BIOLOGY AND MANAGEMENT OF SPIRALLING WHITEFLY, *Aleurodicus dispersus* (Russell) (Homoptera : Aleyrodidae)

Thesis submitted in part fulfilment of the requirements for the award of the degree of **Doctor of Philosophy** in **Agricultural Entomology** to the Tamil Nadu Agricultural University, Coimbatore.

By

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CERTIFICATE

This is to certify that the thesis entitled **"BIOLOGY AND MANAGEMENT OF SPIRALLING WHITEFLY, *Aleurodicus dispersus* (Russell) (Homoptera : Aleyrodidae)"** submitted in part fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURAL ENTOMOLOGY** to the Tamil Nadu Agricultural University, Coimbatore is a record of **bonafide** research work carried out by **Mrs. B. GEETHA** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazines.

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[B. GEETHA]

ABSTRACT

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BIOLOGY AND MANAGEMENT OF SPIRALLING WHITEFLY *Aleurodicus dispersus* (RUSSELL) (HOMOPTERA : ALEYRODIDAE)

By

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Spiralling whitefly, *Aleurodicus dispersus* (Russell) an exotic polyphagous pest introduced accidentally has established as a key pest on cassava, guava and other economic crops in India due to its rapid dispersal rate. Integrated management strategies are required to keep the pest under check. Studies were made on the distribution, host range, biology, damage potential, management and population dynamics of *A. dispersus* with special reference to cassava (*Manihot esculenta* Crantz.) and guava (*Psidium guajava* L.).

Spiralling whitefly occurrence was recorded all over Tamil Nadu except Udhagamandalam. Heavy incidence and damage intensity of *A. dispersus* was found in Coimbatore, Salem, Namakkal, Dharmapuri, Erode, Kanyakumari and Tuticorin. A wide host range of 128 crop plants belonging to 52 families was found with the high incidence of 99.83 per cent in Euphorbiaceae family. Twenty five weeds belonging to 12 families were also identified as alternate hosts for *A.dispersus* around cassava and guava fields in Coimbatore. The life cycle of *A. dispersus* varied with host plants. The total developmental period from egg to

nymphal stages and adult longevity varied between 22.50 to 29.66 and 13.30 to 21.70 days respectively on various host plants and *A. dispersus* had successfully completed its life cycle on *Carica papaya* fruit.

The per cent adult emergence and fecundity were highest on *Gossypium* spp. and *M. esculenta.* Regular pattern of wax egg spirals were more on all the host plants during the initial period of infestation, whereas the egg laying pattern was appeared in irregular manner at the later stage. All the stages of *A. dispersus* were found mostly on bottom leaves of young cassava plants. In grown up plants egg laying was more on top leaves whereas nymphs and adults were more on middle and bottom leaves respectively.

The yield reduction was 53.10 and 30.07 per cent in plots released with 250 and 50 *A. dispersus* adults respectively. The young shoots after pruning attracted more number of whitefly adults for feeding and oviposition in guava. Setting up of yellow sticky traps at crop canopy recorded more adult catches. Yellow and green coloured traps attracted more number of whiteflies. Bihourly light trap catches were very high at early morning hours (4 to 6 a.m.). Attractancy of yellow coloured light trap was higher than white, green and orange light traps.

Triazophos and phosalone had more ovicidal effect in both the field trials conducted which recorded 98.68 to 99.73 and 92.04 to 97.13 per cent respectively at 3 days after spraying. Neem products also had better ovicidal effect. Triazophos was most effective in mortality of early, late instar nymphal and adult stages. Malathion, neem products, phosalone were also effective in nymphal and adult mortality. Dish wash soap solution and FORS also caused mortality of early instar nymph to some extend. Egg and early instar nymph were more vulnerable to chemicals as they had poor wax coverage. Among the predators, *cybocephalid, Cybocephalus* sp., coccinellids *viz., Cryptolaemus montrouzieri* Mulst., *Axinoscymnus puttarudriahi* Kapur and Munshi and *Chilomenes* *sexmaculatus* (Fab.), chrysopids *viz.*, *Apertochrysa* sp, and *Mallada astur* (Banks) and a spider *Oxyopus* sp were more predominant species on *A. dispersus*. Predatory potential of *C. montrouzieri* and larvae of *M. astur* were high.

