INFESTATION REACTIONS AND MANAGEMENT OF *Helopeltis theivora* (Waterhouse) (Miridae:Hemiptera) IN COCOA CLONES

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that the thesis entitled **'Infestation reactions and management of *Helopeltis theivora* (Waterhouse) (Miridae:Hemiptera) in cocoa clones'** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that the thesis entitled '**Infestation reactions and management of *Helopeltis theivora* (Waterhouse) (Miridae:Hemiptera) in cocoa clones'** is a record of research work done independently by **Ms.Beena Nair,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Dedicated to my

parents and sisters,

husband and son

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Introduction

INTRODUCTION

Among the insect pests of cocoa, mirids constitute the most widespread and destructive group. The first report of attack of mirids on cocoa dates back to 1863 in Ceylon, now Sri Lanka, by Wright (1907). Since then the pest has been reported to be serious in other countries including Java (Betrem, 1941) and Malaysia (Tan, 1974). Detailed reports on the incidence of mirids on cocoa have also been provided by Lavabre (1977), Bigger (1981) and Gapud *et al.* (1993). Among the different species of *Helopeltis* attacking cocoa, *Helopeltis theivora* (Waterhouse) is the most serious in Ghana and Malaysia which are the major cocoa growing countries in the world.

Since the first report of *H. theivora* by Abraham and Padmanabhan in 1967 on cocoa in South India, it was again reported as a pest of cashew in 1983 by Ambika and Abraham and on tea by Das (1984). In the cocoa plantations of the Cadbury-KAU Co-operative Cocoa Research Project implemented at the College of Horticulture, Vellanikkara, the incidence of *H. theivora* has been observed since 1992. There is a distinct possibility of *H. theivora* assuming the status of a major pest of cocoa in the state of Kerala.

The adults and nymphs suck sap from the pods and flushes causing black lesions on the surface due to the injection of a phytotoxic salivary secretion. When the damage is in the cherelle stage they are liable to wilt and dry up. On the bark of young shoots and midribs of new leaves elongate, elliptical lesions are formed and the leaves attached near the points of attack wither and drop. In field studies conducted in Malaysia, Tan (1974) observed that the nymphs and adult males are causing more damage to the green shoots of fan tips compared to the shoots of new flushes. He has reported upto 85 per cent of pod damage based on the number of pods infested by the bug.

Cocoa (*Theobroma cacao* L.) is one of the most important beverage crops of the world; next to tea and coffee. Presently, the world production of cocoa beans is around 27 lakh tonnes. About 6000 tonnes of beans produced in India accounts for only 0.22 per cent of the world production. In India, cocoa cultivation is at present concentrated in the states of Kerala and Karnataka. In the 1980s around 25,000 hectares of land was under cocoa cultivation, but it declined drastically in the 1990s. Recently, the cocoa cultivation is again picking up in Kerala due to a hike in price of the commodity. It is estimated that the internal requirement of cocoa in India by the year 2000 will be 20,000 tonnes. To achieve this objective an area of 40,000 hectares will have to be brought under the cultivation of cocoa. Effective and safer methods are not currently available to manage *H. theivora* infesting the cocoa crop in the country. In the present study and attempt has been made to:

i) identify the resistant and high yielding cocoa clones

ii) select out an effective management approach using insecticides.

Review of Literature

2. REVIEW OF LITERATURE

The mirids constitute the most injurious and widespread among the insect pests of cocoa, a crop of highly heterogenous nature (Keshavachandran, 1979). About forty species of mirids hitherto recorded in cocoa belong to the subfamily Bryocorinae which is further subdivided into two tribes, namely, Monalioni and Odoniellini. The tribe, Monalioni is the most widespread and comprises of the two genera *Helopeltis* and *Monalion*. The genera *Distantiella, Sahlbergella* and *Pseudodionella* belong to the tribe Odoniellini (Carvalho, 1957). The Oriental and African species of *Helopeltis* are classified under the subgenera *Helopeltis* and *Afropeltis*, respectively.

Plant bugs of the genus *Helopeltis* have a paleotropical distribution and they occur throughout the Oriental and Australian regions. The first record of the species, *Helopeltis antonii* Signoret from cocoa dates back to 1863 in Ceylon (Wright, 1907). Some of the other species recorded on cocoa pods are *H. bakeri* Poppius, *H. fasciaticollis* Poppius, *H. sulawesi* sp.n. and *H. sumatranus* Roepke (Stonedahl, 1991). Heavy damage to cocoa pods by mirid bugs of different species have been reported by several workers (Betrem, 1941; Lavabre, 1977; Bigger, 1981; Chong, 1987 and Gapud *et al.*, 1993).

In field studies conducted at Malaysia, Tan (1974) observed that the nymphs and adult males of *H. theivora* (Waterhouse) are causing more lesions on green shoots of fan tips than on shoots of new flushes. He also noticed reduction in pod weight and dry bean weight due to infestation. The mirid bug, *Sahlbergella singularis* Hagl. has been found to reduce the quality of cocoa pods in Nigeria (Ojo, 1985). Awang *et al.* (1988) in a comparison of the cocoa pod and shoot as food source for *H. theivora* found better growth of nymphs, higher adult longevity and fecundity when fed on cocoa pods.

The first report of *H. theivora* on cocoa in India was by Abraham and Padmanabhan (1967). It was also reported as a pest of cashew in 1983 by Ambika and Abraham and on Indian long pepper, *Piper longum* by Abraham (1991). This mirid bug has been reported as a major pest of tea also (Das, 1984). Detailed information on the feeding reactions of *H. theivora* in cocoa and their management using insecticides in India are not available. A review of the available literature on the different aspects such as damage, host range, reaction of host plants to feeding, and management of mirids and other related insect pests are furnished hereunder.

2.1 *Helopeltis* damage on cocoa and other crops

2.1.1 Damage on cocoa

The mirid bugs feed on almost all the tender and green parts of cocoa such as pods, young shoots, leaf petioles and veins. The feeding results in the formation of lesions on pod surface due to the injection of a highly phytotoxic salivary secretion which breaks down the cells of the parenchymatous tissue (Crowdy, 1947). Miles (1987) reported the occurrence of a pectinase (polygalacto uronase) in the salivary gland secretion of *H. clavifer* Walk.

Tan (1974) has reported that pod wilt occurs when young pods of length 5-10 cm are attacked by the bugs. He also observed reduction in bean weight and malformation when larger pods are infested. Geisberger (1983) observed warty pustule development on pod surface due to attack. Reduction in pod weight, husk weight, bean number and bean weight by the attack of mirid bugs were reported by other workers also (Ojo, 1985; Jamaludin and Samsuddin, 1988).

Fungi like *Botryodiplodia* sp. have been usually found to invade the pods attacked by the mirids either through the cracks on pod surface or through the feeding lesions (Jamaludin and Samsuddin, 1988).

The commonly known `capsid blast' is the result of mirid bug damage on bark of young shoots and midribs of leaves. Elongate, elliptical lesions are formed by the movement of the toxic salivary secretion injected at the time of feeding. The leaves attached to these points are seen to wither and drop.

2.1.2 Damage on cashew

Various authors have reported the symptoms of damage by *Helopeltis* on cashew (Pillai and Abraham, 1975; Sathiamma, 1977; Devasahayam and Nair, 1986). Nymphs and adults of *Helopeltis* feed on the tender shoots of cashew resulting in the exudation of a resinous and gummy substance which on contact with air, gets hardened. The tissue around the feeding points turns black and scabby in two to three days and the tender shoots get dried up. Higher damage levels present a scorched appearance of the entire plant. Infestation on floral branches results in `blossom blight'.

The colonisation by different fungi in association with *Helopeltis* damage is well documented. The malady due to infestation by mirids was thought to be the joint effect of mirids and fungal pathogens. However, Nambiar *et al.* (1973) found that the fungi are only secondary pathogens. Some of the fungi found associated with mirid damage are *Phomopsis anacardii, Gleosporium cingulata* (Intine and Sijaona, 1983), *Fusarium* sp., *Colletotrichum* sp. (Devasahayam and Nair, 1986) and *Botryodiplodia theobromae* (Varma and Balasundaran, 1990).

2.1.3 Damage on other crops

As a result of mirid bug damage, drying of leaves and fruits of grape vine was noticed by Puttarudraiah and Appanna (1955), wartlike blisters on fruit surfaces of guava by Gopalan and Perumal (1973) and dieback of terminal shoots, drying up of inflorescence and incomplete development of flush in *Moringa* by Pillai *et al.*

(1979). *H. antonii* is reported to cause occasional dieback of shoots and deformity of leaves of black pepper in Sarawak (Blacklock, 1954). In allspice, irregular necrotic spots were found on tender leaves which were mostly confined to the mid region of leaf lamina. The infested tender shoots dried up completely and the intensity of damage ranged between 14.3 to 42.9 per cent (Devasahayam *et al.*, 1986). Javaid (1986) has observed *H. schoutedeni* to cause leaf spots and fruit cankers on wild mango fruit trees in Zambia. Pillai and Gopi (1990) reported the drying up of tender shoots and leaves (dieback) of neem during December to April in South India by *H. antonii*. Deformity of tea leaves was the result of infestation due to mirid bugs (Gope and Handique, 1991).

Abraham (1991) has described the damage caused by *H. theivora* on Indian long pepper, *Piper longum* Linn. Feeding punctures developed into truncated water-soaked lesions within 48 hours. The affected tissues on the leaf lamina turn brownish black, followed by necrosis and shot hole formation. Tender foliage was preferred over shoots and petioles.

Some other records of host plants of *Helopeltis* spp. include mahogany and annatto (Fletcher, 1914), red gum in South Kerala (Rau, 1937) *Coffea arabica, Passiflora* spp., species of *Dioscorea, Capsicum annuum, Solanum nigrum, Mikania scandens, Bidens pilosa, Melostoma malabathricum, Begonia semperflorens* (Lever, 1949), *Acacia mangium* in Sarawak (Hamid, 1987) and Philippines (Leugo, 1990), *Psophocarpus tetragonolobus* in Sri Lanka (Shanthichandra *et al.*, 1990) and *Eucalyptus* in Indonesia (Rahardjo, 1992).

2.2 Host plant resistance to mirid bugs in cocoa

Decazy and Lolode (1975) have reported variations in the susceptibility of cocoa hybrids to *Helopeltis*. Smith and Moles (1982) reported significant differences among sixteen Trinitario clones in respect of their susceptibility to attack by the mirids. The percentage of pods damaged by the mirids in the clone KT 140 was below 10 per cent, while it ranged between 39 and 42 per cent in highly susceptible clones. In another study, Trinitario clones of cocoa plants were tested in the nursery stage for their resistance to *Pantorhytes*. The clones K-82 and KA2-101 recorded the highest damage while the other clones were more or less resistant (Anon., 1984). Samiyanto (1987) located two hybrids EET 376/UF 667 and UITI/NA 32 not preferred by *H. collaris* in a field study using twelve hybrids.

2.3 Host plant resistance to insect pests in cashew

Swaine (1959) reported that damage by *Helopeltis* sp. is generally heavier in younger trees around four years old than in older cashew trees around 8-14 years old. Tree to tree variation in the intensity of damage by *Selenothrips rubrocintus* (Giard) on cashew has been observed by Fennah (1963). Ambika *et al.* (1979) screened five year old seedling progenies belonging to eleven accessions in Kerala against infestation by *H. antonii*. The accession number 665 was comparatively more tolerant with respect to panicle and shoot damage whereas K-10-2-1232 and K-10-2-1218 were found most susceptible. Pillai *et al.* (1979) have also observed tree to tree variation in the population density and intensity of incidence of *H. antonii* on cashew.

Screening of 74 cashew accessions was carried out by Sathiamma (1979) at Vittal during 1975-'77 for evaluating the field tolerance to tea mosquito. Observations on shoot and panicle damage and counts of nymphs and adults of the bug at different intervals showed that the accession VTH-153 (10/8, Epurupalam, Bapatla) was the most resistant and VTH-54 (H-3-17, Anakayam) most susceptible. In another study by Ghosh and Chatterjee (1987), seventeen types of cashew plants were evaluated against tea mosquito bug damage. They observed lowest shoot and leaf damage as well as lowest panicle damage and highest yield in BLA-39-4. With regard to shoot and leaf damage, the type TN-119 also performed better while

H-3-17 recorded the highest damage. The panicle damage was highest (40 per cent) and yield was lowest in NLR-2/1. In the studies by (Sundararaju and John, 1993) on four month old soft wood grafts with tender flushes, it was observed that the accession numbers G-11/6 and VTH-153/1 were moderately susceptible to mirid damage while all others were susceptible. The cashew accession number 9/78 was found most resistant to attack by *Helopeltis* in field studies by Uthaiah *et al.* (1994).

That a certain minimum level of damage intensity is necessary for the manifestation of relative susceptibility spectrum of rice varieties to infestation by insects has been reported (IRRI, 1980).

2.4 Biophysical factors influencing resistance to crop pests

2.4.1 Hairiness

Balasubramanian and Iyengar (1950) reported that varieties of cotton resistant to leaf hopper were hairy though all hairy varieties were not resistant to the pest. *Aphis gossypii* Glover could not settle on *Solanum mamosum* L. as it was beset with closely arranged leaf hairs (Sambandam and Chelliah, 1970). Smith *et al.* (1975) stated that pubescent varieties of cotton impeded the movement of larvae of the pink boll worm. A close negative correlation has been found between high hair densities on leaf of cotton varieties and susceptibility to *Amrasca devastans* Dist. (Sivasubramanian *et al.*, 1991).

A. gossypii was monitored by Weathersbee *et al.* (1994) on 24 cotton genotypes. Lower numbers of aphids were found on glabrous than on pubescent varieties. Trichomes had been found to confer resistance to *Solanum* spp. against green peach aphid, potato leaf hopper and potato aphid (Gibson and Turner, 1977). Insect resistance mediated by glandular trichomes has been reported by Stipanovic (1983).

2.4.2 Anatomy of plants

The thickness of various plant tissue influences the degree of resistance. Blum (1968) reported that sorghum varieties resistant to shoot fly had distinct lignification and thickness of cell walls enclosing vascular bundle sheaths within the central whorl of young leaves. The hardness of the rind and the content of stalk were the key factors of resistance against older larvae of *Diatraea saccharata* (F.) in sugarcane.

