish contained graded aqueous solutions of sodium hydroxide prepared according to the method of Madge (1961) to produce a relative humidity of 20, 40, 60, 80 and 95 percent in the chamber.

First and Second instar nymphs - The frequency distribution of first and second instar nymphs in a linear relative humidity gradient of 20, 40, 60, 80 and 95 percent and in a saturated atmosphere of the gradient apparatus are presented in Table - 4.28, 4.29; Fig. 16, 17. The frequency of first and second instar nymphs significantly higher in the moist sectors (60 percent - 95 percent r.h.) than in the dry sectors with humidity values of 20 percent and 40 percent. In the control experiment, the same number aggregated at both ends of the chamber probably due to the usual edge effect and the analysis of the numbers of insect recorded at different regions along the gradient showed a significant preference for the two ends. A similar analysis of the number of insect recorded under the different humidity level and at different regions of the gradient apparatus showed a significant preference for the region with a humidity ranges of 80 percent - 95 percent.

Table 4.28 : Distribution of H.theivora nymphs (First and second instar) in linear relative humidity gradient.

Relative Humidity	Frequency in % (mean of ten replications)
20	23(28.65)
40	11(19.36)
60	12(20.26)
80	17(24.35)
95	37(37.46)

Figure in parenthesis are angular transformed values.

Table 4.29: Distribution of H.theivora nymphs (First and second instar) in a uniform relative humidity gradient (saturated air).

Relative humidity	Frequency in % (mean of ten replications)
20	22(27.97)
40	18(25.10)
60	15(22.78)
80	16(23.57)
95	29(32.58)

Figure in parenthesis are angular transformed values.