Occurrence of an aphelinid, solitary endoparasitoid, *Encarsia* sp near *meritoria* was found on nymphs of *A. dispersus* for the first time in Tamil Nadu. High parasitism was observed on guava in Coimbatore during December '99 to January 2000. Total developmental period of the parasitoid was recorded as 31 ± 8.0 days. A parasitic mite, *Leptus* sp (Erythraeidae) was found feeding on nymphs of *A. dispersus* on various hosts plants of *A. dispersus* around cassava field. Thirteen cassava accessions were found with low population and damage intensity by *A. dispersus*. The accessions *viz.*, CIAT 94, Nilgiris vella, CIAT 199, CIAT 200, CTCRI Chenguvallai Red, CTCRI Kalikallan and CTCRI H7 showed their relative resistance against *A. dispersus*. Among the guava varieties, Redflesh was less preferred. In cotton, *Gossypium arborium*, *G. thurberi*, Surabhi and Anjali had low population of *A. dispersus*. Population density of *A. dispersus* was high during May '99 on guava with the high per cent parasitism by *E.* sp nr *meritoria* during November '99 to January 2000. Parasitism had significant negative association with *A. dispersus* population. Whitefly population was high during August '98 to October '98 and again in May '99 to September '99 on cassava. Predator population increased with increasing population of *A. dispersus*. Maximum temperature and rainfall reduced the population of *A. dispersus*, whereas minimum temperature significantly increased the population of *A. dispersus*.

Biology and Management of spiralling whitefly, *Aleurodicus dispersus*

B. Geetha

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CHAPTER I

INTRODUCTION

Spiralling whitefly, *Aleurodicus dispersus* (Russell) (Aleyrodidae: Homoptera) is an introduced polyphagous pest of vegetables, fruit trees, ornamentals and shade trees. It is native of Caribbean islands and Central America (Russell, 1965). It was first noticed as a pest in Hawaii in 1978 (Kumashiro *et al.*, 1983) from where it spread to the Pacific islands, African continents and further west to Sri Lanka and the Maldive islands (Waterhouse and Norris, 1989). In India, it was first recorded in western ghats of Kerala, which might have been accidentally introduced from Maldives through free entry of propagation materials through ports without plant quarantine. In Kerala, this pest was first reported on cassava at Thiruvananthapuram during November 1993 to April 1994 (Palaniswami *et al.*, 1995). A steady spread of this pest from Kerala to near by States like Tamil Nadu and Karnataka was reported (Ranjith, 1998). A severe incidence of *A.dispersus* on guava was first noticed around Bangalore and Coimbatore in 1996 (Mani and Krishnamoorthy, 1996). During the past five years, the pest has established throughout Tamil Nadu due to rapid dispersal rate and emerged as a key pest on several crops like guava, cassava, cotton, chillies, tomato, brinjal, bhendi and papaya.

Adaxial surface of the affected leaves are covered with dense mass of spiralling whitefly adults and nymphs with waxy flocculent materials. Both nymphs and adults suck the sap from their host plants and severe infestation results in weakening of the plant growth, premature leaf fall and subsequently drying of the plant. Since the pest is of ubiquitous nature and covered with white waxy flocculent materials, management through chemicals were found to be impracticable and less effective. Hence biological control would be one prime area on which efforts can be made. Since it is a newly introduced pest, information on the biology and management of *A. dispersus* in India is very limited. More knowledge on its biology on various crops, distribution, damage, seasonal occurrence, natural enemies, chemical control are required to take up better control measures to manage this pest. Hence there is a need for detailed studies on this pest.

Keeping in view that *A. dispersus* has the potential to become a serious menace on plant species, this study was taken up with the following objectives.