Khaemba (1985) associated thickness of pod wall of cowpea to resistance against *Riptortus dentipens*. Screening trial of brinjal varieties for resistance to *Leucinodes orbonalis* Guen. revealed long fruited variety Katrain-4 as relatively more resistant than the round fruited variety. Thick fruit skin was also observed to be a possible cause for resistance (Mishra *et al.*, 1988).

Leaf thickness, midrib thickness and leaf area were found positively correlated with infestation of *A. biguttula biguttula* (Gaikwad *et al.*, 1991) on egg plant.

When Sivasubramanian *et al.* (1991) evaluated 954 accessions of cotton, they found that varieties resistant to the leaf hopper *A. devastans* had higher boll weights.

2.4.3 Surface waxes

Chemicals of plant epicuticular waxes have been shown to affect feeding behaviour in number of ways for various insects. Host plant resistance of barley to the cereal aphid *Rhopalosiphum padi* was in part, attributed to the leaf surface wax (Tsumauki *et al.*, 1989). Leaf surfaces of some alfalfa plants resistant to the spotted alfalfa aphid, *Therioaphis maculata* (Buckton) were found to have as much as 50 per cent more wax esters than did some susceptible ones (Bergman *et al.*, 1991).

2.4.4 Plant height

Differences in plant height also affect the reactions by insects. Neither canopy architecture nor shade intensity levels within canopy was found to affect infestation intensity of *H. antonii* on cashew (Thomas and Abraham, 1981). But greater plant heights was reported to decrease susceptibility of sorghum plants to *Melanaphis sacchari* (Mote and Shahane, 1994).

2.4.5 Presence of silica in plant cells

The presence of silica containing cells in the rice plant imparts resistance to rice stalk boring *Lepidoptera*. Djamin and Pathak (1968) found that increased stem silica content increased the level of resistance of rice to the striped stem borer *Chilo suppressalis*. Larvae feeding on cultivars with high silica content are found to lose mandibular teeth during the feeding process.

2.5 Management of insect pests using insecticides

2.5.1 Mirid bugs

Of the chemical insecticides, DDT was the first to be used against *Helopeltis* on tea (Lever, 1949). Damodaran and Nair (1969) reported that two sprays of DDT given at 15 days interval provided effective control of *H. antonii* on cashew . The application of arprocarb and lindane at 840 g ai/ha gave good control of mirids on cocoa (Manchart, 1971).

Laboratory and field evaluation of γ-BHC and technical DDT on the cashew mirids in Srilanka, showed γ-BHC to be more toxic and quick acting

(Jeevaratnam and Rajapakse, 1981). Even though lindane is still recommended for mirid bug control in many countries, the development of newer chemicals such as organophosphates and carbamates opened up new avenues in the control strategy. Endosulfan was reported to be effective against *H. theivora* on tea (Mukerjea, 1968) and propoxur against *Sahlbergella singularis* and *Distantiella theobromae* (Dist.) on cocoa (Ehsanullah, 1972).

Chemical control trials conducted at Kasargod, Kerala revealed that endosulfan at 0.05 per cent applied as high volume spray and 0.1 per cent as low volume spray at the time of emergence of new shoots, panicles and fruit set was effective in controlling tea mosquito population in cashew and in reducing yield losses (Pillai *et al.*, 1976). Endosulfan(0.05 per cent), carbaryl (0.15 per cent), phosphamidon (0.03 per cent) and quinalphos (0.05 per cent) were found to be relatively more effective than other insecticides tested in reducing shoot and floral infestations in cashew (Nair and Abraham, 1982). Effective reduction of shoot damage by dusting carbaryl and phosalone was noticed against *H. antonii* (Nair and Abraham, 1983 and 1984). When the effect of several insecticides was tested for the control of tea mosquito bug by Samiayyan and Palaniswamy (1984) methyl parathion at 0.05 per cent as spray application recorded the lowest incidence of the pest.

Pappiah *et al.* (1985) obtained good control of *H. antonii* by applying a combined spray of three per cent urea and endosulfan at 0.05 per cent on ten year old cashew trees. Smith *et al.* (1985) have recommended spraying with endosulfan at 440 g ai/ha in 60 litres of water for control of *H. clavifer* on tea in New Guinea. The results of field experiments conducted in Karnataka state by Hiremath *et al.* (1987) indicated that five per cent malathion dust as quite promising against *H. antonii* on cashew. The effectiveness of propoxur and isoprocarb in controlling *H. theobromae* on cocoa in Malaysia was evidenced by Tuck (1987). Chatterjee

(1989) reported endosulfan and monocrotophos at 0.05 per cent to be effective against *H. antonii.* The effectiveness of endosulfan against *H. schoutedeni* on tea was confirmed by Rattan (1989). In some other experiments, Rattan (1984 and 1985) has found deltamethrin and cyfluthrin to be effective in controlling *H. shoutedeni.* The various insecticides reported to be effective against *Helopeltis* spp. include carbaryl 0.01 per cent, endosulfan 0.05 per cent and phosalone 0.07 per cent (Godase *et al.*, 1992).

In a six year trial in a tea estate infested with *Helopeltis* sp., application of cypermethrin at bud-break of tea, followed by need based additional sprays gave tremendous yield increase (Mkwaila, 1983). Tuck (1987) found decamethrin and permethrin applied as fogs giving good control of *H. theobromae* on cocoa and based on these results synthetic pyrethroids have been recommended as suitable alternatives to γ-HCH. Application of carbaryl at 500 g ai/ha was found to control *Calocoris angustatus* on sorghum (Sharma and Leuschner, 1987).

2.5.2 Aphids

Various field and laboratory experiments have been conducted to assess the efficacy of insecticides on aphids. During 1971-'73, among the eighteen insecticides tested at Ludhiana for the control of mustard aphid, *Lipaphis erysimi* (Kalt) on brown sarson chlorpyriphos, dicrotophos, monocrotophos, phosalone, dimethoate and oxydemeton methyl were the most effective (Brar and Sandhu, 1981). Tests conducted by Bhadoria *et al.* (1982) using seven insecticides at Gwalior in Madhya Pradesh proved that foliar sprays of monocrotophos at 0.32 l/ha, fenvalerate at 0.16 l/ha and cypermethrin at 0.08 l/ha were effective in reducing the aphid populations. In a laboratory study against *L. erysimi* on *Brassica campestris* var *toria* the order of toxicity was deltamethrin > cypermethrin > phosphamidon > methyl-o-demeton > dimethoate > monocrotophos > quinalphos > carbaryl > endosulfan > Sevisulf (a mixture of carbaryl and sulphur) (Tripathi *et al.*, 1985).

Sublethal doses of demeton-S-methyl proved to stimulate the progeny of treated green peach aphid, *Myzus persicae* but no such effects were manifested when the nymphs themselves were exposed to the insecticides (Coombes, 1983). Phosphamidon and monocrotophos each applied at 0.03 per cent on appearance of *M. persicae* and two weeks later gave good control on *Cuminum cyminum* (Gupta and Yadava, 1986). Increased yields in tobacco was reported by foliar applications of triazophos at 280 g/ha against *M. nicotianae* in Virginia (Semtner *et al.*, 1990). *M. persicae* on aubergines was controlled for fifteen days by the systemic insecticides dimethoate and monocrotophos applied at 250 g ai/ha and the contact insecticides endosulfan (300 g ai/ha) and fenvalerate (100 g ai/ha) (Nagia *et al.*, 1992).

When the cabbage aphid, *Brevicoryne brassicae* (Linnaeus) was released on treated cauliflower leaves, quinalphos closely followed by phosalone were found most toxic (Duhra and Hameed, 1988).

Application of dimethoate, monocrotophos and formothion at 0.05 per cent were equally effective in controlling *Aphis gossypii* Glover (Bodhade *et al.*, 1987). Of the 48 aphicides tested by Menozzi *et al.* (1987) against *A. gosypii* on cotton, monocrotophos applied at 300 g ai/ha was found most effective while studies for insecticide schedule on cotton in Orissa by Senapati and Behera (1989) revealed that spraying twice with demeton-methyl and subsequently with monocrotophos 5 times at 0.5 kg ai/ha at 20 day intervals commencing 30 days after sowing afforded excellent control and increased the seed cotton yield by 83.09 per cent. Sprays of dimethoate, demeton-o-methyl and phosphamidon effectively controlled *A. craccivora* on cowpea (Khotadia and Bhalani, 1992).

2.5.3 Aleyrodids

Spray application of methyldemeton at 0.20 kg ai/ha and dimethoate at 0.18 kg ai/ha once in the nursery beds of tobacco after germination and three times in the field at 15 day intervals starting on the tenth day of transplanting gave effective control of *Bemisia tabaci* Genn. (Chavan, 1983). When field experiments were carried out on groundnut in Orissa, the aleyrodid population was reduced by 74.68 per cent in plots treated with 0.2 per cent dimethoate (Dash, 1989). *B. tabaci* was effectively controlled by spraying endosulfan on brinjal (Naik *et al.*, 1993).

2.5.4 Cicadellids

Patel and Vora (1981) showed that sprays of monocrotophos, dimethoate and demeton-o-methyl, all at 0.03 per cent gave protection to groundnut against *Empoasca kerri* Pruthi for three weeks. In Punjab, field studies indicated the effectiveness of dimethoate at 0.3 kg ai/ha against cotton aphid, *Amrasca biguttula biguttula* Ishida (Jogindher *et al.*, 1982). Narke and Suryawanashi (1987) and Shah *et al.* (1990) observed monocrotophos 0.5 per cent as most effective for control of the jassid on okra and cotton, respectively.

Nachiappan and Baskaran (1986) observed endosulfan to give best results in terms of reduced population of mango hoppers, *Idioscopus niveosparsus* and *I. clypealis* and higher retention of fruits when sprayed at one week after flowering and again after two weeks. To keep the population of mango hoppers very low, Patel *et al.* (1987) suggested two rounds of application of carbaryl at 0.1 per cent; first in December-January preceeding development of inflorescence and the second in June-July preceeding fresh vegetative growth.

2.5.5 Other hemipterans

Field studies in Brazil to investigate the systemic effect of sprays of monocrotophos on soyabean at 100-500 g/ha in the control of *Nezara viridula* (L.), showed up to 77 per cent mortality in 5 and 9 days after treatment (Bertoldo and Corseuil, 1980).

The contact toxicity of different insecticides and their mixtures was studied by Heinrichs *et al.* (1982) and they obtained 100 per cent motality of the stink bug, *Leptocorisa oratorius* (F.) with monocrotophos, monocrotophos-mevinphos mixture and endosulfan at 0.06 per cent, chlorpyriphos at 0.16 per cent, phosphamidon at 0.07 per cent and diazinon at 0.21 per cent sprays.

2.6 Use of botanicals in insect pest management

Saxena and Khan (1984) found that duration of survival of brown plant hopper, *Nilaparvata lugens* Stal. decreased markedly in rice seedlings sprayed with neem oil emulsified in water with one percent liquid detergent. Strong antifeedant effect of seed oil of neem has been observed in laboratory and greenhouse studies in China (Chiw *et al.*, 1983). Sankaram *et al.* (1986) tested the biological activity of different neem compounds against several pests including the mirid *Calocoris angustatus* and they observed a marginal level of control of the pest.

Pillai and Ponniah (1988) reported that two per cent neem oil, 250 ml/ha of phosphamidon 100 EC and 500 ml/ha of fenthion 100 EC were equally effective in controlling rice thrips *Stenchaetothrips biformis*.

Neem kernel suspension reduced *H. theivora* damage to 70 per cent (Abraham, 1991). At Vridhachalam, three sprays of neem seed kernel extract and neem oil (two per cent) gave minimum tea mosquito damage of 6.04 and 6.90 per cent respectively (Anon., 1993b). Neem products and pongamia seed oil have also been reported by Anon. (1993a) to be effective against *H. antonii.* A significant repellent action of pongamia and other vegetable oils on *Callosobruchus chinensis* was observed by Khaire *et al.* (1993).

Materials and Methods

3. MATERIALS AND METHODS

3.1 Experiment I - Field studies on the infestation reactions of *Helopeltis theivora* (Waterhouse) in cocoa clones and the role of clonal traits on infestation

The field experiment was conducted in the experimental field of Cadbury-KAU Co-operative Cocoa Research Project at the College of Horticulture, Vellanikkara. The experiment was carried out during the period from July 1995 to June 1996.

Fifteen high yielding clones planted in two sets as Series I and Series II during the years 1986 and 1987, respectively were utilised for the study. The Series I comprised of four hybrids and six parents and Series II of three hybrids and two parents. The clones were selected on the basis of their promising yield performance during 1994.

The details of the clones evaluated in the study are as follows:

Hybrids	Cross/parent
Series I	
H_1	GI-5.9 x GVI-54
H_2	GI-10.3 x GVI-61
H_3	GI-10.3 x GVI-64
H_4	GI-5.9 x GVI-68
Series II	
H_5	GI-15.5 x GVI-64
H_6	M-13.12 x GI-5.9
H_7	GI-5.9 x GVI-61

Parents

Series I

P_1	GI-5.9
P_2	GI-10.3
P_3	GVI-54
P_4	GVI-61
P_5	GVI-64
P_6	GVI-68

Series II

P_7	M-13.12
P_8	GI-15.5

Five trees were selected at random for recording observations on the different parameters. The clones were considered as treatments and each tree as a replication.

3.1.1 Infestation reactions of *H. theivora* in cocoa clones

3.1.1.1 On pods at different stages of growth

The visual assessment of pod damage was recorded on the basis of percentage surface area covered by lesions on a 0-5 scale as follows:

0 - no necrotic lesion

1 - up to 20 per cent surface area covered by lesions

2 - 21-40 per cent surface area covered by coalescing/non-coalescing lesions

3 - 41-60 per cent surface area covered by coalescing/non-coalescing lesions

4 - 61-80 per cent surface area covered by coalescing/non-coalescing lesions

5 - 81-100 per cent surface area covered by coalescing/non-coalescing lesions

The rating was done separately for the three stages of growth of the pod, namely, young stage, medium growth stage and ripening stage (Plates 1 and 2). The extent of damage was calculated as follows:

$$\text{Percentage infestation} = \frac{\text{Sum of all ratings}}{\text{Total number of ratings x Maximum damage rating}} \times 100$$

The percentage infestation for each replication for all the three growth stages of the pod and the mean was worked out.