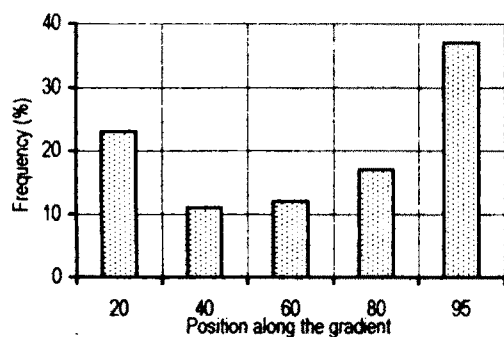


Fig. 16 1st and 2nd instar nymph

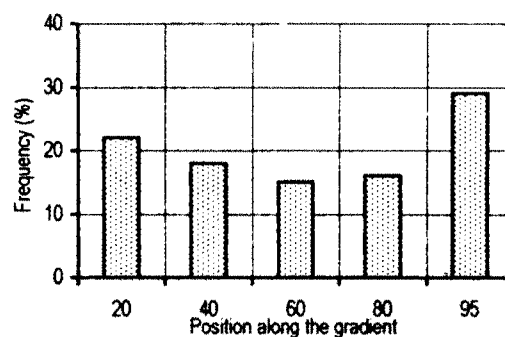


Fig. 17 Control

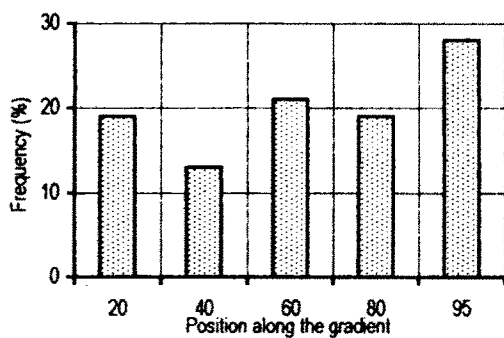


Fig. 18 3rd instar nymph

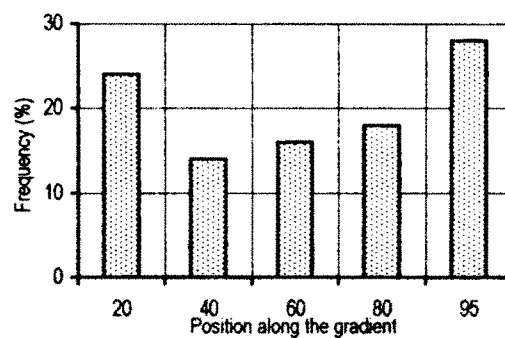


Fig. 19 Control

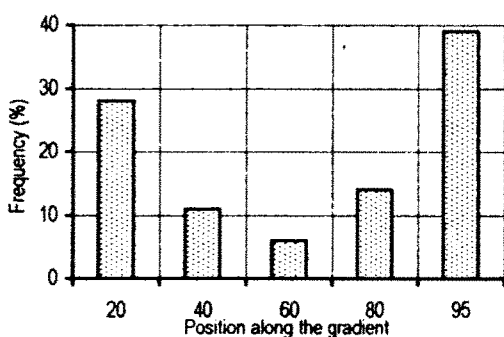


Fig. 20 4th instar nymph

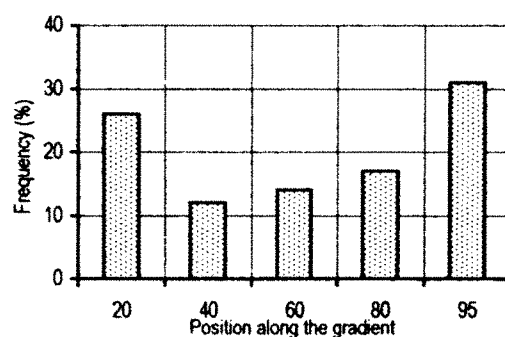


Fig. 21 Control

Distribution of *Helopeltis theivora* in linear relative humidity gradient

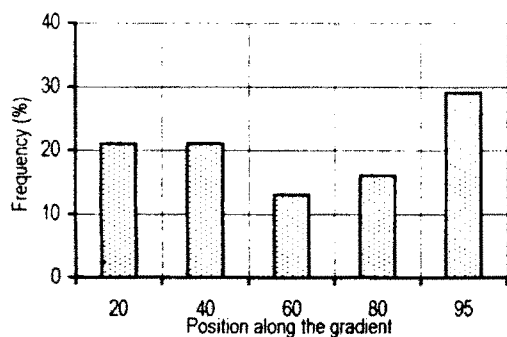


Fig. 22 5th instar nymph

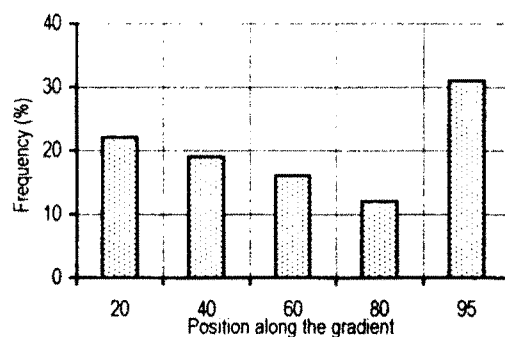


Fig. 23 Control

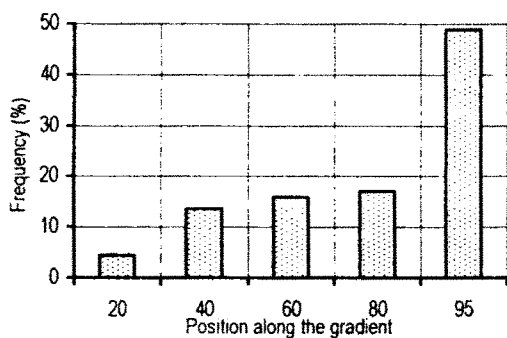


Fig. 24 Female

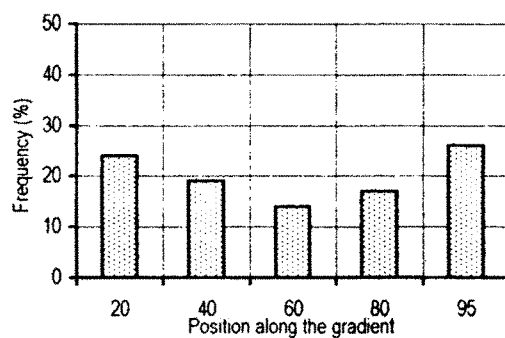


Fig. 25 Control

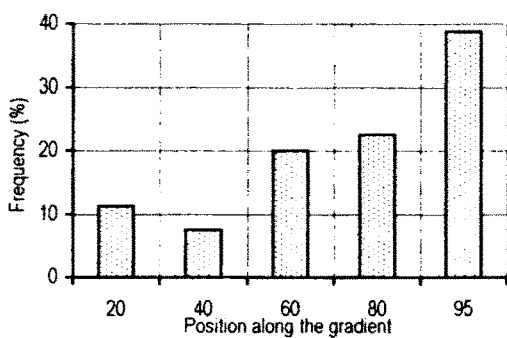


Fig. 26 Male

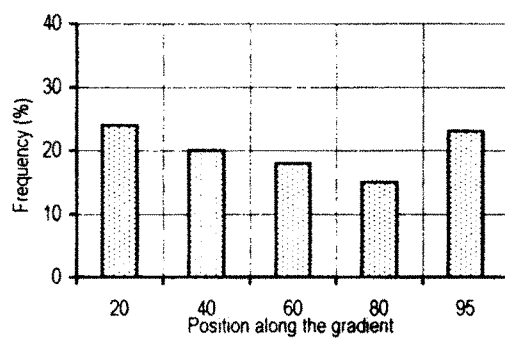


Fig. 27 Control

Distribution of *Helopeltis theivora* in linear relative humidity gradient

Third instar nymphs - The frequency distribution of third instar nymphs in a linear relative humidity gradient of 20, 40, 60, 80 and 95 percent and in a saturated atmosphere of the gradient apparatus are presented in Table 4.30, 4.31, Fig. 18,19. The frequency was higher in the moist sectors (60 percent - 98 percent r.h.) than in the dry sectors with humidity values of 20 percent and 40 percent.

Fourth instar and fifth instar nymphs - Similarly the frequency distribution of forth and fifth instar nymph in a linear relative humidity gradient of 20, 40, 60, 80 and 95percent and in a saturated atmosphere of the gradient apparatus an percent in Table 4.32, 4.33 and 4.34, 4.35, Fig. 20, 21 and 22,23. In both cases the frequency was significantly higher in the moist sector (60 percent, 95 percent) than in the dry sectors with humidity values of 20 percent and 40 percent. In the control experiments, the same number of either forth or fifth instar nymphs aggregated at both ends of the chamber probably due to the usual 'edge effect'.

Female and male - The frequency distribution of H.theivora in a linear relative humidity gradient of 20; 40, 60, 80 and 95 percent and in a saturated atmosphere of the gradient apparatus are presented in table 4.36, 4.37 and 4.38, 4.39, Fig. 24,25 and 26,27. The frequency of both female and male were significantly higher in the moist sectors (60 percent - 95 percent) than in the dry sectors with humidity values of 20 percent and 40 percent. In the control experiment, the same number of either female or males aggregated at both ends of the chamber, probably due to the usual 'edge effect'. The

Table 4.30: Distribution of H. theivora nymph (Third instar) in linear relative humidity gradient.

Relative humidity	Frequency in % (mean of ten replications)
20	19(25.84)
40	13(21.13)
60	21(27.27)
80	19(25.84)
95	28(31.94)

Figure in parenthesis are angular transformed values.

Table 4.31: Distribution of H. theivora nymph (Third instar) in a uniform relative humidity gradient (saturated air).

Relative humidity	Frequency in % (mean of ten replications)
20	24(29.33)
40	14(21.97)
60	16(23.57)
80	18(25.10)
95	28(31.94)

Figure in parenthesis are angular transformed values.

Table 4.32. Distribution of H. theivora nymphs (Fourth instar) in linear relative humidity gradient.

Relative humidity	Frequency in % (mean of ten replications)
20	28(31.94)
40	11(19.36)
60	6(14.17)
80	14(21.97)
95	39(38.64)

Figures in parenthesis are angular transformed values.

Table 4.33: Distribution of H. theivora nymph (Fourth instar) in a uniform relative humidity gradient (saturated air)

Relative humidity	Frequency in % (mean of ten replications)
20	26(30.65)
40	12(20.26)
60	14(21.97)
80	17(24.35)
95	31(33.83)

Figure in parenthesis are angular transformed values.

Table 4.34: Distribution of H.theivora nymph (Fifth instar) in linear relative humidity gradient.

Relative humidity	Frequency in % (mean of ten replications)
20	21(27.27)
40	21(27.27)
60	13(21.13)
80	16(23.57)
95	29(32.58)

Figure in parenthesis are angular transformed values.

Table 4.35: Distribution of H.theivora nymph (Fifth instar) in a uniform relative humidity gradient (saturated air).

Relative humidity	Frequency in % (mean of ten replications)
20	22(27.97)
40	19(25.84)
60	16(23.57)
80	12(20.26)
95	31(33.83)

Figure in parenthesis are angular transformed values.

Table 4.36: Distribution of H.theivora (Female) in linear relative humidity gradient.

Relative humidity	Frequency in % (mean of ten replications)
20	4.5(12.24)
40	13.63(21.66)
60	15.90(23.49)
80	17.04(24.38)
95	48.85(44.34)

Figure in parenthesis are angular transformed values.

Table 4.37: Distribution of H.theivora adult (Female) in a uniform relative humidity gradient (saturated air).

Relative humidity	Frequency in % (mean of ten replications)
20	24(29.33)
40	19(25.84)
60	14(21.97)
80	17(24.35)
95	26(30.65)

Figures in parenthesis are angular transformed values.

Table 4.38: Distribution of H.theivora adult (Male) in linear relative humidity gradient.

Relative humidity	Frequency in % (mean of eight replications)
20	11.25(19.59)
40	7.50(15.89)
60	20 (26.56)
80	22.50(28.31)
95	38.75(38.49)

Figure in parenthesis are angular transformed values.

Table 4.39: Distribution of H.theivora adult (Male) in a uniform relative humidity gradient(saturated air).

Relative humidity	Frequency in % (mean of ten replications)
20	24(29.33)
40	20(26.56)
60	18(25.10)
80	15(22.78)
95	23(28.65)

Figure in parenthesis are angular transformed values.

analysis of the numbers of insects recorded under different humidity levels at different regions with a humidity of 95 per-cent by first and second instar ($F = 4.60$, $p < 0.05$) forth instar ($F = 13.31$, $p < 0.05$), fifth instar nymph ($F = 3.15$, $p < 0.05$), male $F = 5.08$, $p < 0.05$) and female ($F = 9.08$, $p < 0.05$) showed a significant preference for moist sector.

Although the data from such studies on insect behaviour in the laboratory are difficult to interpret in relation to what obtains in nature, they however give a relative indication of the temperature or relative humidity ranges within which the animal thrives best in nature. Moffitt and Reynolds (1972) showed that a cool temperature range $18.0^{\circ}\text{C} - 24.0^{\circ}\text{C}$ was optimal for the population increase in an Empoasca sp., E. solana De Long.

It is, therefore, noteworthy the observed ranges of "preferred" temperature and humidity for H. theivora in this study are very much within those (about $21.0^{\circ}\text{C} - 28.0^{\circ}\text{C}$ and 65% - 95% R.H.) that obtain in the field in Dooars, Jalpaiguri.