1. To survey the occurrence of spiralling whitefly on various host plants and assess population build up in Tamil Nadu,

2. To study the bio-ecology and damage potential of the spiralling whitefly,

3. To survey native natural enemies complex,

4. To study the parasitization and predatory potential of promising biocontrol agents of spiralling whitefly and

5. To evaluate the efficacy of various pest management components for spiralling whitefly.

REVIEW OF LITERATURE

CHAPTER II
REVIEW OF LITERATURE

2.1. Origin and distribution

2.1.1. Distribution in the world

Spiralling whitefly, *Aleurodicus dispersus* (Russell) (Aleyrodidae : Homoptera) is an introduced polyphagous pest. It is native to the Caribbean region and Central America. It was reported to occur in North America, Central America, Caribbean islands, South America, Africa, Asia and several Pacific islands. In North America, it was first observed in 1957 in Southern Florida (Russell, 1965; Anonymous, 1985). Like most whiteflies, *A. dispersus* are of tropical and subtropical origin (Mound and Halsey, 1978). In the Caribbean and Central America, it was known from the Bahamas, Barbados, Costa Rica, Cuba, Dominica, Haiti, Martinique and Panama. In South America, it occurred in Brazil, Ecuador and Peru in late sixties. In Africa, it occurred in Canary islands, Nigeria, Tego, Benin, Ghana, Congo and Guinea, Bissau (Anonymous, 1993; M'Boob and Oers, 1994 and Manzano *et al.*, 1995). In West Africa, *A. dispersus* occurred only in villages and towns in human habitats in the Southern part of Benin in 1993. (D'Almeida *et al.*, 1998).

In Pacific islands, *A. dispersus* was first noticed as a pest under field conditions in Hawaii in 1978, from where it spread to other islands (Kumashiro *et al.*, 1983). It was found in Honolulu in 1978 and has spread throughout Oahu, and parts of Maui and Guam islands.

It was reported from American Samoa, Palau, Majuro, Pohnpei, Mariana island, Saipan, Western Samoa, Fiji, Nauru, Papua New Guinea, Kiribati, Tokelau, Tonga (Nechols, 1981; Lauofo and Iwamoto, 1982; Kumashiro *et al.*, 1983; Schreiner and Nafus, 1986). In Asia, it was first reported in Philippines in 1982

(Martin and Lucas, 1984), Taiwan (Wen *et al.*, 1994a), Malaysia (Waterhouse and Norris, 1989) and Sri Lanka (Chandrasekara, 1990).

2.1.2. Intrusion into India

In India, this pest was first reported in Kerala on cassava at the Central Tuber Crop Research Institute, Thiruvananthapuram during November 1993 to April 1994 (Palaniswami *et al.*, 1995). In March, 1994, this whitefly was noticed at Nedumangad (Thiruvananthapuram), heavily infesting wild cassava and wild rubber (David and Regu, 1995). As this pest had already established in the Maldives, Thiruvananthapuram is connected to the Maldives by flight and unrigid plant quarantine measures might be the reasons for the entry of this pest accidentally into Kerala through free entry of planting material through ports (Muniappan, 1993 and 1996). From Kerala, the pest might have entered to Kanyakumari district of Tamil Nadu. A severe incidence of *A. dispersus* on guava was first noticed by Mani and Krishnamoorthy (1996) around Bangalore and Coimbatore. The occurrence of this pest was noticed on more than 20 plant species including guava, cassava, wild thespesia and acalypha in and around Coimbatore in November 1996. The pest had spread throughout Kerala, parts of Tamil Nadu and Karnataka (Ranjith, 1998). The incidence was reported on more than 45 plant species belonging to 24 families including fruit trees, ornamentals and vegetables in Coimbatore and Bangalore in 1996 (Mani and Krishnamoorthy, 1999c).

2.2. Host range

Being highly polyphagous, *A. dispersus* has been recorded on many plant species in different countries. It was reported on 44 host plants in Florida, Central and South America and Caribbean islands (Russell, 1965), 27 plant families (Weems, 1971), 100 host plants in Hawaii (Nakahara, 1978), 60 plant species in Sarawak (Megir - Gumbek, 1987), 27 plant species in Kiribati (Waterhouse and

Norris, 1989), 22 plant species in Indonesia (Kajita *et al.*, 1991), 30 plant species in Sri Lanka (Chandrasekara, 1990) and 144 plant species in Taiwan (Wen *et al.*, 1994a).

It was first collected on coconut in Florida and used for the description and identified as a distinct species in 1965 (Russell, 1965) and black olive was the most preferred host in Florida (Cherry, 1980). It was recorded on *Terminalia catappa* in Puerto Rico (Medina *et al.*, 1991).