3.1.2 Damage on vegetative flushes

Each tree was divided visually into three sectors based on ground coverage of canopy and from each sector one branch was selected for the study. From these three branches, the number of damaged flushes (Plate 3) and the number of lesions from a maximum of ten damaged flushes were recorded in the fortnightly observations.

The counts of lesions on the flushes (Plate 4) were rated on the following scale used by Ambika *et al.* (1979) for the study of *H. antonii* damage in cashew.

0 - no necrotic lesions/streaks

1 - up to 3 necrotic lesions/streaks - general vigour of flushes unaffected

2 - 4-6 coalescing or non-coalescing lesions/streaks - general vigour of flushes affected

3 - above 6 coalescing or non-coalescing lesions/streaks - general vigour of flushes affected

4 - lesions/streaks confluent and drying of affected flushes

Plate 1. Lesions caused by *H. theivora* at young stages of cocoa pods

Plate 2. Lesions caused by *H. theivora* at medium stages of cocoa pods


Plate 3. A damaged flush of cocoa along with nymphs

Plate 4. Lesionscaused by *H. theivora* on a cocoa flush

The damage intensity on flushes was then calculated by using the formula adopted for damage to pods (section 3.1.1.1).

3.1.2 Influence of biophysical characters of pods on *H. theivora* infestation

Observations on the different biophysical characters of pods were recorded from July 1995 to June 1996. The ripe pods were harvested at an interval of two to three weeks. The total number of pods harvested including those damaged by rodents was recorded. But only ripe healthy pods free from rodent damage were taken into account for study of the pod characters.

3.1.2.1 Number of pods

The number of ripe pods harvested from each tree at each harvest was recorded and the total number of pods harvested during an year was worked out. The data from each tree replicate was used for further statistical analysis.

3.1.2.2 Length of pod

Length of each harvested pod was measured in centimetres using a meter scale. The average pod length for each tree was estimated from the data recorded.

3.1.2.3 Width of pod

The width of the harvested pods was measured in centimetres using a meter scale and data recorded. The average pod width was calculated for each tree.

3.1.2.4 Pod weight

The weight of each pod was recorded in grammes and the mean pod weight for each tree replicate was estimated for statistical analysis.

3.1.2.5 Thickness of pericarp

The thickness of pericarp at ridge as well as at furrow was measured for each pod in millimetres using vernier calipers after cutting across through the centre of the pod. The mean pericarp thickness was then worked out for each tree from the data recorded.

3.1.2.6 Wet bean weight

The wet bean weight from each single pod was recorded in grammes after breaking the pods open. The average wet bean weight for each tree was calculated at the end of the study.

3.1.2.7 Number of beans per pod

The number of beans in each pod was recorded and the mean worked out for each tree.

3.1.2.8 Total wet bean weight

The total wet bean weight for each tree was calculated by multiplying the mean number of healthy pods undamaged by rodents with the mean wet bean weight of the tree.

3.1.3 Role of canopy architecture of different clones on *H. theivora* infestation

In order to ascertain whether variations in canopy configuration regulates susceptibility of the tree to infestation by *H. theivora*, the parameters height and maximum canopy spread were recorded.

3.1.3.1 Height of tree

The height of the tree was recorded using a calibrated pole in centimetres.

3.1.3.2 Spread of tree

The maximum canopy spread of the tree was measured along diametrical lines passing through the trunk as centre and recorded in centimetres.

3.2 Experiment II - Evaluation of toxic stimulus of chemical and non chemical insecticides to *H. theivora*

The experiment was conducted at the College of Horticulture, Vellanikkara during 1995-96.

3.2.1 Treatments

The treatments consisted of six chemical insecticides, one insecticide of plant origin and an untreated control. The details of the treatments are presented in Table 1.

Table 1. Details of the treatments

No.	Active ingredient	Proprietory product	Name of manufacturer	Rate/Dose tested
1	Endosulfan	Endosulfan 35EC	M/s.Rallis India Ltd. Ralli House 21, Subhadvala Marg Bombay-400 001	0.50 kg ai/ha
2	Carbaryl	Sevin 50WP	M/s.Bhopal Pesticides Pvt. Ltd, 101, Industrial Area, Govindpura Bhopal-462 023	1.25 kg ai/ha
3	Monocrotophos	Nuvacron 36EC	M/s.Hindustan Ciba Geigy Ltd., 14-I. Tata Road Bombay-400 020	0.50 kg ai/ha
4	Quinalphos	Ekalux 20AF	M/s.Sandoz (India) Ltd. Sandoz House Annie Besant Road Worli, Bombay-400 018	0.25 kg ai/ha
5	Alphamethrin	Alphaguard 10EC	M/s.Gharda Chemicals Ltd., Factory and R&D Centre, B-27, MIDC Dombivili (E) 421 203 (India)	0.10 kg ai/ha
6	Ethofenprox	Trebon 10EC	M/s.Mitsui Toatsu Chemicals Inc, 2-5 Kasumigaseki 3-Chome, Chiyodaku Tokyo, Japan	0.75 kg ai/ha
7	Pongamia oil	--	Local market	1 per cent
8	Untreated control	--	--	--

3.2.2 Emulsfier

Triton X-100 manufactured by S.D. Fine Chemicals Ltd., Boisar was used as emulsifier for emulsification of pongamia oil.

3.2.3 Rearing of test insects

The stock culture of *H. theivora* was developed in the laboratory from field collected fourth and fifth instar nymphs. The nymphs were reared on tender shoots of cocoa, the leaves of which were clipped off. The cut end of the shoots were kept in water contained in glass tubes and the mouth plugged with cotton plug. The shoots along with the glass tubes were placed in glass chimneys and the nymphs at the rate of ten per cage were released into it. The bottom of the chimney was placed in a petri-dish and the top was covered with muslin cloth held in position using rubber bands.

The nymphs on attaining maturity were sexed and transferred into chimneys with tender shoots at the rate of 10 adults for two shoots in a chimney for egg laying. The male-female ratio was maintained at 1:1 in each cage. The adults were transferred to new chimneys after two days of egg laying. The shoots with the eggs were separately maintained for emergence of young ones. In 5-7 days after oviposition most of the eggs emerged. The freshly emerging nymphs were carefully transferred to fresh shoots kept in chimneys using a camel hair brush. One day old third instar nymphs were used for the insecticide evaluation. A portion of the culture was used for further multiplication of the test insect. Frequent pooling of field collected nymphs and adults was done to avoid the chances of inbreeding depression in the stock culture.

3.2.4 Selection of green pods and computation of surface area for spraying

Uniform sized green pods in medium growth stage having length ranging between 11 and 15 cm and Width ranging between 6 and 9 cm were collected from a clone that showed more damage by *H. theivora* and used for insecticide evaluation studies. The surface area of each pod was computed from the length and maximum width of the pod using standard methods, considering the pod to be made up of two cones of equal size.

3.2.5 Preparation and application of treatments

Based on the rate of application, the insecticide emulsions were prepared by adding the required quantity of water. The quantity of spray fluid per hectare of area was fixed as 500 litres (50 ml/m^2). In the case of pongamia oil, emulsifier was first mixed with the oil in the ratio of 1:1 and it was then emulsified by adding the required quantity of water and used in the experiments.

Based on the surface area of each green pod, the required quantity of spray fluid of each treatment was applied thoroughly on the pod surface using an atomiser. Each sprayed pod formed a replication and there were five such replications for each treatment.

The treated pods were dried under an electric fan. Each of the treated pod was then transferred to glass jars and five third instar nymphs were released carefully on to the pod. The top of the jar was covered by muslin cloth and held in position using rubber bands. The ambient temperature inside the insectary during the study period ranged between 17°C and 40.4°C and the humidity between 34 and 96 per cent.

3.2.6 Collection of data

The mortality of the test insects in each replication was recorded at 24 hours after treatment. The moribund insects were also counted as dead.

3.3 Statistical analysis of data

3.3.1 Experiment I

The data were statistically analysed using M Stat-C package available at the Central Computer Facility of the College of Horticulture, Vellanikkara. The analysis of variance technique described by Snedecor and Cochran (1967) was made use of for analysis of infestation under field conditions. Simple correlation coefficients were worked out to evaluate the possible role of pod and tree characters on *H.theivora* infestation.

3.3.2 Experiment II

Data was statistically analysed as for CRD experiments using the M Stat-C software package.

Results

4. RESULTS

The present study to investigate infestation reactions of *H. theivora* in cocoa clones and the role of clonal traits on infestation was carried out at the Cadbury - KAU Co-operative Cocoa Research Project, Vellanikkara. Fifteen high yielding clones comprising of four hybrids and six parents designated as Series I and three hybrids and two parents designated as Series II were utilised for the study.

The evaluation of the toxic stimulus of chemical and non-chemical insecticides to *Helopeltis theivora* (Waterhouse) was undertaken at the College of Horticulture, Vellanikkara. The treatments consisted of six chemical insecticides, one insecticide of plant origin and an untreated control.

The data were statistically analysed using the M-Stat C package available at the Central Computer Facility at the College of Horticulture, Vellanikkara.

4.1 Field studies on the infestation reactions of *H. theivora* (Waterhouse) in cocoa clones and the role of clonal traits on infestation

4.1.1 Infestation reactions of *H. theivora* in cocoa clones

4.1.1.1 On pods at different stages of growth

The percentage intensity of damage due to *H. theivora* in different clones at different stages of pod development are presented in Table 2. The results of the study show that there is no significant difference among the clones in respect of the damage caused by *H. theivora* in the overall mean damage intensity for the entire development period of the pods.

The mean percentage damage intensity ranged between 0.33 in clone GVI-68 to 5.26 in clone GI-10.3 x GVI-61 at young stage, 0.27 in GI-10.3 x

Table 2. Mean percentage damage intensity by *H. theivora* in different clones at young, medium and ripening stages of pod growth and overall mean damage intensity

Clone No.	Cross/parent	*Mean damage intensity on pods at			Overall mean
		Young stage	Medium stage	Ripening stage	
Series I					
H_1	GI-5.9 x GVI-54	1.45(1.12)^{a}	3.62(1.43)^{a}	1.50(1.13)^{a}	2.70(1.31)^{a}
H_2	GI-10.3 x GVI-61	5.26(1.60)^{a}	0.80(1.33)^{a}	0.25(0.81)^{a}	2.12(1.23)^{a}
H_3	GI-10.3 x GVI-64	4.17(1.49)^{a}	0.27(0.84)^{a}	0.28(0.85)^{a}	1.85(0.74)^{a}
H_4	GI-5.9 x GVI-68	1.51(1.33)^{a}	0.90(1.01)^{a}	3.41(1.40)^{a}	1.25(1.09)^{a}
Series II					
H_5	GI-15.5 x GVI-64	1.29(1.093)^{a}	0.48(0.91)^{a}	0.52(0.92)^{a}	0.42(0.89)^{a}
H_6	M-13.12 x GI-5.9	1.11(1.058)^{a}	0.56(0.93)^{a}	0.71(0.97)^{a}	0.55(0.92)^{a}
H_7	GI-5.9 x GVI-61	1.51(1.252)^{a}	2.56(1.43)^{a}	4.10(1.62)^{a}	2.25(1.41)^{a}
Series I					
P_1	GI-5.9	1.11(1.058)^{a}	0.33(0.86)^{a}	1.00(1.04)^{a}	0.34(0.87)^{a}
P_2	GI-10.3	0.82(0.994)^{a}	0.44(0.89)^{a}	0.26(0.83)^{a}	0.82(0.99)^{a}
P_3	GVI-54	0.59(0.937)^{a}	0.64(0.95)^{a}	1.37(1.11)^{a}	1.00(1.04)^{a}
P_4	GVI-61	4.72(1.548)^{a}	1.46(1.12)^{a}	2.22(1.25)^{a}	1.87(1.90)^{a}
P_5	GVI-64	5.16(1.997)^{a}	1.26(1.23)^{a}	2.50(1.57)^{a}	2.04(0.43)^{a}
P_6	GVI-68	0.33(0.858)^{a}	0.79(0.99)^{a}	0.25(0.81)^{a}	0.51(0.91)^{a}
Series II					
P_7	M-13.12	3.27(1.573)^{a}	5.84(1.52)^{a}	5.30(1.85)^{a}	3.34(1.58)^{a}
P_8	GI-15.5	2.25(1.395)^{a}	2.19(1.39)^{a}	5.71(1.93)^{a}	2.88(1.53)^{a}

* Figures in parentheses are transformed $\sqrt{x}$ values. In a column, means followed by a common letter are not significantly different at 5 per cent level by DMRT.

GVI-64 to 5.84 in M-13.12 at medium growth and 0.25 in GI-10.3 x GVI-61 and GVI-68 to 5.71 in GI-15.5 at ripening stage while the overall mean damage was lowest in GI-5.9 (0.34%) and highest in M-13.12 (3.34%).

4.1.1.2 Damage on vegetative flushes

The data relating to the intensity of damage on flushes of the clones studied are furnished in Table 3.

With regard to the damage intensity on flushes there was no significant difference among the clones. The lowest mean damage intensity rating was 0.36 per cent in GI-5.9 x GVI-68 followed by 0.80 per cent in GVI-61. The parents GI-15.5 and M-13.12 and the hybrid M-13.12 x GI-5.9 recorded the highest damage rating of 8.29, 5.58 and 5.58 per cent, respectively.

However, there existed a strong positive correlation (r) between the damage intensity on pods and flushes (0.56). The per cent damage intensity of *H. theivora* on pods and flushes depicted in Fig.1 showed that in all the clones except M-13.12 x GI-5.9, GI-5.9 and GVI-68, the damage levels on pods are reflected on the damage on flushes. In the clones M-13.12 and GI-15.5 which showed higher damage intensity on pods (3.34 and 2.88 per cent, respectively) had higher damage on flushes also (5.58 and 8.29 per cent, respectively).

4.1.2 Influence of biophysical characters of pods on *H. theivora* infestation

The different biophysical attributes of pods of the clones such as total number of pods in a year and the means of length of pod, width of pod, pod weight, thickness of pericarp at ridge and furrow, the number of beans per pod, wet bean weight per pod and the total wet bean weight per tree are presented in Table 4.