4.7 Distribution of Helopeltis (adult & nymph) in different regime of light intensity in tea bushes at Banarhat Sub-district during August-September, 1993:

The photo-negative response of the adult and nymphal stages of tea mosquito bug has been reported by Das (1965). Smith et al. (1985) reported that the feeding activity of Helopeltis clavifer Walk. on tea, was highest in the early morning and late

afternoon. So studies were undertaken to work out the spatial distribution of tea mosquito bug (adult and nymph) in different regime of light intensity in tea bushes during August to September, 1993. The light intensity at the site of their feeding was measured by a lux meter.

In the present investigation the maximum tea mosquito bug adult population (10.60%) was present in the range of 5001-10,000 lux when the apical portion of bush was considered (Table 4.40). The next highest population (8.83%) was found in the range of 10,000-15,000 lux. The population gradually decreased with the increase in light intensity. No population of the pest was recorded in between 35,000-50,000 lux. Again, when the middle portion of a bush was considered to study the distribution of adult Helopeltis vis-a-vis light intensity, it was observed that the maximum concentration (26.5%) of adult was recorded where the light intensity ranged between 801-1100 lux followed by 1101-1400 lux (21.55% population). It may therefore be said that Helopeltis adult preferred this particular regime of light i.e. 801-1100 lux. The analysis of the number of insect (adult) recorded shows negative correlation both at top ($r = -0.127$) and the middle portion ($r = -3.78$) of the bush.

Similar observation was undertaken in case of nymphs. Here maximum (5.22%) Helopeltis nymph was found within the light intensity 45,000-50,000 lux and minimum in between 10,000-30,000 lux

Table 4.40 : Distribution of Helopeltis (Adults) in different region of light intensity in tea bushes at Banarhat sub-district during August - September, 1993.

Sl.No.	Position of Plant	Light intensity (Lux)	% adult recorded
TOP			
1		1 - 5,000	4.24
2		5,001- 10,000	10.60
3		10,001- 15,000	8.83
4		15,001-20,000	3.88
5		20,001- 25,000	1.06
6		25,001-30,000	0.70
7		30,001- 35,000	0.35
8		35,001- 40,000	0.00
9		40,001- 45,000	0.00
10		45,001- 50,000	0.00
MIDDLE			
1		501- 800	3.88
2		801- 1,100	26.50
3		1,101- 1,400	21.55
4		1,401- 1, 700	8.48
5		1,701- 2, 000	4.95
6		2,001- 2, 300	2.82
7		2,301- 2, 600	2.12

Correlation 'r'

Top = - 0.127

Middle=-3.78

when the apical zone of tea bush was considered (Table 4.41). Similarly in the middle zone of tea bushes maximum concentration of the pest (23.21%) was noticed in between 4500-5000 lux. But the nymphal population was very low under low regime of light i.e. in between 500-3000 lux. It indicates that nymph's preference for light regime is somewhat higher (4500-5000 lux) than adult (800-1100 lux). Again the analysis of the number of insect (nymph) recorded shows positive correlation both at top ($r = +7.34$) and also the middle portion ($r = +8.46$) of the bush. Though no work was done in preference of tea mosquito bug for light intensity. But the available literature support that tea mosquito bug are active in early morning, late afternoon, shaded area, cloudy, dull day and in the evening (Das 1965; Das 1984; Smith, 1985).

4.8 Distribution of tea mosquito bug in three segment of tea bush at Nagrakata , Jalpaiguri, W.Bengal :

The distribution of tea mosquito bug was studied in tea bush. For the purpose of investigation of the preferred zone, the bush was divided three sectors viz. at the plucking table, above and below the plucking table and the feeding spot and the percent shoot infestation were considered for their activity from nymph to adult. It is evident from the investigation (Table 4.42) that the percent infested shoots were 43.05 at middle and 45.83 at bottom portion of bush. Only 23.79% shoot was found to be infested above the plucking table. The analysis shows the significant difference among the three region of the bush. The average diameter of the

Table 4.41: Distribution of Helopeltis (nymphs) in different regions of light intensity in tea bushes at Banarhat sub-district during August - September, 1993.

Sl.No.	Position of Plant	Light intensity (Lux)	% Adult recorded
TCP			
1		10,001 - 15,000	0.41
2		15,001 - 20,000	0.82
3		20,001 - 25,000	0.00
4		25,001 - 30,000	0.82
5		30,001 - 35,000	2.07
6		35,001 - 40,000	2.48
7		40,001 - 45,000	3.73
8		45,001 - 50,000	5.22
MIDDLE			
1		501 - 1000	0.00
2		1001 - 1500	1.34
3		1501 - 2000	2.23
4		2001 - 2500	3.57
5		2501 - 3000	5.80
6		3001 - 3500	12.50
7		3501 - 4000	15.18
8		4001 - 4500	18.30
9		4501 - 5000	23.21

Correlation 'r'

Top = + 7.34

Middle = + 8.46

Table 4.42: Distribution of tea mosquito bug in three segments of tea bush (mean of 10 bushes) at Nagrakata.

Segments of tea bush	% shoot infested on 1st day	Spot diame-ter(mm) on 1st day	% shoot infested on 7th day	Spot diame-ter(mm) on 7th day	% shoot infested on 14th day	Spot diameter (mm) on 14th day
TOP (90 cm from ground level)	23.79	0.81	32.82	1.87	57.50	2.33
MIDDLE (76 cm from ground level)	43.05	0.82	58.38	1.87	67.94	2.30
BOTTOM (Below 76 cm)	45.83	0.80	65.91	1.88	61.76	2.31
C.D. at 5% level	1.079		1.024		0.944	

puncturing spots was 0.81 mm which was produced by the early instar (first and second) nymph.

After 7 days it was found that the rate of infestation increased in all the three regions. The descending value of infestation from top to bottom were 32.83%, 58.38% and 65.91% respectively. There is a significant difference among the infestation. Subsequently, the diameter of the spots increased due to the advancement of the instar.

The average diameter of the spots increased to 1.88 mm after 10-12 days. The bushes were found to be heavily infested. The infested shoots at the three points were 57.50% ; 67.94% and 61.76% from top to bottom, respectively. Again a significant difference was found among the three region of the bush. The average diameter of the spots during this period was 2.3 mm which was similar inside to those produced by adults. The leaves suitable for feeding by the insect were more at the plucking table. Very few shoots emerged in the zone of maintenance leaves. These lateral shoots developing inside this zone were mostly damaged by first and second instar nymphs and thus the early instar nymphs multiply in a safe ecological niche giving no chance of identification. Their presence can be felt only when they become adult causing several leaf and shoot damage.

The thick foliage of tea often prevents spray droplets from penetrating deep into the canopy where pests are often located. Only

30 percent of spray droplets are able to penetrate the top 20cm of the foliage and the balance quantity getting drifted away (Banerjee, 1986). So the insects remain unaffected even when the insecticides are sprayed. This is the main reason for suboptimal control of pest and recurrence of pest problem.

So the middle and bottom portions of the bush are the most preferred zone of tea mosquito bug as they are getting food for their development.

4.9 Feasibility of wild plants as host of Helopeltis at Jiti Tea Estate, Dooars, Jalpaiguri, during December to February, 1991-1992 and October-February, 1992-1993 :

It is seen from Table 4.43 that four species of wild plants were found to bear the puncture mark of the mosquito bug within the vegetation around the Jiti Tea Estate during December to February, 91-92. Among the four species of wild plants, three appear to be the new record of host plants of the tea mosquito bug. The already known host plant of the pest i.e. Mikania was found as the most preferred host of the pest based on the number of plant infested. The rate of infestation was as high as 89.99% as compared to 4.03, 4.34 and 6.49 in three other newly recorded host plant. But the rate of egg laying was found to be the lowest in Mikania (0.30 egg/plant) when compared to other three plant species where it varied between 3.74 - 4.23 eggs/plant. For further confirmation this study was continued again in the next year i.e. October - February, 92-93.