In Hawaii, it was first recorded on 64 different kinds of plants including vegetables, fruit trees, ornamentals and shade trees in 1978 in Honolulu and migrated to Oahu and some parts of Maui, where this pest first widely established on fruit crops such as banana, guava and pawpaw. The problem was further escalated by its extensive host range of over 100 plant species, of which guava, banana, plumeria, mango, sea grape and tropical almond appeared to be most preferred (Nakahara, 1978 and Kumashiro *et al.*, 1983). Guava is the most commonly and severely attacked host plant by the *A. dispersus* in many countries. Other feeding host plants include Indian banyan, fig, hibiscus, banana, mango, lipstick plant, bottle brush, mountain apple, avocado, surinam cherry, mulberry, christmas berry, papaya, bread fruit, strawberry, rose, pepper, tomato, egg plant, citrus, coconut, plumeria in Hawaii and Guam (Anonymous, 1980; Muniappan, 1980; Chang, 1981). In American Samoa, it was recorded on guava, citrus and ornamentals (Kumashiro *et al.*, 1983). In Guam, this was reported first in 1981 on coconut, frangipani, guava, mango and *Plumeria obtusa* and pest incidence was found to be high in 1982 (Nechols, 1981 and Lauofo and Iwamoto, 1982). In continental Africa, this was first reported in early 1992 on cassava, soybean, pigeonpea, citrus, papaya and numerous ornamentals and shade trees (Akinlosotu *et al.*, 1993).

In India, the incidence was reported on various plant species from Kerala, Tamil Nadu and Karnataka. The pest was collected from wild tapioca and wild rubber in September 1994 and also from *Anacardium occidentale* L., *Manihot utilisima* Crantz, *Solanum* spp. L., and *Psidium guajava* L., from Marayapuram in Kanyakumari district of Tamil Nadu during 1995 (David and Regu, 1995). Palaniswami *et al.* (1995) reported the incidence on cassava, annona, banana, okra, egg plant, cassia, citrus, chillies, coconut, fig, guava, jasmine, leucinia, mango, *Ocimum sanctum, O. basilicum*, rose and sapota.

Mani and Krishnamoorthy (1999c) observed the attack of spiralling whitefly on more than 45 species including fruit trees, ornamentals, vegetables, shade trees and other crops such as tapioca, cashew, mulberry and cotton in penninsular India. Ranjith (1998) enlisted the breeding hosts and feeding hosts of spiralling whitefly. He recorded its infestation on coconut, banana, brinjal, lady's finger, chillies, sapota, citrus, pepper, tomato, jack, cashew, cocoa, pigeon pea, papaya, guava and castor. Among the ornamentals, its infestation was reported on rose, balsam, poinsettia, dahlia, heliconia, canna, acalypha and polyalthia. An ornamental shrub, *Dombeya spectabilis* Boj, medicinal plant, *Solanum trilobatum* L. and groundnut were recorded as new hosts for *A. dispersus* during field surveys in 1997-98 in Tamil Nadu (Geetha *et al.*, 1998 and 1999).

Asia Mariam (1999) reported 53 plant species as alternate hosts around mulberry ecosystem and the plant species belonging to Euphorbiaceae, Solanaceae and Fabaceae were more susceptible to *A. dispersus* attack.

2.3. Biology

2.3.1. Adults

A. dispersus is very much larger than whitefly species. The body length is usually greater than 2.0 mm, total length from vertex to wing tip is greater than 2.0 mm and the wing span is 3.5 - 4.0 mm. The eyes are dark reddish - brown and the forewings with two characteristic dark spots. Males have a very short simple adeagus and often have extremely long claspers (Gill, 1990). They congregate on the lower surface of leaves on host plants (Anonymous, 1990).

2.3.2. Adult emergence and longevity

Adults emerge from their pupal cases through a "T" shape exit. The wings of newly emerged adults are clear, but develop a covering of white powder over the next few hours. Adults are particularly active during the early morning hours (Waterhouse and Norris, 1989). Adult longevity is varied with temperatures. Wen *et al.*, (1994a) reported that the life span of adults of *A. dispersus* shortened with rise in temperature from 15 to 30°C and both sexes lived for 17.0 to 18.5 days. Wijesekera and Kudagamage (1990) reported that adults lived for about two weeks at 17 to 26°C and 63 to 76 per cent relative humidity. Adult longevity was 14.2 to 15.7 days on mulberry (Asia Mariam, 1999). Cherry (1979) noted that adults had least tolerance to temperature. Wen *et al.* (1994a) observed the heat and chill coma for *A. dispersus* adults at 45.5°C and 5.2°C respectively.