Table 3. Mean percentage damage intensity by *H. theivora* in flushes on different cocoa clones

Clone No.	Cross/parent	*Damage intensity on flushes
Series I		
H_1	GI-5.9 x GVI-54	2.86 (1.34) [a]
H_2	GI-10.3 x GVI-61	2.50 (1.29) [a]
H_3	GI-10.3 x GVI-64	1.76 (1.18) [a]
H_4	GI-5.9 x GVI-68	0.36 (0.87) [a]
Series II		
H_5	GI-15.5 x GVI-64	1.88 (1.19) [a]
H_6	M-13.12 x GI-5.9	5.58 (1.63) [a]
H_7	GI-5.9 x GVI-61	2.00 (1.21) [a]
Series I		
P_1	GI-5.9	4.00 (1.47) [a]
P_2	GI-10.3	2.33 (1.26) [a]
P_3	GVI-54	2.00 (1.21) [a]
P_4	GVI-61	0.80 (0.99) [a]
P_5	GVI-64	4.80 (1.56) [a]
P_6	GVI-68	3.10 (1.37) [a]
Series II		
P_7	M-13.12	5.58 (1.94) [a]
P_8	GI-15.5	8.29 (2.27) [a]

* Figures in parentheses are transformed $\sqrt{x}$ values. In a column, means followed by a common letter are not significantly different at 5 per cent level by DMRT.

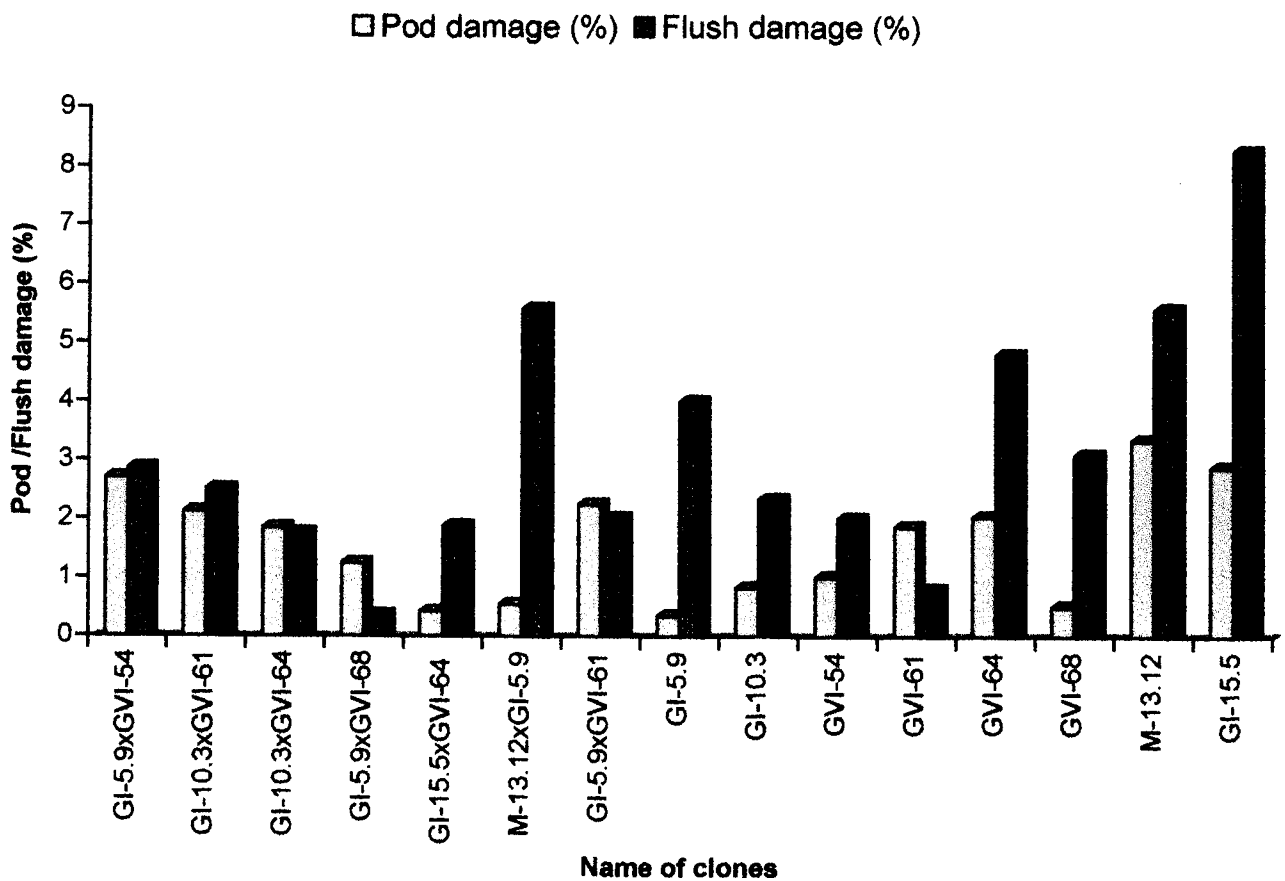

Fig. 1. Per cent damage intensity by *H. theivora* on cocoa pods and flushes

Table 4. Mean of different biophysical characters of pods belonging to different cocoa clones

Clone No.	Cross/parent	Biophysical parameters of pods*								
		*No. of pods	Length of pod (cm)	Girth of pod (cm)	Pod weight (g)	Thickness of pericarp at ridge (mm)	Thickness of pericarp at furrow (mm)	Wet bean weight per pod (g)	No. of beans per pod	**Total wet bean weight per tree (g)
Series I										
H_1	GI-5.9 x GVI-54	20.20(4.44) ^{a}	12.64 ^{b}	7.63 ^{ab}	260.5 ^{a}	10.58 ^{abc}	5.46 ^{bcd}	87.05 ^{a}	36.52^{ab}	481.80(1.32) ^{a}
H_2	GI-10.3 x GVI-61	10.20(2.93) ^{a}	13.49 ^{b}	7.67 ^{ab}	234.0 ^{a}	9.65 ^{bcd}	7.41 ^{ab}	74.09 ^{a}	41.26^{ab}	421.64(1.16) ^{a}
H_3	GI-10.3 x GVI-64	15.00(3.60) ^{a}	12.55 ^{b}	6.66 ^{b}	258.3 ^{a}	9.59 ^{bcd}	5.76 ^{bcd}	73.94 ^{a}	38.58^{ab}	760.18(1.35) ^{a}
H_4	GI-5.9 x GVI-68	23.00(4.64) ^{a}	13.30 ^{b}	7.54 ^{ab}	263.5 ^{a}	10.17 ^{abcd}	6.71 ^{abcd}	84.92 ^{a}	44.42^{a}	1263.98(1.50) ^{a}
Series II										
H_5	GI-15.5 x GVI-64	16.20(3.95) ^{a}	13.70 ^{b}	7.26 ^{ab}	270.6 ^{a}	9.49 ^{bcd}	5.12 ^{bcd}	79.63 ^{a}	37.94^{ab}	651.11(1.39) ^{a}
H_6	M-13.12 x GI-5.9	16.80(3.75 ^{a}	13.14 ^{b}	7.73 ^{ab}	289.0 ^{a}	8.80 ^{bcd}	6.03 ^{abcd}	86.06 ^{a}	38.01^{ab}	1275.45(1.47) ^{a}
H_7	GI-5.9 x GVI-61	17.60(4.10) ^{a}	13.59 ^{b}	7.02 ^{b}	226.2 ^{a}	8.15 ^{d}	4.28 ^{d}	83.68 ^{a}	40.27^{ab}	822.99(1.34) ^{a}
Series I										
P_1	GI-5.9	11.60(3.19) ^{a}	12.23 ^{b}	7.39 ^{ab}	281.6 ^{a}	8.42 ^{d}	6.37 ^{abcd}	95.38 ^{a}	42.37^{a}	502.99(1.34) ^{a}
P_2	GI-10.3	18.20(3.76) ^{a}	13.32 ^{b}	7.69 ^{ab}	290.1 ^{a}	12.03 ^{a}	8.42 ^{a}	77.09 ^{a}	37.29^{ab}	797.70(1.28) ^{a}
P_3	GVI-54	11.40(3.03) ^{a}	12.82 ^{b}	7.74 ^{ab}	305.1 ^{a}	10.27 ^{abcd}	6.51 ^{abcd}	86.63 ^{a}	32.94^{b}	694.96(1.28) ^{a}
P_4	GVI-61	23.00(4.51) ^{a}	15.89 ^{a}	6.73 ^{b}	295.7 ^{a}	9.67 ^{abcd}	7.21 ^{abc}	95.86 ^{a}	41.75^{ab}	1520.39(1.47) ^{a}
P_5	GVI-64	25.40(4.76) ^{a}	13.65 ^{b}	6.78 ^{b}	301.0 ^{a}	10.96 ^{ab}	6.98 ^{abc}	83.63 ^{a}	39.76^{ab}	1615.57(1.51) ^{a}
P_6	GVI-68	30.00(5.13) ^{a}	14.05 ^{ab}	7.25 ^{ab}	327.2 ^{a}	10.82 ^{ab}	6.17 ^{abcd}	91.29 ^{a}	41.78^{ab}	1937.47(1.59) ^{a}
Series II										
P_7	M-13.12	32.40(5.46) ^{a}	12.46 ^{b}	8.38 ^{a}	332.9 ^{a}	12.28 ^{a}	4.75 ^{cd}	80.70 ^{a}	37.78^{ab}	1880.19(1.57) ^{a}
P_8	GI-15.5	21.00(4.43) ^{a}	12.76 ^{b}	6.59 ^{b}	246.9 ^{a}	8.70 ^{bcd}	6.06 ^{abcd}	83.71 ^{a}	40.11^{ab}	790.03(1.26) ^{a}

* Figures in parentheses are transformed √x values

** Figures in parentheses are transformed log x values

In a column, means followed by a common letter are not significantly different at 5 per cent level by DMRT.

The results of analysis of simple correlation coefficients of different pod parameters with *H. theivora* damage intensity at different stages of growth of pods and with the damage intensity on flushes are presented in Table 5.

4.1.2.1 Number of pods

Even though the number of pods per tree in different clones ranged between 10.20 in the hybrid GI-10.3 x GVI-61 to 32.40 in the parent M-13.12 and 30.00 in GVI-68, no significant difference was observed in the case of total number of pods produced in a year (Table 4). Among the parents, GVI-61, GVI-64, GVI-68, M-13.12 and GI-15.5 yielded more than twenty pods per plant the highest production being in M-13.12. Among the hybrids studied, GI-5.9 x GVI-54 and GI-5.9 x GVI-68 recorded more than twenty pods.

Significant positive correlations were detected between the number of cocoa pods on the one hand and the infestation intensity at all the three pod stages namely, young, medium and ripening. The correlations between the number of pods and the overall mean intensity of damage on pods and flushes were however, positive and highly significant (Table 5).

It is evident from Fig.2 and 3 that the clone M-13.12 which recorded the highest number of pods showed higher damage intensity on pods (3.34%) and flushes (5.58%). Similar trends in damage levels were also observed in the case of other clones except GI-10.3 x GVI-61 which recorded lowest number of pods but higher damage intensity. In the case of GI-5.9 x GVI-68, the pod number was comparatively higher but the damage intensities on pods and flushes were lower.

Table 5. Simple correlation coefficients of different pod characters with *H. theivora* damage intensity at different stages of growth of pods/damage intensity on flushes

Damage intensity on	Simple correlation coefficients (r)							
	No. of pods	Length of pod	Girth of pod	Pod weight	Thickness of pericarp at ridge	Thickness of pericarp at furrow	Wet bean weight	No. of beans per pod
Young stage pods	0.280*	0.054 ^{NS}	-0.087 ^{NS}	0.005 ^{NS}	0.046 ^{NS}	0.003 ^{NS}	-0.020 ^{NS}	0.041 ^{NS}
Medium growth stage pods	0.269*	-0.003 ^{NS}	0.002 ^{NS}	-0.154 ^{NS}	-0.047 ^{NS}	0.019 ^{NS}	-0.183 ^{NS}	0.038 ^{NS}
Ripening stage pods	0.229*	0.077 ^{NS}	-0.082 ^{NS}	-0.014 ^{NS}	-0.038 ^{NS}	-0.081 ^{NS}	-0.054 ^{NS}	0.146 ^{NS}
Overall growth period of pods	0.337**	0.027 ^{NS}	-0.023 ^{NS}	-0.098 ^{NS}	-0.004 ^{NS}	0.060 ^{NS}	0.153 ^{NS}	0.073 ^{NS}
Flushes	0.403**	0.090 ^{NS}	0.084 ^{NS}	-0.051 ^{NS}	-0.033 ^{NS}	0.014 ^{NS}	0.040 ^{NS}	0.059 ^{NS}

NS - Not significant by F test
* Significant at 5 per cent level
** Significant at 1 per cent level