Table 4.43: Feasibility of wild plants as host of Helopeltis at Jiti Tea Estate, Dooars, Jalpaiguri, West Bengal during December - February, 1991-92.

Host plant	Number of plant examined	% of plant infested	Number of <u>Helopeltis</u> eggs recorded /plant
<u>Mikania micrantha</u>	500	89.99	0.30
<u>Similax</u> sp.	500	4.03	3.74
<u>Solanum</u> sp.	500	6.49	4.23
<u>Phlogocanthus pubinervius</u>	500	4.35	3.86

It was evident from the next year study Table 4.44) that six wild plants were found infested by tea mosquito bug. Out of which other plant species appears new record. Among the six wild plants the infestation was the highest in Mikania i.e. 91.60%. All the other plants the infestation was much less i.e. 8.36, 6.91, 6.64, 5.49 and 5.78% respectively. The rate of egg laying was found the highest in Solanum sp. i.e. 6.68 which confirms the last year observation, where as the lowest egg laying was found in Mikania. During investigation both adult and nymph were found feeding on the wild plants except Polygonum chinensis were only puncture marks recorded. The highest number of population i.e. both nymphs and adult were 8 and 22 respectively recorded in Mikania followed by Phlogocanthus pubinervius, Similex sp. Eupetorium odoratum and Solanum sp. i.e. (16,6), (11,15), (6,9), (7,4) respectively. Das (1965) reported that Helopeltis attacks a number of plants, especially in the jungle, such as Melastoma mala bathricum L., Maesa ramentacea A.D.C., Eurya acuminata D.O. and Jasminum scandens Vahl.

The present study includes five new natural hosts in the jungle near tea garden.

- 4.10 Rearing of tea mosquito bug Helopeltis theivora Waterh. on wild plants under laboratory condition at temperature $27 \pm 1^{\circ}\text{C}$ and relative humidity $80 \pm 5\%$.

Studies were undertaken in laboratory condition in conformity with the wild plants as the host plant of tea mosquito bug. It is also revealed from the present investigation that all the wild

Table 4.44: Feasibility of wild plants as host of Helopeltis at Jiti Tea Estate, Dooars, Jalpaiguri, West Bengal during October - February, 1992-93.

Plant species	Number of plant examined	% plant infested	Number of <u>Helopeltis</u> egg recorded /plant
<u>Mikania micrantha</u>	536	91.60	0.25
<u>Similax</u> sp.	434	6.91	5.50
<u>Solanum</u> sp.	286	6.64	6.68
<u>Phlogocanthus pubinervius</u>	415	5.78	4.04
<u>Eupatorium odoratum</u>	263	8.36	3.04
<u>Polygonum chinensis</u>	500	6.49	4.23

plants mentioned in table 4.45 are suitable for development of tea mosquito bug. The pest had been found to complete their life cycle successfully on all the wild plants. The intensity of feeding was the highest in Similax sp. and lowest in Phlogocanthus sp. while the incubation period was shortest in Solanum sp. The nymphal period and the adult period was shortest in Solanum sp. but the number of eggs laid was the highest (10). Mikania sp. was not suitable for egg laying. This is also confirmed by the findings of Gope^{and Handique} (1991). The number of egg laid was considerably higher in other host plants compared to those of Mikania sp. where it was very negligible (4). Among the new recorded wild plants Similax sp. and Solanum sp. may be the most suitable host of tea mosquito bug.

Das (1965) reported a number of plants as common alternative hosts, out of which Helopeltis theivora completes its life cycle in M.micrantha, Melastoma malabathricum L. and Maesa ramentacea.

The present investigation confirms that tea mosquito bug breeds in all the newly recorded wild plants. Miller (1941) and Das (1984) reported a number of cultivated crop as host of tea mosquito bug (H.theivora Water) where it breeds,

Table 4.45 : Rearing of Helopeltis on different wild plants during February, 1993 at Nagrakata in laboratory condition ($26 \pm 1^\circ\text{C}$) ($80 \pm 5\%$) r.h.

Host plants	Incubation period (days)	Nymphal period (days)	Adult period (days)	Number of egg laid	Number of spots produced from first instar to adult
<u>Mikania micrantha</u>	13 (11-15)	18.5 (18-19)	23.5 (22-25)	4 (3-5)	515.4
<u>Similax</u> sp.	12.5 (12-13)	16 (15-17)	21 (20-22)	9 (8-10)	707.0
<u>Solanum</u> sp.	11 (10-12)	12.5 (12-13)	20 (18-22)	10 (9-11)	626.8
<u>Phlogocanthus pubinervius</u>	12.5 (12-13)	14.5 (13-16)	22.5 (21-24)	7 (6-8)	408.4
<u>Eupatorium odoratum</u>	12 (11-13)	15 (14-16)	21.5 (20-23)	6.5 (5-8)	577.4
<u>Polygonum chinensis</u>	14.5 (13-16)	15.5 (15-16)	24.5 (23-26)	7.5 (6-9)	451.5
C.D. at 5%	(1.91)	(2.53)	N.S.	(2.34)	

4.11 Presence of Helopeltis theivora Waterh. in tea clones during December to February, 1991 - 1992 at Nagrakata, Jalpaiguri, West Bengal :

In the North-East region of our country, tea passes through a kind of dormancy during December to February. The course is followed by intermittent short dormant period in between different flush period. The length of flushing and dormant period varied significantly among the clones (Das, 1981). So studies were undertaken to know the activities of tea mosquito bug during this resting period i.e. December, January and February. The clones like TV-9, TV-10, T₁₄ gives little flush and the other clones and seed plants shows total dormancy during winter period, therefore they were not included in this study. It was evident from the findings (Table 4.46) that the mean number of eggs per shoot in TV-9 was the highest among the three clones during this period (0.73, 0.84, 0.95) and also the percent shoot damage gradually increased with a sharp decline during February. The highest percent of shoot infested (21.72) recorded during January and the highest mean number of eggs per shoot (0.95) during February. This was followed by TV-10 and TV-14. The lowest mean number of eggs per shoot (0.10) and the percent shoot infested (4.59) recorded in TV-14, during February.

Table 4.46 : Distribution of Helopeltis in tea clones during December to February, 1991-92 at Dooars, Nagra-kata, Jalpaiguri , W.Bengal.

Period	Clones	No.of shoots examined	No.of egg recorded/shoot	% of shoot infested
December	TV-9	500	0.73	19.32
	TV-10	500	0.33	17.45
	TV-14	500	0.52	15.33
January	TV-9	450	0.84	21.72
	TV-10	450	0.23	18.55
	TV-14	430	0.44	17.39
February	TV-9	500	0.95	16.61
	TV-10	500	0.43	19.52
	TV-14	500	0.10	4.59

N.B. Other quality clones & seed plants shows total dormancy during winter period therefore were not included in this study.

4.12 Cultural control of tea mosquito bug by light skiffing and black plucking in the Clone TV-1 during July-August, 1993 at Karballa Tea Estate, Dooars, Jalpaiguri, W.B. :

Realising the importance of residue free tea, an integrated and planned execution of agronomic practices with the objective of reducing the crop loss by pest and disease, cultural practices are essential in tea pest management.

So an experiment was conducted to study the effect of light skiff and black plucking against standard plucking in reducing the infestation of tea mosquito bug in TV-1 at Karballa Tea Estate during July-August 1993.