2.3.3. Oviposition

Adults oviposit eggs on the lower surface of leaves in loose spirals of finger print-like wax derived from their body, hence commonly known as spiralling whitefly (Martin, 1990; Palaniswami *et al.*, 1995). Spiralling patterns of waxy material are produced also on non-host plants and inanimate surfaces, although the presence of eggs has not been confirmed (Henderson, 1982). Females oviposit throughout their life, commencing within a day of emergence. Mated females produce offsprings of both sexes, whereas unmated females produce male progenies only. In an experiment, 20 pairs produced 1549 individuals of various stages of the life cycle in 37 days (Waterhouse and Norris, 1989). Female whitefly lays 14 - 26 eggs (Wijesekera and Kudagamage, 1990). The mean fecundity was highest (28 ± 14.5 eggs) at 25°C (Wen *et al.*, 1994a).

2.3.4. Egg

Eggs are smooth surfaced, elliptical (0.3 mm long), yellow to tan coloured, laid singly at right angle to the leaf veins. Eggs have a characteristic short subterminal stalk or pedicel which is inserted during oviposition into the host plants usually on the lower surface of a leaf (Waterhouse and Norris, 1989) mainly into leaf stomata in order to facilitate the egg to meet its moisture requirements (Henderson, 1982 and Paulson and Beardsley, 1985). Each egg rests on a stalk, longer than itself (Palaniswami *et al.*, 1995). Eggs hatch in 9 to 11 days at 20 to 39°C (Waterhouse and Norris, 1989), 7 to 10 days (Wijesekara and Kudagamage, 1989), 4 to 6 days (Palaniswami *et al.*, 1995) and 5.1 to 7.3 days (Asia Mariam, 1999).

2.3.5. Crawlers (I instar nymph)

A. dispersus has four distinct nymphal instars in its life cycle. First instar larvae are tiny (0.32 mm long) generally settle in a spiral pattern near the eggs, from which they were derived, although some move within the confines of the leaf. They have distinct antennae and functional legs and can crawl actively. First instar lasts for 6 to 9 days (Waterhouse and Norris, 1989) and 5.3 to 7.2 days on mulberry (Asia Mariam, 1999).

2.3.6. Sessile nymphal instars

The legs and antennae of the remaining instars (second and third instars) are atrophied and these instars tend to be sedentary. Second (0.5 mm long) and subsequent nymphal instars usually remain feeding on the same place. The duration was 4 to 5 days for second instar (Waterhouse and Norris, 1989) and 6 to 9 days for first and second instars (Wijesekara and Kudagamage, 1990). The third instar nymphs (0.65 mm long) can be distinguished by the numerous evenly spaced short, glass like rods of wax along the sides of the body with duration of 5 to 7 days (Waterhouse and Norris, 1989), 5 to 13 days (Wijesekara and Kudagamage, 1990) and 5.2 to 8.1 days on mulberry (Asia Mariam, 1999). As the nymphs mature, they develop a characteristic row of anterior and mid-dorsal waxy tufts.

2.3.7. Pupa

The fourth instar is often called as 'pupal' stage. Fourth instar nymphs (1.06 mm long) are soon covered with copious amounts of white waxy material and long glass like rods are produced from a single pair of cephalic and three pairs of abdominal pores (Waterhouse and Norris, 1989; Akinlosotu *et al.*, 1993 and Palaniswami *et al.*, 1995). Rods upto 8 mm in length may occur, although most are shorter due to fragmentation. The fourth instar is at first a feeding stage like earlier instar, but later ceases feeding and undergoes internal tissue reorganisation before moulting to the adult. Fourth instar lasts for 10 to 11 days (Waterhouse and Norris, 1989). 5 to 16 days (Wijesekara and Kudagamage, 1999), 2 to 3 days on cassava (Palaniswami *et al.*, 1995) and 3.5 to 5.5 days on mulberry (Asia Mariam, 1999).