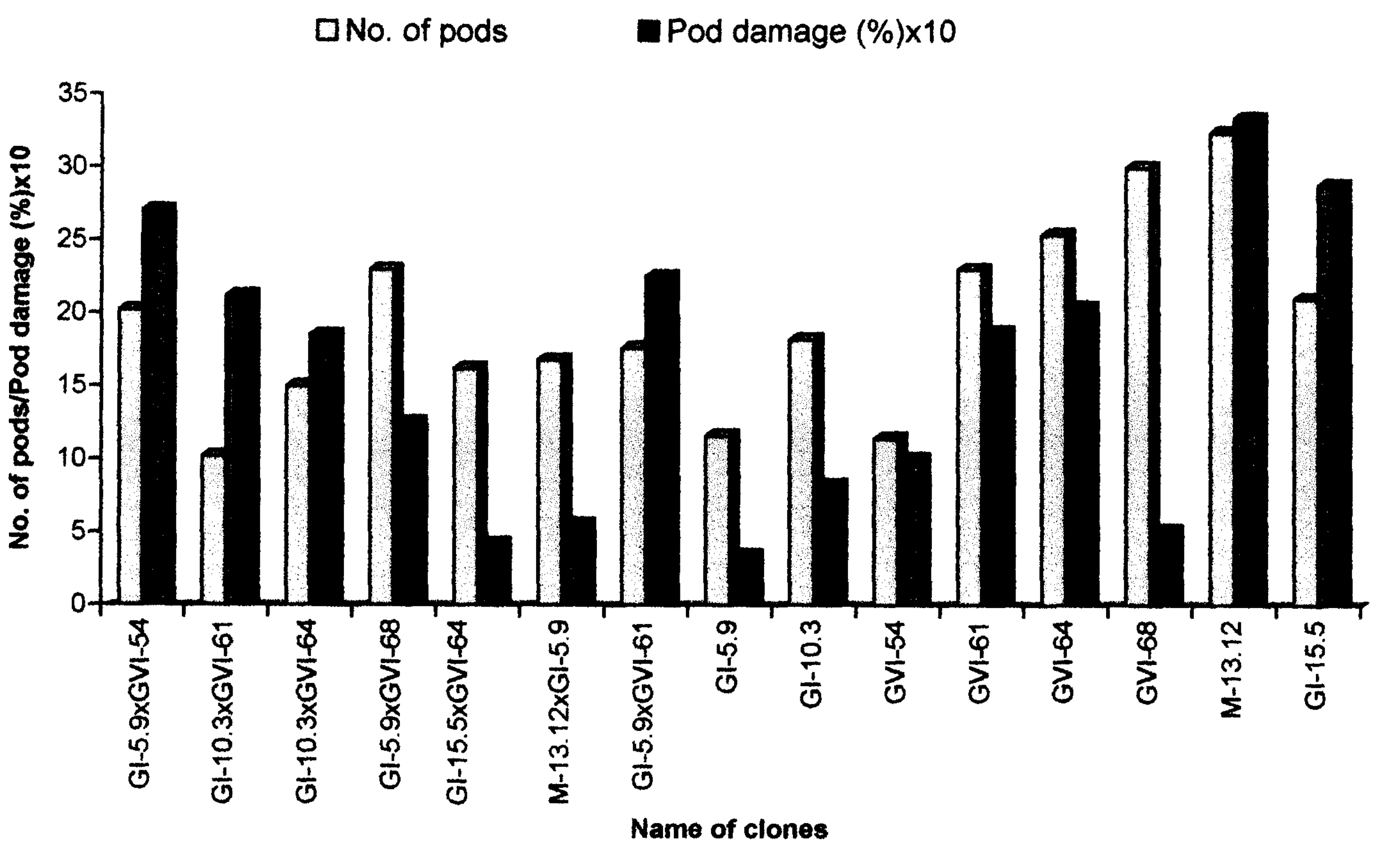

Fig. 2. No. of pods on cocoa clones and per cent damage intensity by *H. theivora* on cocoa pods

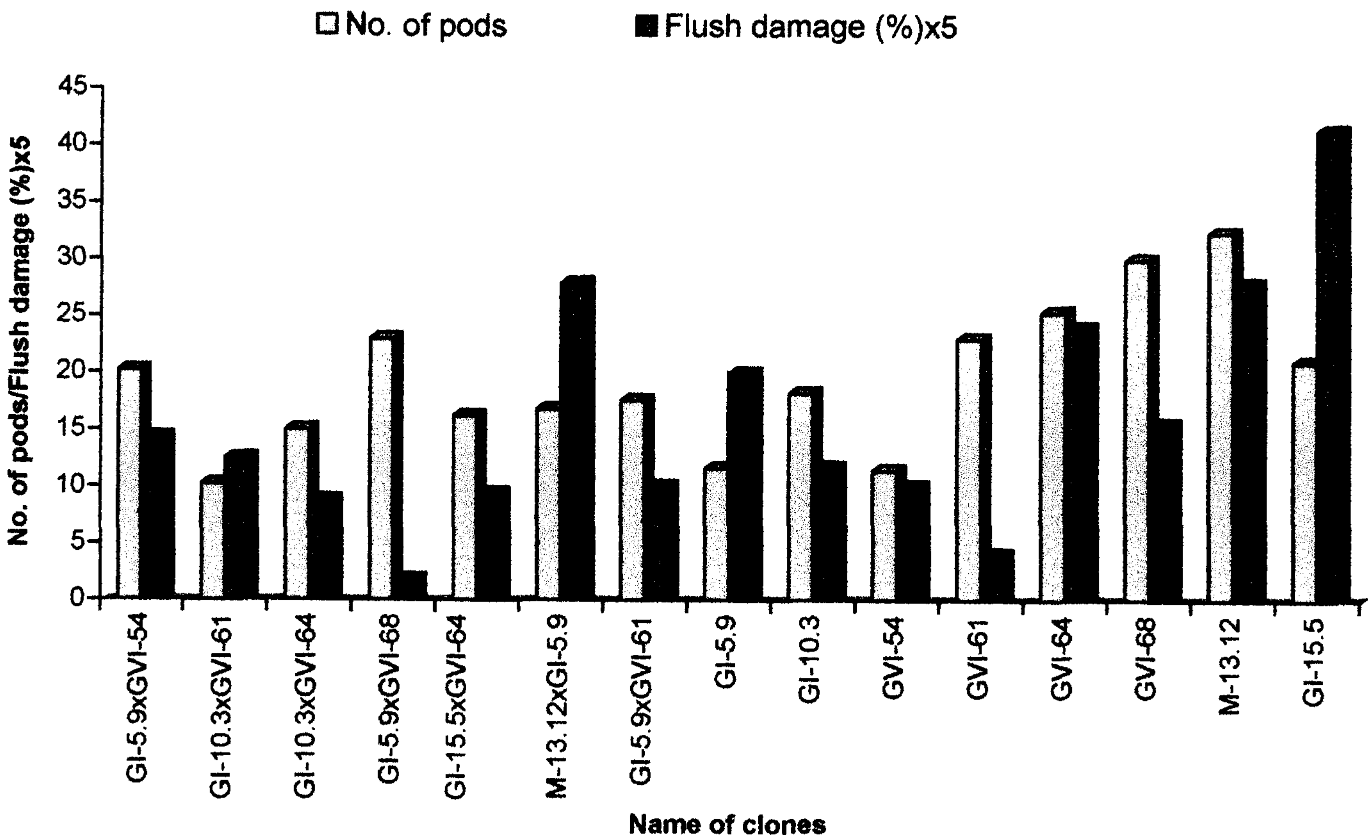

Fig.3. No. of pods on cocoa clones and per cent damage intensity by *H. theivora* on cocoa flushes

4.1.2.2 Length of pod

Pod length of the different clones evaluated was found to differ significantly on analysis of the data (Table 4). Highest pod length was observed in the parent clone GVI-61 (15.89 cm), closely followed by GVI-68 (14.05 cm) and these two parental clones were on par. All the other clones studied yielded pods with significantly lower length when compared to the clone GVI-61. Pods with lowest length were obtained from the parental clone GI-5.9 (12.23 cm). Even though the clones GVI-68 was on par with GVI-61 it showed parity with other clones which recorded pods of lower length.

The simple correlation coefficients involving length of pod and damage intensities at different stages of growth of pods and on flushes showed that length of pods did not influence the intensity of damage by *H. theivora* (Table 5).

4.1.2.3 Width of pod

The data relating to the width of pod are presented in Table 4. There was significant difference between the clones in respect of the width of pod. The mean values ranged from 6.59 cm for the parent clone GI-15.5 to 8.38 cm for M-13.12. The parent clone M-13.12 which recorded maximum pod width was significantly superior to the hybrids, GI-10.3 x GVI-64 and GI-5.9 x GVI-61 and the parents GI-15.5, GVI-61 and GVI-64. However, the parent GI-15.5 with the lowest width (6.59 cm) was found to be on par with all the other clones except the parent M-13.12.

The results of analysis of simple correlation presented in Table 5 showed that there was no correlation between the width of pod and the intensity of damage to pods as well as flushes.

4.1.2.4 Pod weight

The data on pod weight are furnished in Table 4. Even though the parents and hybrids did not differ significantly, the parents in general showed higher pod weights. The pod weight in different clones ranged from 226.2 g in the hybrid GI-5.9 x GVI-61 to 332.9 g in the parent clone M-13.12. The clone M-13.12 was closely followed by GVI-68 (327.2 g), GVI-54 (305.1 g), GVI-64 (301.0 g) and GVI-61 (295.7 g), all of them parents.

The simple correlation studies of the pod weight with the damage intensity on pods and flushes showed that the pod weight did not influence the damage intensities (Table 5).

4.1.2.5 Thickness of pericarp

The thickness of pericarp at ridge as well as furrow differed significantly between the clones (Table 4). The highest thickness of pericarp at ridge was noticed in the parent clones M-13.12 (12.28 mm) followed by GI-10.3 (12.03 mm) and these clones were on par with the hybrids GI-5.9 x GVI-54 and GI-5.9 x GVI-68 and also the parents GI-10.3, GVI-54, GVI-61, GVI-64 and GVI-68. The hyrbid GI-5.9 x GVI-61 recorded the lowest thickness of pericarp at ridge (8.15 mm) which was on par with all the other hybrids except GI-5.9 x GVI-54 and the parents GI-10.3, GVI-64, GVI-68 and M-13.12.

In the case of thickness at furrow, the hybrid GI-5.9 x GVI-61 recorded the lowest value of 4.28 mm whereas the value for GI-10.3 was 8.42 mm which was the highest and these two clones differed significantly. The parent GI-10.3 was found to be on par with the hybrids except GI-5.9 x GVI-54, GI-10.3 x GVI-64, GI-15.5 x GVI-64 and GI-5.9 x GVI-61 and all the parents except M-13.12. The clone with the lowest value, GI-5.9 x GVI-61 was also found to be on par with all the clones other than GI-10.3, GI-10.3 x GVI-61 and GVI-64.

The role of thickness of pericarp of the pods at ridge and furrow on the damage intensity of *H. theivora* on pods at different growth stages and on flushes were assessed through simple correlation coefficients and are presented in Table 5. From the results of simple correlation furnished, it was seen that the thickness of the pericarp at the pod ridge and the furrow did not regulate the damage intensity on pods and flushes.

4.1.2.6 Wet bean weight

With regard to wet bean weight, the clones did not differ significantly (Table 4). The mean values ranged from 73.94 g in GI-10.3 x GVI-64 to 95.86 g in GVI-61.

On estimating the simple correlation coefficients of wet bean weight with the damage intensity of *H. theivora* on the pods and flushes no significant direct correlation was identified (Table 5).

4.1.2.7 Number of beans per pod

Significant difference was observed between the clones in the case of number of beans per pod. The maximum number of 44.42 was found to occur in the cross GI-5.9 x GVI-68 followed closely by the parent clone GI-5.9. These two clones were on par with all the other clones except GVI-54 which recorded 32.94 beans per pod (Table 4).

From the correlation coefficients it could be seen that there was no significant influence of number of beans per pod on damage intensity by *H. theivora* either on pods or flushes (Table 5).

4.1.2.8 Total wet bean weight

On the basis of total wet bean weight yielded from a tree, even though there existed wide variations between different clones, the analysis of the data did not show statistical significance (Table 4). Highest bean weight per tree was from the parent clone GVI-68 which recorded 1937.47 g per tree and was followed by the parental clones M-13.12 (1880.19 g), GVI-64 (1615.57 g) and GVI-61 (1520.39 g). None of the hybrids recorded comparable bean yield as that of the above parental clones. Among the hybrids studied highest bean yield was obtained from the cross M-13.12 x GI-5.9 (1275.45 g) closely followed by GI-5.9 x GVI-68 (1263.98 g). In both these hybrids, one of the parents was found to be a high yieder as far as the total wet bean weight yielded from a tree is concerned. The other clones recorded only very low bean yields. The lowest yields were obtained from GI-10.3 x GVI-61 (421.64 g) follwed by GI-5.9 x GVI-54 (481.80 g). The correlation between bean yield and pod number was highly significant and positive (0.869). The clones such as M-13.12, GVI-68, GVI-64 and GVI-61 which registered higher number of pods yielded higher wet bean weight also (Fig.4). Only very low bean yields were obtained from GI-10.3 x GVI-61 and GI-5.9 and these clones showed lower number of pods.

4.1.3 Role of canopy architecture of different clones on *H. theivora* infestation

The data relating to the canopy architecture of the trees such as height and spread of the different clones were studied and the results are presented in Table 6.

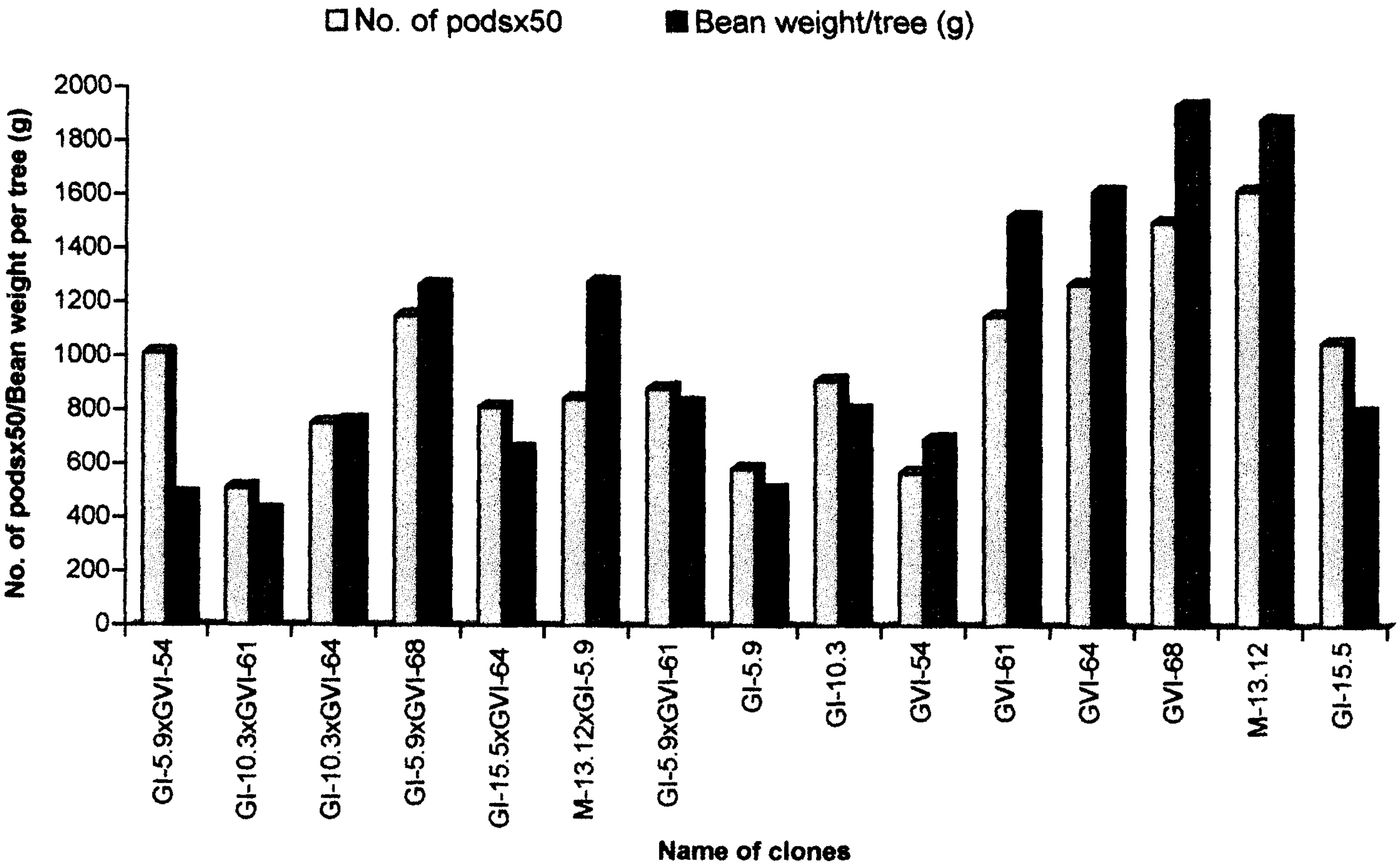

Fig.4. No. of pods on cocoa clones and corresponding wet bean weight

Table 6. Means of different traits of canopy architecture of different cocoa clones