The results of the experiment (Table 4.47) show that the infestation of the treatments T_1 , T_2 and T_3 (skiffing, black plucking and standard plucking) are at par with one another (pre-treatment) i.e. 47.13%, 45.88% and 46.54% respectively. At 21 days, after the skiffing and plucking operations, the percent infested shoots per bush was the lowest (6.23) at light skiffing and followed by black plucking (7.31). At standard plucking the infestation was the highest (20.13). In both the cases (light skiffing & black plucking) the infestation gradually decreased at 28 days and 35 days. On the other hand the infestation, at standard plucking, gradually increased and become almost double (40.89). All the treatments were significantly different among themselves.

Table 4.47 : Cultural control of tea mosquito bug by light skiffing and black plucking in the clone TV-1 during July-August, 93 at Karballa Tea Estate, Dooars, Jalpaiguri, West Bengal (mean of seven replications).

Sl.No.	Treatments	Pre-treatment observation % shoot infested /bush	Post treatment observation % shoot infested/bush		
			21 days	28 days	35 days
1.	T ₁ = Light skiffing	47.13	6.23 (14.45)	4.29 (11.95)	2.56 (9.20)
2.	T ₂ = Black plucking	45.88	7.31 (15.68)	5.98 (14.15)	3.87 (11.34)
3.	T ₃ = Standard plucking	46.54	20.13 (26.65)	27.89 (31.87)	40.89 (19.26)
	C.D. at 5% level	N.S.	(0.82)	(0.63)	(0.71)

Figures in parenthesis are aresine transformed values.

A perusal of the experiment shows that the cultural practices like light skiffing and black plucking are the most effective as compare to standard plucking in reducing the recurring infestation of tea mosquito bug.

The results of the present finding confirms the effectiveness of light skiffing and black plucking in severe tea mosquito bug infestation as reported by Das (1965), Chakraborty and Singh (1994).

As a result of skiffing and black plucking the Helopeltis ^{and Handique} eggs and immature stages are destroyed (Gope, 1991) followed by delayed flushing (Barua, 1989) responsible for less infestation in the later flush because absence of food (Zero pluckable shoots) in the bushes.

In case of standard plucking, the residual population of tea mosquito bug remain in the bush inspite of little disturbance due to plucking, and getting one leaf and bud, small buds for their development.

4.13 Relative incidence of tea mosquito bugs, thrips and the predator Chrysoperla sp. in tea bushes (TV-18) during February to May 1992 at Nagrakata, Dooars, W.Bengal :

Studies were undertaken in field to know the relative incidence of tea mosquito bug, thrips and their natural enemies during the initial stage of buildup of the pest population from February to May with a weekly interval of observation.

It is evident from the table 4.48 that the percent bush infestation started increasing from first week of February and reaching its peak during the end of this month, after that there was a sharp declines. On the other hand the population of thrips and predator (Chrysoperla sp.) increased gradually till first week of May and after that both the population declined. It reveals from the observation that there is a negative co-rrelation ($r = -.34$) between tea mosquito bug and thrips but the positive correlation ($r = .011$) found between tea mosquito bug and predator. Only significant positive correlation ($r = 0.865$) found between thrips and predator.

and Handique
Gope_A (1991) found weak correlation between tea mosquito bug and spider.

It was found from the investigation that tea mosquito bug and predator had very weak association.

Table 4.48: Relative incidence of tea mosquito bugs, thrips and their predator, Chrysoperla sp. in tea bushes (TV-18) during February-May, 1992 at Nagrakata, Jalpaiguri, W.Bengal.

Sl.No.	Date of observation	Mean percent bush infested by <u>Helopeltis</u>	Mean number of thrips/shoot	Mean number of predator/bush
1.	5-2-92	1.44	1.32	0
2.	10-2-92	0.29	1.64	1.34
3.	15-2-92	1.73	1.96	1.63
4.	20-2-92	1.16	2.20	0
5.	25-2-92	3.75	2.50	2.31
6.	29-2-92	7.23	3.30	2.95
7.	5-3-92	0	4.48	0
8.	10-3-92	0	6.35	2.76
9.	15-3-92	0.87	7.40	1.86
10.	20-3-92	0.29	7.53	1.97
11.	25-3-92	0	7.68	1.62
12.	2-4-92	0	11.16	2.89
13.	9-4-92	0	13.32	3.78
14.	16-4-92	0	15.68	4.76
15.	23-4-92	0	16.24	3.77
16.	30-4-92	0	17.48	5.38
17.	7-5-92	0	14.92	3.41
18.	14-5-92	0	2.00	1.07
19.	21-5-92	0	1.04	0
20.	28-5-92	0	1.04	0

Correlation 'r'

Helopeltis - Thrips = - 0.34
Helopeltis - Predator = 0.011
Thrips - Predator = 0.865

4.14 Occurrence of egg parasitism in tea mosquito bug under natural condition at Dalgaron T.E., Dooars, Jalpaiguri, West Bengal, during 1993 :

A great number of natural enemies of Helopeltis spp. have been reported in the literature. A list of the known parasitoids, predators and pathogens of African and Asian Helopeltis spp. is compiled in an article by CIBC (1983). So an attempt was taken to investigate any egg parasite present in tea. From January to December 1993, large number of eggs were collected from such an area when no insecticide were being applied for last five year. It is evident from the table 4.49 that the highest number (610) of eggs found during August when as the lowest (78) during December - June to September is the season so large number of eggs found in the field. More than 50% of the eggs hatched except November and December. The shrivelled eggs were critically examined under microscope and did not find any parasite inside. The eggs shrivelled probably due to dessication. Though earlier works found some egg parasite of Helopeltis species. In Malayasia egg parasite Erythemelus helopeltidis reported to parasitized (36%) of Helopeltis cinchonae on tea (Lever, 1949) and 11-47% of the eggs of H.theivora on cocoa (Ibrahim, 1989). Devashayan (1986) found this egg parasite of H.antonii in cashew.

Another promising egg parasite reported by Lodos (1968) and Sundararaju (1993) found in different spp. of Helopeltis other than Helopeltis theivora. It appears from the present investigation that none of the two egg parasite (Erythemelus helopeltidis, Jelenomus sp.) found on Helopeltis theivora on tea.

Table 4.49: Occurrence of egg parasitism in tea mosquito bug under natural condition at Dalgaon, Tea Estate, Dooars, Jalpaiguri, West Bengal, during - 1993.

Period	Number of eggs examined	Fate of Helopeltis eggs after (15-20) days		% parasitised
		Hatched	Shriveled	
January'93	80	52	28	0
February'93	145	87	58	0
March'93	260	203	57	0
April'93	390	312	78	0
May'93	480	408	72	0
June'93	570	445	125	0
July'93	600	540	60	0
August'93	610	580	30	0
Sept.'93	560	420	140	0
Octo.'93	430	280	150	0
Nov.,93	125	50	75	0
Dec.,93	78	26	52	0

4.15 Effect of insecticides on the predator
Chrysoperla sp. in laboratory :

In most instances, it appears that natural enemies, while playing an important role in control, can not maintain population of Helopeltis spp. below economic thresholds. Integrated control programmes with reduced pesticide use and the monitoring of natural enemies have been suggested as reasonable alternatives to blanket spraying (CIBC, 1983). Both Simmonds (1970) and Collingwood (1977) concluded that there is not enough information available at present to make any definite recommendations about biological control of mirids.

Chemical treatment is necessary to keep populations of tea mosquito bug below damaging levels, but blanket spraying with broad spectrum insecticides has caused problem with resistance and tainting of tea.