2.3.8. Developmental periods

The total nymphal period was 12 to 14 days (Palaniswami *et al.*, 1995). Development from egg to adult occupied 30 days (Esguerra, 1987), 34 to 38 days at 20 to 39°C (Waterhouse and Norris,1989). 26 to 36 days (Wijesekara and Kudagamage, 1990) and 18 to 23 days (Palaniswami *et al.*, 1995). A curvilinear relationship was found between temperature and developmental rate in

A. dispersus immatures in the range 10 to 32°C and a linear regression at 15 to 25°C, when reared in growth chamber on *Canna indica* L., (Wen *et al.*, 1994a).

2.4. Damage

2.4.1. Direct damage

Nymphs and adults congregate and infest heavily the lower surface of leaves of all the varieties of plants. They suck sap from their host plants and cause premature leaf drop (Esguerra, 1987). Infestation by *A. dispersus* causes extensive desapping (Akinlosotu *et al.*, 1993) which leads to chlorosis and early dehiscence of leaves (M' Boob and Oers, 1994). Yellow speckling, crinkling and curling of the leaves was noted when the infestation by *A. dispersus* was severe (Palaniswami *et al.*, 1995). Damage by *A. dispersus* in young plants, would lead to reduced growth. Tree species may escape death, but would have reduced vigour considerably (Ranjith, 1998). Wen *et al.* (1995) estimated that four month long infestation could result in 80 per cent fruit yield loss in guava.

In Florida, overall field infestation of black olive, sea grape and sweet orange was low. Although 35.3 per cent of the trees were infested, only one per cent of the leaves in the infested tree was covered with whiteflies (Cherry, 1980). Heavy infestations of *A. dispersus* were observed on young coconut palms near Madeng in papua New Guinea (Waterhouse and Norris, 1989). Several plants got killed by this whitefly infestation in Sri Lanka (Chandrasekara, 1990) and India (Nambiar, 1997). Considering the wide spread and severe incidence of this whitefly species on a variety of plants in Kerala and Tamil Nadu, it is likely that this species may soon pose a threat to cultivation of economically important field and plantation crops in India (David and Regu, 1995). The occurrence and spread of this insect is alarming. Attack by this pest on rubber is likely to cause unseasonal leaf fall and consequent yield reduction by way of reduced latex flow.

Production of banana might also be severely reduced due to the attack of this whitefly (Ranjith, 1998).

2.4.2. Indirect damage

Much sticky honeydew excreted by this insect serves as a substrate for dense growths of sooty moulds which interfere with photosynthesis. Honeydew also serves as an attractant to other pests including flies and ants (Akinlosotu *et al.*, 1993; M' Boob and Oers, 1994). This whitefly was once suspected as being vector of the mycoplasma causing coconut lethal yellow disease in Florida (Weems, 1971).

2.4.3. Nuisance to the public

The copious white, waxy flocculent materials secreted by the nymph are readily spread elsewhere by wind and adhere to windows, doors and walls of the houses. Some residents also find it difficult to remove the honeydew from automobiles parked under infested trees which causes annoyance to them. Adult whiteflies were observed on vehicles and new infestations were frequently found near bus stops and parking areas in Oahu and Honolulu of Hawaii (Waterhouse and Norris, 1989). In Hawaii, at the height of the infestation, complaints were received on allergies and dermatitis, although it is not known whether the adult whitefly or the flocculent material were responsible. They also cause respiratory problems if the white waxy powder is inhaled (Anonymous, 1981; Chang, 1981; Kumashiro *et al.*, 1983 and Esguerra, 1987).

2.5. Management of *A. dispersus* using chemicals

2.5.1. Chemical control

Management of *A. dispersus* through chemicals has certain difficulties and proved to be nearly impractical because of abundance of host plants including extremely large size trees and wide spread distribution (Anonymous, 1990; Kajita *et al.*,1991). Akinlosotu *et al.*, (1993) advised to avoid chemicals as they did not appear to give sustained control. Synthetic chemicals do not adequately control this whitefly since the nymphs are covered with heavy waxy flocculent materials which acts as an impregnable layer on which the insecticide solution falls. Insecticidal applications temporarily reduce the whitefly abundance (Waterhouse and Norris, 1989 and Ranjith, 1998).