Clone No.	Cross/parent	Traits of canopy architecture*	
		Height of tree (cm)	Spread of tree (cm)
Series I			
H_1	GI-5.9 x GVI-54	442^{abcd}	226^{f}
H_2	GI-10.3 x GVI-61	388^{bcd}	288^{def}
H_3	GI-10.3 x GVI-64	526^{abc}	466^{abcd}
H_4	GI-5.9 x GVI-68	558^{a}	579^{ab}
Series II			
H_5	GI-15.5 x GVI-64	456^{abcd}	315^{cdef}
H_6	M-13.12 x GI-5.9	474^{abc}	415^{abcde}
H_7	GI-5.9 x GVI-61	547^{ab}	488^{abc}
Series I			
P_1	GI-5.9	313^{d}	397^{bcde}
P_2	GI-10.3	397^{bcd}	429^{abcde}
P_3	GVI-54	395^{bcd}	203^{f}
P_4	GVI-61	377^{cd}	474^{abc}
P_5	GVI-64	465^{abcd}	409^{abcde}
P_6	GVI-68	491^{abc}	589^{a}
Series II			
P_7	M-13.12	586^{a}	513^{ab}
P_8	GI-15.5	436^{abcd}	427^{abcde}

* In a column, means followed by a common letter are not significantly different at 5 per cent level by DMRT.

The results of simple correlation analysis of height and spread of trees with intensity of damage on pods at different stages of growth and on the damage intensity on flushes are presented in Table 7.

4.1.3.1 Height of tree

The maximum height of 586 cm was recorded in the parent clone M-13.12 followed by the cross GVI-5.9 x GVI-68 in which the height was 558 cm. These two clones differed significantly from the hybrid GI-10.3 x GVI-61 and the parental clones such as GI-5.9, GI-10.3, GVI-54 and GVI-61 in tree height. The parental clone GI-5.9 recorded the lowest height of 313 cm (Table 6).

From the correlation coefficients it could be seen that no correlation exists between the height of the tree and damage intensity of *H. theivora* on pods and flushes (Table 7).

However, the correlation between height of tree and number of pods was positive and significant (0.234). The clones such as M-13.12, GVI-68 and GVI-64 with higher number of pods were found to be taller the clones GI-10.3 x GVI-61 and GI-5.9 which had lower number of pods were shorter (Fig.5).

4.1.3.2 Spread of tree

With reference to the spread of canopy of the different clones evaluated, there existed wide variations. The spread of the canopy ranged from 203 cm in GVI-54 to 589 cm in GVI-68 and recorded significant difference between each other. The clones with the maximum spread GVI-68 was also significantly different from the hybrids GI-5.9 x GVI-54, GI-10.3 x GVI-61 and GI-15.5 x GVI-64 and also the parent GI-5.9 and GVI-54. Similarly, the clone with the lowest spread

Table 7. Simple correlation coefficients of traits of canopy architecture with *H. theivora* damage intensity at different stages of growth of pods/damage intensity on flushes

Damage intensity on	Simple correlation coefficients (γ)	
	Height of tree	Spread of tree
Young stage pods	0.005^{NS}	-0.055^{NS}
Medium growth stage pods	0.022^{NS}	-0.078^{NS}
Ripening stage pods	0.170^{NS}	-0.070^{NS}
Overall growth period of pods	0.079^{NS}	-0.024^{NS}
Flushes	-0.142^{NS}	0.006^{NS}

NS - Not significant at 5 per cent level by F test

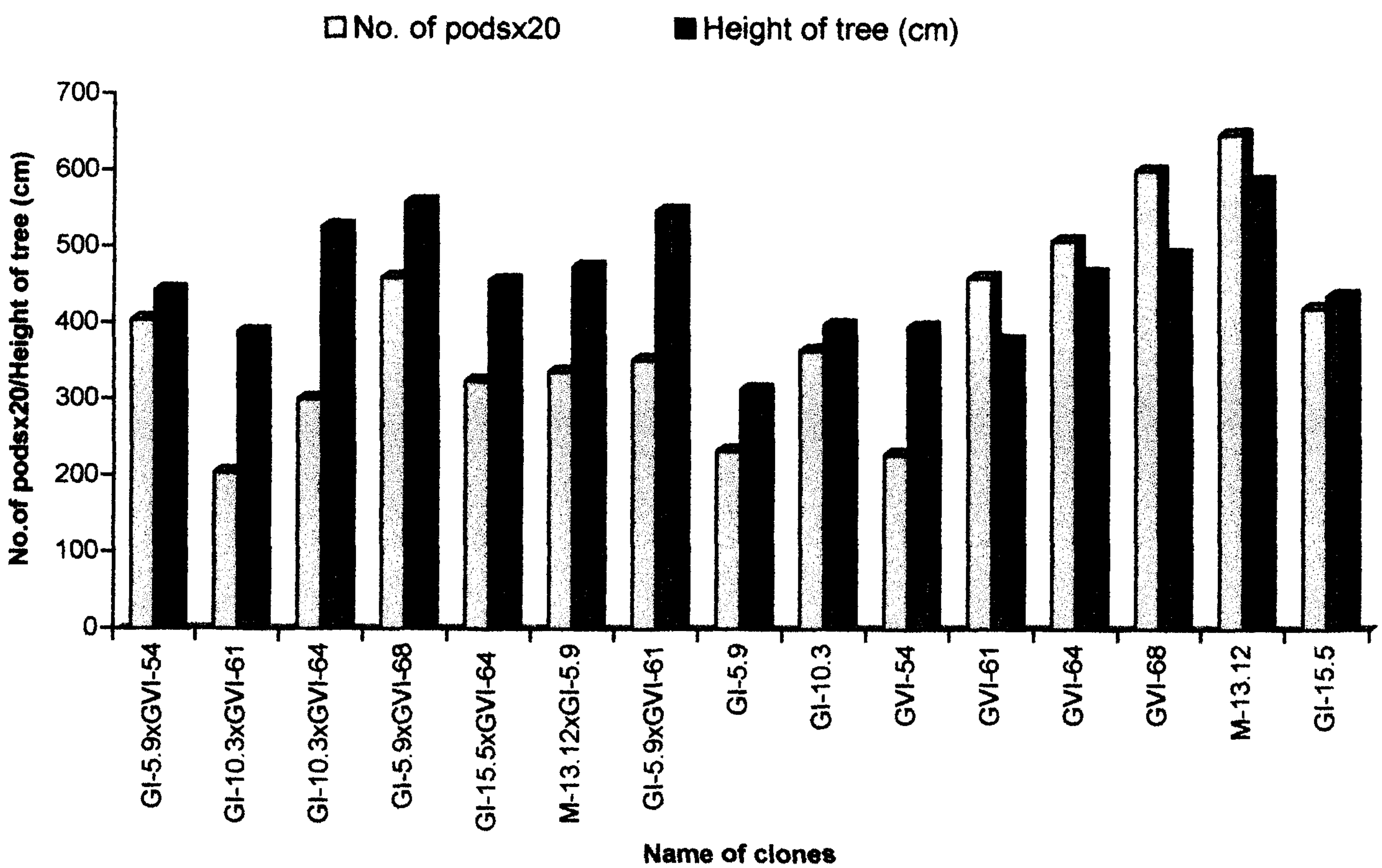

Fig.5. No. of pods on cocoa clones and corresponding height

GVI-54 was on par with the clones which showed significant difference with GVI-68 except GI-5.9 (Table 6).

From the correlation coefficients it could be seen that the canopy spread of the tree has no direct influence on the damage intensity on pods and flushes (Table 7).

But its influence on the number of pods is evidenced through the correlation coefficient (0.371) between these characters. It is seen from Fig.6 that the clones GVI-68, GI-5.9 x GVI-68, M-13.12 and GVI-61 which showed higher canopy spread produced more number of pods and GVI-54 and GI-10.3 x GVI-61 with lesser canopy spread recorded only lower number of pods.

4.2 Evaluation of toxic stimulus of chemical and non chemical insecticides to *H. theivora*

The experiment was undertaken at the College of Horticulture, Vellanikkara as described in the Materials and Methods. The data on the results of statistical analysis are presented in Table 8.

There was significant difference between the treatments. The mortality ranged from 28 per cent in the treatment with pongamia oil emulsion at 1.0 per cent to 96 per cent in the treatment with carbaryl at 1.25 kg ai/ha. All the treatments were superior to untreated control in their efficacy against the third instar nymphs of *H. theivora*. Carbaryl was found to be on par with monocrotophos applied at 0.5 kg ai/ha which gave 84 per cent mortality. Endosulfan at 0.5 kg ai/ha, monocrotophos at 0.5 kg ai/ha and alphamethrin at 0.1 kg ai/ha were equal with regard to their effectiveness against *H. theivora*. Quinalphos at 0.25 kg ai/ha and ethofenprox at 0.75 kg ai/ha were comparatively lower in effectiveness.

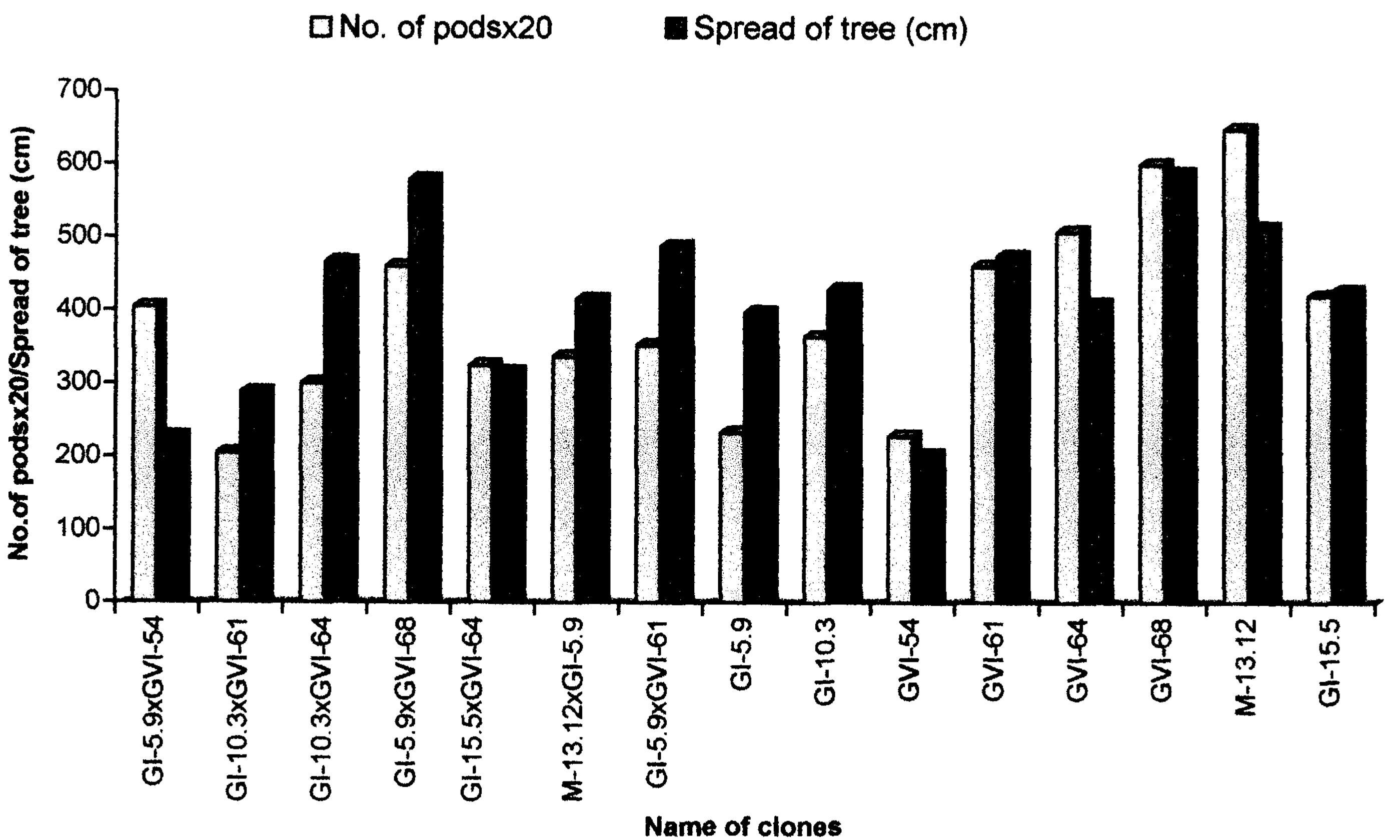

Fig.6. No. of pods on cocoa clones and corresponding spread

Table 8. Mean mortality of *H. theivora* nymphs treated with different insecticides

Sl.No.	Treatments	*Mean mortality (%)
1	Endosulfan 35 EC - 0.50 kg ai/ha	64 (53.13) [bc]
2	Carbaryl 50 WP - 1.25 kg ai/ha	96 (78.46) [a]
3	Monocrotophos 36 EC - 0.50 kg ai/ha	84 (66.42) [ab]
4	Quinalphos 20 AF - 0.25 kg ai/ha	52 (46.15) [c]
5	Alphamethrin 10 EC - 0.10 kg ai/ha	68 (55.55) [bc]
6	Ethofenprox 10 EC - 0.75 kg ai/ha	60 (50.77) [c]
7	Pongamia oil - 1 per cent	28 (31.95) [d]
8	Untreated control	0 (0.00) [e]

* Figures in parentheses are transformed arc-sin values. In a column, means followed by a common letter are not significantly different at 5 per cent level by DMRT

5. DISCUSSION

The field studies were aimed to ascertain the infestation reactions of the cocoa mirid *Helopeltis theivora* (Waterhouse) in seven hybrids and eight parental clones of cocoa with a view to identify sources of resistance/moderate resistance in hybrids/parents. The direct influence if any of different pod characters and canopy spread on the infestation levels of the mirids at different stages of pod development as well as on the flushes had been quantified. The contact toxicity of different synthetic insecticides and an insecticide of plant origin at field recommended doses was tested in the laboratory to identify a promising candidate for inclusion in the IPM of *H. theivora*.