So attempts were made to know the relative toxicity of some common insecticides to larvae of Chrysoperla sp. feeding on tea mosquito bug nymphs.

It was observed from the table 4.50 that quinalphos was the most toxic while cypermethrin was the least toxic as stomach poison to the larvae of Chrysoperla. Therefore, spray programmes should be limited to times of the year when the tea mosquito bug attack is the most severe, as a part of integrated pest management (IPM).

Table 4.50: Relative toxicity of some common insecticides to larvae of Chrysoperla sp. at $27^{\circ}\text{C} \pm 1^{\circ}\text{C}$ and $80 \pm 5\%$ r.h. (mean of three replications)

Sl.No.	Insecticides	Concentration(% a.i.)	% mortality on 3rd day
1.	Endosulfan	0.05	66.66
2.	Quinalphos	0.03	80.33
3.	Monocrotophos	0.03	70.00
4.	Cypermethrin	0.005	50.00
5.	Control	-	0.33
	C.D. at 1%		1.82

Table 4.51 : Evaluation of Chrysoperla sp. as bio-control agent under field caged condition (3m x 3m x 1.5m) on TV-1 to control of tea mosquito bug at TRA Nagrakata, Jalpaiguri, West Bengal during June, 1992 (Based on four replications).

Treatments	Insect:Predator	Mean percent shoots infested			
		3 DAT	5 DAT	7 DAT	14 DAT
T ₁	10:10	14.43 (22.32)	20.33 (26.80)	30.87 (33.75)	49.58 (44.75)
T ₂	10:20	13.25 (21.34)	21.41 (27.56)	30.96 (33.80)	48.79 (44.30)
T ₃	10:30	12.64 (20.82)	18.56 (25.51)	25.38 (30.25)	35.12 (36.34)
T ₄	10:40	8.23 (16.67)	14.33 (22.24)	20.43 (26.87)	29.97 (33.19)
T ₅	10:0	14.56 (22.43)	22.81 (28.52)	31.48 (34.12)	51.48 (45.84)
	C.D. at 5% level	(1.07)	(0.50)	(0.54)	(0.49)

- 4.16 Evaluation of Chrysoperla sp. as bio-control agent under field caged condition on TV-1 to control of tea mosquito bug at TRA, Nagrakata, Jalpaiguri, W.Bengal during June, 1992.

Chrysoperla sp. an important predator. It has high searching capacity, works at low host density level. So studies were undertaken to control of tea mosquito bug by inundative release of this predator under field caged condition.

The first instar larvae of Chrysoperla sp. were released on each cage where second instar tea mosquito bug nymphs were already posted providing a gap of six hours. The percent shoots damaged was counted at 3,5,7 and 14 days after release of predator and host.

It was evident from the table 4.51 that the percent shoots damaged was significantly low over control set at the third day of observation except in case of insect: predator ratio maintained at 1:1. The best result was obtained when the insect predator ratio was at 1:4 and it was significantly superior over all other treatments. Similarly all the treatments were found significant over control set at 5,7 and 14 days of observation. The percent shoot damaged ranged from 8.23 to 29.97 at the insect and predator ratio 1:4. This was due to the effect of predator and pray interaction.

4.17 Use of microbial pesticide (DISPEL^(R))
against tea mosquito bug :

Microbial control using insect pathogens is harmless and nontoxic to many forms of life. There is a relatively high degree of specificity in most cases. Upon contact with the target pest, the fungal spores attach themselves to the cuticle. The spore then secrete enzyme which attack and dissolve the cuticle. This enables the fungal spore to send hyphae into the body of the insect. The production and proliferation of the fungal hyphae cause the release of toxicants from the fungus into the insect. Mortality is suspected to be a combination of mechanical (water loss) and nutrient loss effects. The similar toxic effect of the fungus acts on the eggs and unmaturs.

The pathogen is compatible with insecticides and can be easily incorporated in the insect pest management system.

The large-scale culture and application of the pathogen are easy and inexpensive in most cases. Generally, resistance in insects to insect pathogens is not developed.

Microbial control is an ecofriendly biorational technology and has been recognised as an important alternative to chemical insecticides (Jayaraj and Sathiah, 1996).

However, the biological control agents are available only for some selected insect pests and very little for other insects.

In view of these advantages, DISPEL is likely to act on tea mosquito bug, that is why the evaluation of the product was done against tea mosquito bug.

It revealed from the trial (Table 4.52) that the percent control of Helopeltis theivora at different doses were at par with untreated set even after three rounds of spraying.

Table 4.52: Evaluation of microbial pesticide [DISPEL^(R)] against tea mosquito bug at Debpara T.E., Central Dooars, Jalpaiguri during Sept. - Octo., 1993.

Dose	% Control		
	15 days after 1st spray	15 days after 2nd spray	15 days after 3rd spray
2ml/lit	9.98	11.22	10.6
4ml/lit	17.88	18.98	18.43
Control	18.29	18.07	18.93

However the ecological conditions (28°C and 80% r.h.) prevailing in the tea ecosystem was conducive for the pathogen. It may be said that DISPEL was not effective against the mosquito bug. Though Lim et al. (1989) reported that the entomogenous fungus Beauveria bassiana was highly pathogenic to adult cocoa mirid Helopeltis theobromae in Malaysia. It grew and sporulated best at 25°C. This may be due to different agroclimatic condition or some other better strain of Beauveria sp. may be effective against tea mosquito bug H. theivora.

Further studies by utilizing other strain or better form of Beauveria may be tested.

None of the predator or pathogen are available in India. Therefore large-scale trials could not be undertaken.

4.18. Feasibility of applied biocontrol of tea mosquito bug by Chrysoperla sp. :

Studies were undertaken to work out the economics of applied biocontrol of tea mosquito bug by Chrysoperla release .

First stage - Estimation of tea mosquito bug in tea plantation.

It was found from rapid roving survey by suction trap 'D'-vac (Distribution of tea mosquito bug, Table 4.1) from 100 bushes that the average of 6.68 tea mosquito bug were found from tea plantation. So in one hectare tea plantation (containing 12,000 bushes) the approximate number of tea mosquito bug would be 802.

Second stage - Optimum ratio of pest and Chrysoperla sp.

It was evident from the table 4.51 (Evaluation of Chrysoperla sp. as biocontrol agent under field caged condition to control of tea mosquito bug) that the best result (70 to 90% control) was obtained by releasing Chrysoperla, when the insect & predator ratio maintained at 1:4. So the rate of release of Chrysoperla would be at 1:4 .

Third stage - Estimation of approximate dose of Chrysoperla sp.

The approximate population of tea mosquito bug per hectare - 802.

The approximate number of chrysoperla at 1:4 would be $4 \times 802 = 3208$ by single release. So at twice release the number of Chrysoperla i.e. $3208 \times 2 = 6416$.

Fourth stage - Economics of Chrysoperla vis-a-vis conventional pesticides.

Samanta (1995) reported that 2-3 rounds of endosulfan or monocrotophos required to control of tea mosquito bug.

Table 4.53: Cost of conventional pesticides.

Insecticides	Dose	Rate in Rs. per lit.	Cost at 3 rounds application
endosulfan	1:400	270=00	810=00
monocrotophos	1:400	320=00	960=00

Cost of Chrysoperla Rs.20=00/100 eggs or 100 larvae,

So, 6416 Chrysoperla of twice release = Rs. 1283=20

It was evident from the table 4.53 that the cost of Chrysoperla release was little higher than the cost of conventional pesticide application.

Initially the cost of biological control is always higher than chemical control but in the long run, more benefit can be harvested like residue free product, no resistant development, ecofriendly, no chance of resurgence of other pest. The predator Chrysoperla could take care of thrips, Jassids, aphids. So here applied biological control of tea mosquito bug by Chrysoperla would be cheaper, safer and could be incorporated in the Integrated Pest Management of Helopeltis theivora Water.