2.5.2. Synthetic chemicals and plant products

Megir - Gumbek (1987) tested nine insecticides against *A. dispersus* on guava and observed significant reduction in damage and infestation. On low growing vegetables, spraying with either malathion or diazinon with spreader or sticker can control whitefly. While spraying, the nozzle should be directed to the underside of leaves where the whitefly is most often located (Esguerra, 1987).

The contact insecticides temporarily reduce whitefly abundance and systemic insecticides would be even more effective (Waterhouse and Norris, 1989). Minimum whitefly population of *Bemisia tabaci* (Gennadius) was recorded in triazophos treatment followed by amitraz and phosalone on cotton (Natarajan *et al.*, 1991). Wen *et al.*, (1995) recommended 2.8 per cent bifenthrinate EC for best egg control and methomyl for nymphal and adult mortality. They also reported that in low toxic substance treatment, 50 per cent neem oil 200x mixed with Triton 3000x gave the best control, while water spraying at the rate of 12.5 l/minute at 2 days interval for a consecutive month controlled 78.5 per cent of nymphs and 86.4 per cent of adults.

Use of chemicals like thiometon, dimethoate and phosphamidon can help to reduce the pest population to some extent. Chemicals like triazophos (0.04%) + neem oil (0.05%), phosalone (0.05%) + neem oil (0.05%) recommended for other whiteflies can help to suppress the *A. dispersus* population only to some extent. Moreover, migration habit of *A. dispersus* from one field to other, makes chemical control more difficult and expensive (Mani and Krishnamoorthy, 1997a). Experiments were conducted to manage the pest by organophosphates, pyrethroids, chitin synthesis inhibitors and neem products (Ranjith *et al.*, 1997). The results suggested that most conventional insecticides fail to reduce the pest population. Nymphal survival was curtailed to the maximum with the application of dimethoate followed by buprofezin and acephate. Kavitha Kirubavathy *et al.*, (1999) observed the neem products effective to control the *A. dispersus*. Application of 2% and 3% neem oil (NO) 2% neem seed kernel extract (NSKE) and neem oil (2%) + NSKE (3%) were found to be effective in suppressing the nymphal and adult whitefly population.

2.5.3. Soap solution and FORS

A dilute aqueous solution of a dish washing detergent has been suggested as helpful for the management of *A. dispersus* (Waterhouse and Norris, 1989). Per cent egg mortality and nymphal mortality were maximum with three applications of 5% soap solution (Ranjith *et al.*, 1997). Researchers at Kerala Agricultural University found a cheap and environment friendly approach of soap solution 0.5% to the crops have caused some migration of the pest population (Ranjith, 1998).

Researchers are now concentrating to identify effective and safe chemicals with less hazards to the environment and non-target organisms. Fish Oil Rosin Soap (FORS) has been reported to be effective against *B. tabaci* (Venugopal Rao *et al.*, 1990). Natarajan *et al.*, 1991 tested the effectiveness of FORS along with chemicals against *B. tabaci*. FORS treated plot has harboured minimum population of 15.3 nymphs per leaf followed by neem oil (18.0 l/leaf) as compared to 60.6 in monocrotophos. FORS along with phosalone also resulted in less whitefly population.

2.6. Management of *A. dispersus* using sticky traps

2.6.1. Yellow sticky traps

Monitoring of whiteflies using yellow sticky traps has become an integral part in pest management (Gerling and Horowitz, 1984; Uthamasamy *et al.*, 1990). Various types of traps have been designed based on the characteristic response of different whitefly species (Mound, 1962; Cohen and Melamed - Madjar, 1978) and used for pest monitoring and controlling soft bodied homopteran insects like aphids and whiteflies (Taylor and Palmer, 1972; Anonymous, 1995). Several workers reported a positive correlation between the trap catches and field population of whiteflies (Melamed - Madjar *et al.*, 1979).