The results generated in the various experiments are discussed hereunder.

5.1 Field studies on the infestation reactions of *H. theivora* (Waterhouse) in cocoa clones and the role of clonal traits on infestation

5.1.1 Infestation of *H. theivora* in cocoa clones

5.1.1.1 On pods at different stages of growth

The results of mean percentage damage intensity at different stages of growth of the pods are presented in section 4.1.1.1 and Table 2. The results in general have shown that the damage intensities in different clones showed no variations. The overall mean of the damage intensity during the entire period of growth of the pods also did not vary between the clones. It will be seen that the infestation rating in all the growth stages is very low, the range being 0.25 to 5.84 only. This low level of infestation is a result of the low field populations of the pest.

It is quite probable that under such a relaxed biotic pressure, the relative susceptibility differentials are not fully expressed. The requirement of a certain minimum intensity of insect damage in the rice crop for screening of varieties against insect pests has been brought out by IRRI in 1980. In the present case also it is probable that the minimum intensity levels have not been reached. The present study however, clearly shows that none of the entries under testing had absolute resistance.

However, the lower level of overall intensity of damage on pods recorded in the parents, GI-5.9 (0.34 per cent) and GVI-68 (0.51 per cent) and the hybrids such as GI-15.5 x GVI-64, M-13.12 x GI-5.9 and GI-5.9 x GVI-68 shows that moderate level of resistance exists in the cocoa clones.

The highly heterogenous nature of cocoa plants is an established fact (Keshavachandran, 1979). In such cases, data collected from more number of plants may result in a heterogenous data.

Decazy and Lolode (1975) have reported clonal differences in the susceptibility of cocoa clones. Such differences in the susceptibility of Trinitario cocoa clones have also been reported by Smith and Moles (1982). Intra clonal variation in cashew in respect of *H. antonii* infestation has been reported by Fennah (1963) and Pillai *et al.* (1979), respectively.

5.1.1.2 Damage on vegetative flushes

In terms of mean per cent damage intensity rating on flushes (section 4.1.1.2) it was found that the lowest damage was in the hybrid GI-5.9 x GVI-68 (0.36 per cent) and highest intensity on the parent GI-15.5 (8.29 per cent) but such variations were not significant. On comparison of the parents and hybrids in terms of their susceptibility, it will be seen that the higher susceptibility of the parent M-13.12 (5.58 per cent) is reflected in the hybrid M-13.12 x GI-5.9 also. The relative susceptibility of flushes of this clone is thus brought to light. The parental clone GI-15.5 could also be rated as susceptible in view of the damage intensity level (Table 3). These two parental clones namely M-13.12 and GI-15.5 have also shown a higher level of damage to the pods. The correlation of damage intensity on pods with that on the flushes was highly significant and positive (0.56). Since the pods are more preferred by the bugs, they initially colonise on the pods and then move on to the flushes. Literature on clonal variations in the susceptibility of cocoa clones with regard to infestation by *H. theivora* on flushes is lacking. Ambika *et al.* (1979) showed in screening trials with 11 accessions of cashew that accession number 665 was more tolerant with respect to panicle and shoot damage whereas K-10-2-1232 and K-10-2-1218 were most suceptible to *H. antonii*. In another study by Sundararaju and John (1993) on soft wood grafts of cashew with tender flushes, the accession numbers G-11/6 and VTH-153/1 were observed to be moderately susceptible to mirid damage. It was based on the leaf midrib damage. These findings which elucidate the differences in the susceptibility spectrum of cashew accessions to mirid infestation on shoot/leaf midrib are in tune with the present findings on flush damage in cocoa.

5.1.2 Influence of biophysical characters of pods on *H. theivora* infestation

5.1.2.1 Number of pods

The results presented in the section 4.1.2.1 shows that there is no significant difference between the clones in respect of the number of pods, even though wide variations in pod numbers were exhibited between the clones. The number of pods ranged from 10.20 in GI-10.3 x GVI-61 to 32.40 in the parent M-13.12. The cocoa clones namely M-13.12, GVI-68, GVI-64, GVI-61, GI-5.9 x GVI-68, GI-15.5 and GI-5.9 x GVI-54 yielded more number of pods. Correlation studies have clearly established the strong positive correlation between the number of pods and the damage intensity on pods and flushes (Table 5). Awang *et al.* (1988) has reported that *H. theivora* prefers to feed on cocoa pods in preference to flushes. The significantly higher susceptibility of clones with more number of pods is quite expected in the above context. The susceptibility of high pod yielding clones to both pod and flush damage is explicable on the basis of intital preference to plants with more number of pods and due to easy dispersal to the vegetative flushes in such trees after exhausting the pods for feeding. Tan (1974) observed that mirid numbers increased with pod numbers even though no definite relationship could be established by him. This finding was supported by Decazy and Lolode (1975) and found that cocoa hybrids with more number of pods were attractive to the mirid bugs. In the present studies, the parent tree M-13.12 which recorded the highest number of pods showed comparatively higher damage by *H. theivora*, the percentage intensity being 3.34. These results corroborate with the above findings.

5.1.2.2 Length of pod

The length of pods in different clones showed significant variations. The parent clone GVI-61 with 15.89 cm length was different from all the other clones except GVI-68 which had pods of average length 14.05 cm (section 4.1.2.2). With regard to the effect of length of pod on damage intensity by *H. theivora* on pods and also flushes, assessed through simple correlation analysis it is seen that the length of pod in no way influenced the damage by mirids at any of the growth stages of the pods and on the flushes (Table 5). The length of pods influences the total surface area of the pods which is the major feeding site of the mirids. But the feeding puntures by more number of the bugs on a particular pod would certainly reduce the acceptability of the pods by the bugs in a shorter time. To avoid the scarcity of food materials through this phenomenon, the insects would always prefer to be spatially distributed on the plants. Such a distribution has been exhibited by *H. theivora* in the present study. Hence the spatial distribution to increase the food availability for longer periods is attributed to the non-correlation of pod length with intensity of damage. The present results are in conformity with the findings of Ojo (1985) that there was no significant difference between damage levels with regard to pod length. But in the studies by Mishra *et al.* (1988) it was observed that the long fruited Katrain-4 variety of brinjal had a lower percentage of fruit damage than the round fruited varieties suggesting that length and other characters such as thick fruit skin are the possible causes of resistance to *Leucinodes orbonalis*.

5.1.2.3 Width of pod

The results presented in section 4.1.2.3 shows wide variations between the clones with regard to width of pods. The highest width was noticed in the parent clone, M-13.12 (8.38 cm) while the lowest was also in another parent GI-15.5 (6.59 cm).

The clonal differences in the width of pod were not reflected in the intensity of damage by mirids on cocoa as revealed through correlation studies (Table 5). The length of pods and their width taken together will indicate their overall size and surface area. Since these two factors were not found to influence the intensity of infestation, it could be summarised that pod size does not influence the level of infestation by *H. theivora*. It has already been established that the number of pods per plant is a very crucial factor governing the level of infestation (Section 5.1.2.1). Similar results were obtained by Ojo (1985) in earlier studies on cocoa. In his studies no correlation was seen between the damage intensity and width of pods.

5.1.2.4 Pod weight

The results on pod weight presented in the section 4.1.2.4 indicated no significant difference between the clones. Fruit weight is contributed mostly by the length and width of the pods. Thus higher width of pod recorded in the parent clone M-13.12 is reflected in its higher pod weight (332.9 g). In the other clones such as GVI-68, GVI-54, GVI-64 and GVI-61 which showed higher pod weights had either higher width or length for the pods or both. The other clones recorded lower pod weights. Differences in fruit weight in different varieties of crops have been recorded by different workers. Sivasubramanian *et al.* (1991) found that cotton varieties resistant to *Amrasca devastans* had higher weight of bolls.

With regard to the influence of pod weight on the intensity of damage it is found that no correlation exists between these factors. The fruit size variations have not been recorded to influence damage levels of fruit feeding insects. Such influences cannot however be ruled out, but in the cocoa plants such influences are lacking.

5.1.2.5 Thickness of pericarp

In respect of the thickness of pericarp at ridge and furrow significant clonal variations have been detected (section 4.1.2.5). A higher thickness of the pericarp at ridge as well as at the furrow was noticed in the parental clone GI-10.3, the thickness being 12.03 and 8.42 mm, respectively. Similarly the lowest thickness was in the hybrid GI-5.9 x GVI-61 with 8.15 and 4.28 mm at ridge and furrow, respectively. The correlation studies involving the thickness of pericarp at ridge and furrow on the one hand and the intensity of damage on pods and flushes inflicted by *H. theivora* did not reveal any significant correlations (Table 5). This may be due to the low infestation levels recorded in the clones. However, it would be seen that in the clone GI-10.3 which recorded a higher thickness of pericarp at furrow and ridge showed only a low level of damage intensity by *H. theivora*, especially during the medium and ripening stages of pods. Similarly the hybrid GI-5.9 x GVI-61 which showed the lowest thickness at ridge and furrow recorded a higher degree of damage intensity during the ripening stage of the pods and the entire growth period of the pod calculated as the mean damage intensity of different growth stages of the pod. These trends throw light to the fact that the intensity of damage by the mirid bug *H. theivora* can be regulated by the thickness of pericarp at ridge and furrow. No work in this line on cocoa has been reported in literature and hence similar works in other crops are cited in support of the present finding. Khaemba (1985) associated the thickness of pod walls of cowpea as a factor of resistance to the pod bug *Riptortus dentipens*.

5.1.2.6 Wet bean weight

The wet bean weight in different clones did not show any variations (section 4.1.2.6 and Table 4). The correlation of wet bean weight with damage intensity on pods and flushes was also not significant. Tan (1974) reported significant reduction in dry bean weight as a result of damage by mirids on cocoa. Ojo (1985) reported high degree of negative correlation with intensity of damage and wet bean weight. These results are quite expected since bean weight is influenced by damage intensity. But that bean weight cannot influence the extent of damage is brought out in the present studies. As *H. theivora* feeds on the pod surfaces only, the bean characters cannot be directly expected to influence the extent of damage.

5.1.2.7 Number of beans per pod

The results of the data on the number of beans per pod presented in the section 4.1.2.7 was found to be significantly different between the clones. The highest number of beans per pod was in the hybrid GI-5.9 x GVI-68 followed by the parent GI-5.9. These clones were on par with all other clones except the parent GVI-54. When the correlation between the damage intensity on pods and flushes with the number of beans per pod was estimated, no correlation was noticed. The role of number of beans per pod on damage intensity or the influence of damage intensity on the number of beans per pod can not be normally expected since the insect is restricted to the pod surfaces. However, significant difference between damage levels with regard to total number of beans per pod has been reported by Ojo (1985). This is explicable on the basis of the curtailment of bean development in pods which are heavily damaged by *H. theivora*.

5.1.2.8 Total wet bean weight

The total wet bean weight per tree in relation to each clone showed no significant variations (section 4.1.2.8). The parent clone GVI-68 recorded 1937.47 g per tree followed by the parental clones M-13.12, GVI-64 and GVI-61. All the hybrids recorded only lower yield of beans as compared to the above parental clones, even though not significant. Among the hybrids, the best yielders were M-13.12 x GI-5.9 and GI-5.9 x GVI-68. In these hybrids, one of the parents was a high yielder. Lowest yields of beans were obtained from the crosses GI-10.3 x GVI-61 and GI-5.9 x GVI-54.

On comparison of the clones with respect to their bean weight and *H. theivora* damage it could be seen that the parental clone GVI-68 which had a lowest intensity of 0.51 per cent had a total wet bean weight of 1937.47 g indicating that there is a possibility of its resistance to *H. theivora*. But, this is not the case of the clones M-13.12 which is also another high yielder of beans. It had the highest intensity of damage by mirids on pods (3.34%). In the hybrids M-13.12 x GI-5.9 and GI-5.9 x GVI-68 which recorded comparatively higher yields than the other hybrids, showed a lower level of damage by mirids on pods. On comparison of the low yielders, GI-10.3 x GVI-61 received a moderate level of pod damage but GI-5.9 x GVI-54 recorded a higher damage level among the clones studied. This is explicable on the basis of the highly significant and positive correlation (0.869) of yield of beans on the one hand and pod number on the other.

5.1.3 Role of canopy architecture of different clones on *H. theivora* infestation

5.1.3.1 Height of tree

With regard to the height of the tree, the parent clone M-13.12 recorded highest height of 586 cm followed by the hybrid GI-5.9 x GVI-68 with 558 cm and these were statistically on par (section 4.1.3.1). Most of the other clones were also on par with the above clones but statistical difference was revealed in the case of GI-5.9 with 313 cm height and GVI-61 with 377 cm. When the correlations of the height of tree with damage intensity on pods and flushes were worked out, no correlation could be established. However, the parent clone M-13.12 which showed maximum height recorded the highest mean intensity of damage during pod growth and the clone with lowest height GI-5.9 had the lowest damage intensity. This indicates a general trend of positive association with plant height and damage intensity. Taller trees can be expected to possess better canopy formation also and under such conditions the plants may provide congenial shady abodes for the insects. There existed a significant positive correlation (0.234) of height with pod number. The influence of pod number on damage intensity has already been discussed in section 5.1.2.1. The effects of plant height in cocoa on pest infestation levels have not been documented earlier. The decreased susceptibility of taller sorghum plants to the aphid *Melanaphis sacchari* has been reported (Mote and Shahane, 1994). Such variations can be naturally expected among different species of insects in the light of the visual cues adopted in the identification of preferred host plants.