CHAPTER - V

SUMMARY AND CONSLUSION

CHAPTER - V
SUMMARY AND CONCLUSION

✓ Tea mosquito bug (Helopeltis theivora Waterh.) has assumed the status of a major pest of tea in North-East India in recent years. The extent of damage was varied between 80 to 100% . Rapid roving survey during the course of the present study was undertaken in the Central Dooars. Considering the tricky nature of the pest, an IPM schedule would be the effective way to control the pest.

The influence of abiotic and biotic factors on the build up of mosquito bug has been included in this investigation.

The distribution pattern of H.theivora in tea ecosystem indicated a clumped distribution of the pest as the value of the Morista's Index was well above 2. It was primarily a reflection of survival of the pest in the favourable condition of the environment.

The damage potential of different instar of tea mosquito bug was studied exposing to the tea twigs contains five leaves. The maximum percent of spot (89.90) was recorded in case of fifth instar nymph in first leaf followed by first instar (63.24%), third instar (60.33%), fourth instar (53.28%) and Second instar (48.69%) in first, third, second and second leaf from tip of the twig respectively. The differential preference among various instars with respect to leaf age was noticed. The maximum spots was produced (126) per day by forth instar nymph. All the instars have least preference to feed on bud.

An experiment was laid out under the field condition to assess the damage potential of nymph and adult stages of tea mosquito bug over a period of 14 days synchronising with a weekly interval of observation of percent shoot damage. Three levels of nymphal density (5, 10 and 15 nymphs/cage) and four levels of adult density (1, 5, 10 and 15 adults/cage) were used. The percent shoot damage increased with the increase in nymphal density upto 5 nymphs /cage. With further increase to 10 nymphs/cage, a decreasing rate in shoot damage was observed. In case of adult, the percent shoot damage increased with the increase in adult density upto 5 pairs /cage. With further increase to 10 pairs, a decreasing rate in shoot damage was noticed. So both the nymph and adult, the phenomena was noticed upto 5 pairs and a decline in damage percentage recorded thereafter. However, the damage potential of adult was more than that of nymph.

Mass rearing of tea mosquito bug was undertaken under field caged (3m x 3m x 1.5m) condition from March 1993 to December 1993. It was revealed from the present investigation that mass rearing of tea mosquito bug can be successfully done under field condition. The mean number of nymphs reared/cage varied from 785.36 to 2897.62 and the percent nymph reached adult stage varied from 51.23 to 97.92. It was also observed from the co-rrrelation studies of climatological factors on the production of adult stage of tea mosquito bug that there was a significant positive co-rrrelation between rainfall, temperature (maximum and minimum), afternoon relative humidity and the percent nymph reached adult stage.

To develop a reliable monitoring system and assessment of tea mosquito bug population to forewarn the tea estate managers, change in population, abundance, egg laying of the pest different studies were undertaken with the help of yellow sticky trap, light trap, presence of sex pheromone and suction trap. It was revealed from the the present study that the yellow sticky trap, and light traps were not effective to catch the tea mosquito bug. It was evident from the observation through wind tunnel method that the number of two, three and four days old adult male reached the bait chamber were 2,5,7 respectively in one hour. For confirmation only four day old age group female was chosen. Again it was found that four day old female attracted more males indicating the probable presence of sex pheromone. Attempts were made to develop population prediction model based on suction trap catches as dependent variable (Y) and weather parameters as independent variables (X_1 , X_2 and so on). The peak population of the pest was recorded during September to October while it was minimum during December to April. The mean temperature recorded during September to October (peak period of incidence) ranged between 28-31°C while mean relative humidity was around 80%. The mean rainfall during the peak period of incidence was around 12 cm. The number of tea mosquito bugs caught in the suction trap had a negative association with morning relative humidity ($r = 0.233$) and a positive significant association with maximum temperature ($r = 0.728$), minimum temperature ($r = 0.827$) and rainfall ($r = 0.393$). The results of the multiple regression analysis of different weather factors on the suction trap

catches depict ($R^2 = 0.923$ at $p = 0.01$) of the total variation of the population of tea mosquito bug in the trap. As the meteorological factors are dependent among themselves, the cumulative interaction of their association influenced the total variation of population of tea mosquito bug. It is evident from path co-efficient analysis that the total effect of maximum temperature on population reduces to 0.728, minimum temperature and rainfall reduced to 0.899 and 0.392 respectively. But the total effect of the afternoon relative humidity showed positive co-rrrelation with the mosquito bug population (0.829). The multiple regression equation fitted with weather factors to predict the number of tea mosquito bug caught in suction trap.

$$Y = -9.441 + 0.651X_1 - 0.438 X_2 - 0.052 X_3 + 0.158 X_4 - 0.054 X_5$$

Laboratory studies on the behaviour of tea mosquito bug of temperature response in linear temperature gradient apparatus gives a partial explanation of the occurrence of high population in field during the rainy season. All the nymphal stages and adults prefer cool temperatures. The " Preferred" temperature as obtained from the point of intersection of linear temperature graph and the position along the temperature gradient with mode of distributions of first and second, third, fourth, fifth instar nymphs and male, female tea mosquito bugs was as 26.16°C, 25.60°C, 27.75°C, 24.38°C, 20.13°C and 22.81°C respectively. The different stages of tea mosquito bug are uniformly distributed at 26.6°C.

Similarly the reaction of different stages of tea mosquito bug to moisture was studied in a linear relative humidity gradient of 20; 40; 60; 80 and 95 percent. All the stages of Helopeltis were found aggregated at the moist sector i.e. 60-95 % relative humidity. But at the saturated air they were uniformly distributed.

Effect of light intensity on Helopeltis (adult and nymph) in different regime of light intensity in tea bushes was studied with the help of lux meter. The light intensity was measured at the canopy and the middle portion of the bush. At the top portion of the bush, the light intensity varied from 1 to 50,000 lux but the maximum adult mosquito bug population (10.60%) was present in the range of 5001-10,000 lux followed by 8.83% population in the range of 10,000 - 15,000 lux. In the middle portion of the bush the light intensity varied from 501 to 2600 lux but the maximum population of adult (26.50%) was recorded 801-1100 lux. The correlation studies showed the negative correlation at both top ($r=-0.127$) and middle ($r=-3.78$) portion of the bush. Similar observation was undertaken in case of nymph. Again at the top portion of the bush the light intensity varied from 10,000 to 50,000 lux but the maximum (5.22%) Helopeltis nymph was found within the light intensity of 45,000-50,000 lux. Similarly in the middle portion of the bush the maximum (23.21%) nymph population was observed in between 4500-5,000 lux where the light intensity varied from 501 -5000 lux. The correlation studies indicated a positive correlation both at the

top ($r = 7.34$) and middle portion ($r = 8.46$) of the bush.

To identify the safe ecological niche of tea mosquito bug, the spatial distribution of tea mosquito bug in tea bush was studied. The diameter of the spot and the percent shoot infestation were considered for their presence in the three zones (top, middle and bottom) of tea bush. The maximum infestation (45.83%) was found at the bottom and the diameter of the spot was 0.81 mm which was mostly by early instar nymphs. The infestation was gradually increased in all the three zones with the advancement of the stage and also the diameter of the spot. At the 7th day of observation the maximum infestation (65.91%) was found at the bottom followed by 58.38% and 32.83% at middle and top portion of the bush respectively. At 12th day, the maximum infestation (67.94%) was found at the middle portion of the bush and the diameter was also increased to 1.88 mm which indicated the advancement of the stage of tea mosquito bug.