5.1.3.2 Spread of tree

Though maximum spread of 589 cm was registered in the parent clone GVI-68 followed by the hybrid GI-5.9 x GVI-68 with 579 cm, they were on par with most of the clones except the parent clones GVI-54 (203 cm) and GI-5.9 (397 cm) and the hybrids GI-5.9 x GVI-54 (266 cm), GI-10.3 x GVI-61 (288 cm) and GI-15.5 x GVI-64 (315 cm) (section 4.1.3.2). The correlation of the lateral spread of tree with damage intensity on pods and flushes was not significant (Table 7). This result is in agreement with that of Thomas and Abraham (1981) who have observed no correlation between the canopy spread and infestation intensity of *H. antonii* on cashew. From the height and spread of the trees depicted in Table 6, it would be seen that in most of the clones with better spread, the tree height is also high and vice versa. In the section 5.1.3.1, it is established that the tree height has influence on damage intensity. A positive and highly significant correlation (0.371) has been established between spread of tree and pod number. Hence, it is concluded that though tree spread is not directly influencing the damage intensity, it certainly has an indirect effect on damage intensity by *H. theivora*.

5.2 Evaluation of toxic stimulus of chemical and non chemical insecticides to *H. theivora*

Significant differences were observed in the studies on the contact toxicity of different chemical and non-chemical insecticides (section 4.2). Treatment with carbaryl at 1.25 kg ai/ha gave highest mean mortality of 96 per cent and this was on par with monocrotophos applied at 0.5 kg ai/ha giving 84 per cent mortality. The monocrotophos treatment was also on par with alphamethrin at 0.1 kg ai/ha (68%) followed by endosulfan at 0.5 kg ai/ha. Pongamia oil emulsion spray at 1.0 per cent which recorded the lowest mortality (28%) among the treatments other than untreated control was on par with quinalphos applied at 0.25 kg ai/ha, ethofenprox at 0.75 kg ai/ha, endosulfan at 0.5 kg ai/ha and alphamethrin at 0.1 kg ai/ha.

The above results indicate the relatively high toxicity of carbaryl and monocrotophos against the mirid bug *H. theivora*. Nair and Abraham (1982) in a field trial evaluated the efficacy of nine EC formulations against *H. antonii* infesting cashew and they observed endosulfan 0.05 per cent, phosphamidon 0.03 per cent, carbaryl 0.15 per cent and quinalphos and monocrotophos at 0.05 per cent as effective. Spraying with endosulfan at 440 g ai/ha was found effective against *H. clavifer* in cocoa (Smith *et al.*, 1985). These findings are in consonance with the present studies also. The effectiveness of pongamia oil as seed coat treatments on *Callosobruchus chinensis* has been reported by Khaire *et al.* (1993). The effectiveness of pongamia oil against *H. theivora* was very much lower in comparison with carbaryl and monocrotophos. This shows that the oil of pongamia lacks strongly toxiphoric principles that can suppress *H. theivora*. The satisfactory control of *H. antonii* in cashew by pongamia oil emulsion might perhaps be due to antifeedant or repellant modes of action rather than direct and residual contact toxicity.

Summary

6. SUMMARY

Damage to cocoa is caused by the mirid *Helopeltis theivora* (Waterhouse). In India, the pest was originally reported from South India in 1967. It was also reported as a pest of cashew, tea and Indian long pepper in subsequent years. Recently, in the cocoa plantations of Cadbury-KAU Co-operative Cocoa Research Project implemented at the College of Horticulture, Vellanikkara, *H. theivora* infestation has been observed.

The adults and nymphs of *H. theivora* suck sap from the pods and flushes of cocoa causing black lesions on the surface.

Cocoa (*Theobroma cacao* L.) being one of the most important beverage crop of the world, the consumption of beans is estimated to be 20,000 tonnes by the year 2000. Steps are being taken in India to increase the area under cultivation of cocoa to step up production to meet the growing internal demands. As result of area expansion it is quite likely that *H. theivora* might assume the status of a major pest of cocoa in Kerala, since it is already a pest on different crops in the state. An effective and safer management strategy for the control of *H. theivora* infestations in cocoa has not been evolved so far. Therefore, a study has been taken up with the objectives of identifying high yielding cocoa clones possessing resistance to the pest and also to develop an effective and safer management strategy using insecticides. In order to achieve these objectives, field experiment was carried out in the cocoa plantation of Cadbury-KAU Co-operative Cocoa Research Project. Laboratory studies were also held at the College of Horticulture, Vellanikkara to assess the bioefficacy of insecticides.

The field experiment was conducted with a view to study the infestation reactions of *H. theivora* in different clones of cocoa and to evaluate the influence of clonal traits on pest infestation. Fifteen high yielding clones comprising of seven crosses and eight parent clones, planted in the years 1986 and 1987 as series-I and series-II, respectively formed the basis of this study. Observations on *H. theivora* damage intensities at young, medium growth and ripening stages of the pods and on the vegetative flushes were recorded for a period of one year using standard methods. The various characters of pods such as length of pod, width, weight, thickness of pericarp at ridge and furrow, wet bean weight, number of beans per pod and total wet bean weight per tree were determined besides the yield data. In order to ascertain the role of canopy size of the different clones on *H. theivora* infestation, the height as well as the spread of the trees were quantified.

Insectary studies to evaluate the bioefficacy of six synthetic insecticides and one non-synthetic insecticide at recommended rates/dosages were undertaken. The test insects for the study were originally collected from the plantation and reared in cages on tender cocoa shoots under confinement. The emerging adults were maintained in fresh cages with tender shoots at the rate of 10 adults in 1:1 male-female ratio for egg laying. The adults from these cages were transferred to other cages once in two days. One day old third instar nymphs were used as the test insect. Green pods of uniform size and medium growth were obtained from a single clone and the spray treatments were given using an atomiser. Only water was sprayed in untreated control. The insects were released at the rate of five per pod after drying the pods under an electric fan. Each treatment was replicated five times. The mortality at the end of 24 hours after treatment was recorded and percentage mortality was worked out.

All the data were statistically analysed using the M Stat-C package after appropriate transformations. Simple correlation coefficients were also determined to assess the nature of relationship between various characters.

The results of the experiments conducted in the present investigations are as follows. The pod damage intensity on the different clones ranged from 0.25 to 5.84 per cent in the different growth stages. Even though the damage intensity at different developmental stages of the pods and the overall mean intensity did not differ significantly, the parent plants, GI-5.9 and GVI-68 and the hybrids, GI-15.5 x GVI-64, M-13.12 x GI-5.9 and GI-5.9 x GVI-68 showed a moderate level of resistance to *H. theivora* infestation on pods.

In respect of the damage intensity on vegetative flushes, it is seen that the susceptibility in the clone, M-13.12 is reflected in the cross, M-13.12 x GI-5.9 indicating that these two clones along with the parent clone, GI-15.5 are susceptible to *H. theivora*. Since these parental clones namely M-13.12 and GI-15.5 have showed higher damage levels on pods also, these clones are liable to heavy damage. The correlation involving damage intensity on pods and flushes are highly positive and significant.

The clones, GVI-61, GVI-64, GVI-68, GI-15.5, M-13.12, GI-5.9 x GVI-68 and GI-5.9 x GVI-54 recorded higher number of pods. The clone M-13.12 with a higher number of pods showed higher damage by *H. theivora* on pods as well as on flushes whereas the cross GI-5.9 x GVI-68 having higher pod numbers showed lower damage intensity trends on both pods and flushes. The correlation studies have established a highly significant and positive influence among damage intensity and pod number.

Even though length of pod in the clone GVI-61 (15.89 cm) varied significantly except with GVI-68 (14.05 cm), it has no direct influence on the damage intensity on pods and flushes. The width of pod also showed variations between the clones but this difference was not reflected on damage intensity. Since length and width are the major factors contributing to the size of the pod, it is to be suspected that the size of pod and *H. theivora* damage intensity are not correlated. A higher width of pod in the clone M-13.12 is reflected in its higher pod weight (332.9 g). Similarly a higher width or length or both is found to contribute to the higher pod weight in the clones GVI-68, GVI-54, GVI-64 and GVI-61. The pod weight among the clones however did not show any significant variations and was not correlated with damage intensity.

The thickness of pericarp at ridge and furrow detected significant clonal variations, but were not correlated with the degree of damage on pods and flushes. However, the higher thickness of pericarp at ridge and furrow in the parental clone GI-10.3 resulted in a low level of damage intensity especially in the medium and ripening stages of pods and the hybrids with lower thickness of pericarp showed higher damage intensities on pods during ripening stage and in the overall mean intensities. This gives an indication of the possible influence of pericarp thickness on damage by *H. theivora*.

The wet bean weight and number of beans per pod were not correlated with damage intensity either on pods or flushes but the number of beans per pod varied significantly between the clones. The hybrid GI-5.9 x GVI-68 and the parent GI-5.9 recorded significantly higher number of beans than GVI-54. These two pod characters are not normally expected to directly influence the damage intensity on pods caused by *H. theivora* since the bugs feed on the pericarp of the pods.

In spite of wide variations in the yield of wet beans per tree, the clones did not show significant differences. However, comparatively higher yields of beans were recorded from GVI-68 (1937.47 g) followed by M-13.12, GVI-64 and GVI-61 among the parents and M-13.12 x GI-5.9 and GI-5.9 x GVI-68 from among the hybrids. The hybrids GI-10.3 x GVI-61 and GI-5.9 x GVI-54 showed the lowest yields. All these high yielding and low yielding clones behaved differently in their reaction to *Helopeltis* infestation. The parent clone M-13.12 which is a good yielder of beans showed higher damage levels on both pods and flushes. In contrast, the hybrid GI-5.9 x GVI-68 recorded a low damage intensity on pods and flushes. However, the strong positive correlation of number of pods with damage intensity on pods and flushes and the bean yield strongly suggests that the pod yield in cocoa is highly and positively correlated with damage intensity levels. This throws light to the fact that effective and safer management strategies will have to be followed to tackle the problem of *H. theivora* in high yielding cocoa clones. A truely tolerant variety could not be identified among the clones screened in the present studies, but the scope of such a variety in world germplasm materials cannot be ruled out.

With regard to the height of the trees significant differences were observed between clones but height did not show any direct correlation with damage intensity on pods and flushes. However, the clone M-13.12 with highest height (586 cm) showed a higher overall mean damage intensity while the clone GI-5.9 with lowest height had the lowest damage intensity. This gives a trend of positive correlation of plant height with damage intensity. This is substantiated by the positive correlation existing between the height of tree and pod number.

Spread of the tree was maximum (589 cm) in GVI-68 followed by GI-5.9 x GVI-68. The direct influence of spread of tree, worked out through the correlation coefficient was non-significant. The spread of the tree was found more or less in accordance with the height of the tree. Also a positive correlation was shown between spread of the tree. In this context, it has been established that tree spread has an indirect influence on damage intensity on pods and flushes of cocoa by the mirid bug, *H. theivora*.

In respect of the toxic stimulus of synthetic and non-synthetic insecticides, it has been established that carbaryl at 1.25 kg ai/ha and monocrotophos at

0.5 kg ai/ha are most effective as spray application. In terms of low residual toxicity carbaryl may be preferred over monocrotophos for field applications. The other insecticides proving effective, but to a lesser extent, were alphamethrin at 0.1 kg ai/ha and endosulfan at 0.5 kg ai/ha. Pongamia seed oil at one per cent level gave only a low contact efficacy on *H. theivora* nymphs of third instar stage.

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INFESTATION REACTIONS AND MANAGEMENT OF *Helopeltis theivora* (Waterhouse) (Miridae:Hemiptera) IN COCOA CLONES

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ABSTRACT OF A THESIS

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ABSTRACT

Investigations were carried out at the College of Horticulture, Vellanikkara to identify sources of resistance to the cocoa mirid bug *Helopeltis theivora* (Waterhouse) among the various high yielding cocoa clones and also to develop an effective and safer management strategy against the pest using insecticides. In the field trial, seven hybrids and eight parental clones were evaluated for their tolerance to the mirids at different developmental stages of the pods and on flushes. The pod damage intensity was moderate to low, the range being 0.25 to 5.84 per cent and in this situation the resistance traits could not be properly quantified. However, the parental trees GI-5.9 and GVI-68 and the hybrids involving these trees showed a moderate level of resistance. The clones M-13.12 and GI-15.5 were found to be relatively more susceptible to the pest. The correlation studies have established the positive correlation between the yield of pods on the one hand and the intensity of damage to the pods and the vegetative flushes on the other. The various pod characters such as length, width, weight, pericarp thickness, wet bean weight and number of beans per pod did not show any influence on the intensity of pod infestation.

The performance of the various clones in respect of the yield of pods and beans have been discussed in the light of variations in the intensity of damage to the pods and vegetative flushes.

The susceptibility of clones with higher number of pods was detected in the correlation studies. The hybrid GI-5.9 x GVI-68 which produced 23 pods per tree on an average showed lower levels of damage by the mirid bug on the pods and also on flushes indicating a moderate level of resistance coupled with high pod number in this clone. The pod number was also found correlated with total wet bean

yield per tree, height and spread of the tree. With respect to higher wet bean yield the parental clone GVI-68 ranked first with 1937.47 g followed by M-13.12, GVI-64, GVI-61, M-13.12 x GI-5.9 and GI-5.9 x GVI-68. The crosses GI-10.3 x GVI-61 and GI-5.9 x GVI-54 recorded very low bean yields. However, the high yielding and low yielding clones showed varied reactions to the infestation by *H. theivora*.

With regard to the management of *H. theivora* using insecticides the spray application of carbaryl at 1.25 kg ai/ha and monocrotophos at 0.5 kg ai/ha was most effective. However, considering the higher persistent toxicity of monocrotophos, carbaryl is recommended for field applications.