Feasibility of wild plants as host of tea mosquito bug was studied during dormant season (December to February '91, '92) at Central Doars. Five wild plants namely Eupatorium odoratum, Solanum sp., Polygonum chinensis, Similax sp. and Phlogocanthus pubinervius were recorded first time as host of tea mosquito bug. The percent plant infested in natural condition and the egg laying preference was studied. In Mikania micrantha, the maximum infestation (89.99% and 91.6%) was found in the both the years. This

was followed by E.odoratum, Similax sp., Solanum sp., P.chinensis, and P.pubinervious at 8.36%, 6.91%, 6.64%, 6.49% and 5.78% respectively. The number of eggs recorded lowest (0.30) in M.micrantha whereas the highest (6.68) in Solanum sp. . Both the adult and nymph were found feeding on the wild plants. The highest number of nymphs and adults were 8 and 22 respectively recorded in Mikania which was followed by P.pubinervious, Similax sp., E.odoratum, Solanum sp., i.e. (16,6), (11,15), (6,9), (7,4) respectively.

Laboratory studies were undertaken in confirmity with the wild plants as host of tea mosquito bug. It was found that tea mosquito bug completes their life cycle successfully in the wild plants i.e. M.micrantha, E.odoratum, Similex sp., Solanum sp., P.chinensis, P.pubinervious. The duration of nymphal period and the adult period were shortest in Solanum sp. and the number of eggs laid highest (10). Among the newly recorded wild plants Solanum sp. was the most suitable host of tea mosquito bug. During the dormant season of tea, some of the quality clones like TV-9, TV-10, TV-14 produced little shoots. The presence of tea mosquito bug was studied in these quality clones. The maximum percent of shoot infestation (0.73-0.95) was observed in TV-9 which was followed by TV-10 and TV-14. The maximum number of eggs also recorded (16.61 to 21.72) in TV-9.

Influence of light skiffing and black plucking in reducing the infestation of tea mosquito bug was undertaken. The extent of leaf damage was reduced by 4.29, 5.98 and 2.56 , 3.87 after 28 and

35 days of skiffing and black plucking respectively. This two cultural practices were superior over standard plucking in reducing the recurring infestation of tea mosquito bug. The study was undertaken to know the extent of relationship between tea mosquito bug and Chrysoperla under natural condition in the Dooars, indicated a negative correlation. The high 'r' value i.e. 0.865 between thrips and predator showed strong positive correlation between the two.

Seasonal occurrence of egg parasitoid of H. theivora was studied during 1993. None of the 9 eggs collected on tea twigs from various locations produced any of the egg parasitoid of tea mosquito bug.

Relative toxicity of four insecticides such as quinalphos, monocrotophos, cypermethrin, endosulfan, to larvae of Chrysoperla was evaluated under laboratory condition at $27^{\circ}\text{C} \pm 1^{\circ}\text{C}$ and $80 \pm 5\%$ r.h. It was found that quinalphos was the most toxic giving 80.33% mortality on third days after exposure while cypermethrin was the least toxic (50.00% mortality).

The efficiency of Chrysoperla as biocontrol agent against tea mosquito bug was evaluated under field caged condition. It was observed that Chrysoperla gave a moderate check of tea mosquito bug when the ratio between defender : host maintained at 1:4.

Feasibility of applied bio-control of tea mosquito bug by Chrysoperla and its economics vis-a-vis conventional pesticides was worked out. Inandative release of Chrysoperla at pest defender ratio 1:4 , twice at an interval of 15 days was compared with the application of 3 rounds conventional pesticide like monocrotophos and endosulfan.

The commercial formulation $\left[\text{DISPEL}^{(R)} \right]$ of B.bassiana was not effective but better strain would be effective to control of tea mosquito bug.

It was revealed from the study that the cost of Chrysoperla release was little higher than the conventional pesticides. Initially the cost of Chrysoperla release was higher but in the long run more benefits like residue free product, no chance of resistant development and resurgence of pest and the ecofriendly, etc. could be harvested.

Finally based on the study, the IPM of tea mosquito bug would be as follows :

- 1) Monitoring of the pest based on the prediction equation,
- 2) Time being application of selective pesticide on the basis of economic threshold level.
- 3) Cultural control by destroying the wild plants,
- 4) Skiffing & black plucking where infestation already taken.

- 5) Destruction of the flushes produced by the clones TV-9, TV-10, TV-14 during dormant season.
- 6) Use of better strain of fungus, Beauveria bassiana .
- 7) Inandative release of predator Chrysoperla against this pest.

Conclusion :

From the present investigation the following conclusion may be drawn :

1) Helopeltis theivora remains in group and were rarely seen individually spaced apart. This clumping pattern of distribution is due to its behaviour, not due to the environmental factors.

The feeding activity are primarily restricted to the young leaf and a lesser degree in buds. The forth instar nymph produce maximum spots per day among the nymphal stages.

2) Five nymphs or one pair of adult in a 9sq.m. area may cause economic injury to the crop within a time frame of 14 days.

3) Mass rearing of tea mosquito bug can be done successfully in field condition.

4) The descending order of total influence of various factors was afternoon relative humidity, maximum temperature, minimum temperature, rainfall and morning relative humidity to predict the number of tea mosquito bug caught in suction trap.

$$Y = -9.441 + 0.651X_1 - 0.438 X_2 - 0.052 X_3 + 0.158 X_4 - 0.054 X_5$$

5) Three and four day old adult female attract males indicating the presence of sex pheromone. The synthesis of active components of pheromone are necessary for further exploitation of this technique in integrated pest management programme.

6) The preferred temperature and humidity of first and second instar nymph 26.16°C and 60-95% r.h., third instar nymph 27.98°C and 60-95% r.h., forth instar nymph 34.75°C and 60-95% r.h. fifth instar nymph 24.38°C and 60-95% r.h. and female 22.81°C and 95% r.h., male 20.13°C and 60-95% r.h.

7) Helopeltis adult prefers the particular regime of light i.e. between 800-1100 lux which is somewhat lower than nymph's preference i.e. 4500-5000 lux.

8) The development of tea mosquito bug starts from the middle and bottom portion of the bush which is the most safe ecological niche of the pest.

9) Beside Mikania micrantha, Similax sp., Solanum sp. Phlogocanthus pubinervius , Eupetorium odoratum, Polygonum chinensis are newly recorded suitable host plant where they successfully breed during winter season, should destroy in cultural control programme. The shoots of TV-9, TV-10, TV-14 should pluck during dormant season.

10) Light skiffing and black plucking may be advocated in the infested area to control the recurring infestation of tea mosquito bug.

11) Cypermethrin can be used in severely tea mosquito bug infested area during epidemic.

12) Inundative release of Chrysoperla sp. at the predator insect ratio 1:4 to control tea mosquito bug. Predator can also take care of thrips, aphid, jassid and mite. Chrysoperla sp. was moderately effective to check the tea mosquito bug infestation.

13) Better strain of the fungus Beauveria bassiana would be effective.

14) Initial cost of Chrysoperla release was expensive but in the long run it would be cheaper and safer to control tea mosquito bug.

CHAPTER - VI

FUTURE SCOPE OF RESEARCH

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FUTURE SCOPE OF RESEARCH

1. Effect of pruning cycle of tea for the control of tea mosquito bug may be investigated.
2. Better strain of Beauveria bassiana against tea mosquito bug may be studied.
3. More natural enemies are known from West Africa than other areas. So the introduction of exotic predators and its performance against Helopeltis theivora would be worthwhile.
4. Efficacy of bio-pesticides against tea mosquito bug may be investigated.

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B I B L I O G R A P H Y

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