A yellow sticky trap using a plastic petridish, glued on to a rod with inverted cover painted yellow was developed by Berlinger (1980) for use in glass houses. Yellow sticky traps at various heights from the ground level was tested to identify the maximum catches of *B. tabaci* at the optimal height. Traps placed at a height of 30 cm recorded significantly more catches of whitefly in sunflower field (Diraviam and Uthamasamy, 1992) and in cotton (Gerling and Horowitz, 1984; Uthamasamy *et al.*, 1990). Asia Mariam (1999) studied yellow sticky trap catches of *A. dispersus* in mulberry field at two different heights and found that the mean number of catch per day was 0.35 to 2.32 at 4 feet and 1.78 to 7.07 adults at six feet height traps.

2.6.2. Light trap

A simple method for trapping large numbers of *A. dispersus* in home gardens in Tamil Nadu, by coating a transparent cover around a two feet length emergency lighting tube with vasaline was suggested by Srinivasan and Mohanasundaram (1997). Asia Mariam (1999) also tested a flourescent light trap smeared with castor oil in the mulberry field and found that more number of adults were trapped in the early morning hours from 4 to 6 a.m. accounted to 97.9 per cent of the total catch.

2.7. Biological control

Spiralling whitefly is of ubiquitous nature and not easily amenable to chemical control, hence biological control would be the tactic of first choice to manage this pest. Several attempts like searching of natural enemies in its native home lands and introduction of the natural enemies to the places where this insect introduced were done.

Natural enemies of *A. dispersus* have been searched and reported in West Indies, Hawaii, Guam, Indonesia, Sri Lanka, Malaysia and India. In Hawaii three species of coccinellids and two species of aphelinid parasitoids were subsequently introduced from Trinidad and the coccinellid, *Nephaspis oculatus* (= *N. amnicola*) Wingo and the aphelinid parasitoids *Encarsia haitiensis* Dozier and *Encarsia* sp. were the most effective. In 1980 to 1981, peak populations of *A. dispersus* around Honolulu in Hawaii were reduced by 79 per cent in the low lands and 98.8 per cent in the highlands (Anonymous, 1981; Gordon, 1982; Kumashiro *et al.,* 1983 and Paulson and Kumashiro, 1985 and Lai and Funasaki, 1990). From a single release of adult *E. haitiensis* in Lanai in September 1980, it was recovered in December 1980, when whitefly populations were at peak, by July 1981, the whitefly was considered to be under control (Anonymous, 1981).

The predator *N. amnicola* was more effective at low pest population density whereas *E. haitiensis* was effective at parasitizing large populations of *A. dispersus* (Kumashiro *et al.*, 1983). Although *N. oculatus* had a wide prey range in the laboratory, in the field it showed a strong preference for whiteflies. However it was an effective predator only when its prey populations were high (Doutt and DeBach, 1964).

In Guam, On an average, population increased eight fold between July and September. Two other predaceous coccinellids, *Nephus reepki* Fluites and an unidentified black species and a green lacewing (Chrysopidae) were also observed frequently. However, predation on *A. dispersus* was not observed (Nechols, 1982).

In American Somoa three coccinellid predators and the parasitoid *E. haitiensis* were introduced from Hawaii in June 1984 and rapidly brought the pest under effective control. In Cook island, *N. bicolor* and *E. haitiensis* were introduced from Hawaii in 1985. In Palau, *E. haitiensis* was introduced from Guam in 1986 and *A. dispersus* was rapidly brought under control. In Fiji, *E. haitiensis* along with *N. oculatus* and *N. bicolor* were introduced from Guam and Hawaii. *E. haitiensis* become well established within a year and the coccinellids had dispersed upto 2 km from their release site within a few months (Akinlosotu *et al.*, 1993).

E. haitiensis was introduced from Guam to Phonpei in February 1987 and kept the *A. dispersus* population at a low level (Esguerra, 1987). In West Africa, in 1993, *E. haitiensis* and another aphelinid, *E. guadeloupae* viggiani were also known to attack *A. dispersus* (Viggiani, 1993). These two aphelinid parasitoids had arrived by accident, presumably together with *A. dispersus* (D'Almeida *et al.,* 1998).

Extensive field surveys for *Aleurodicus* spp. and *Nephaspis* spp. were made in Trinidad during 1996 and searches for whiteflies and coccinellids were carried out on known host plants (Carl *et al.,* 1996). In Benin, *E. haitiensis* was found feeding on *A. dispersus* (Paulson and Kumashiro, 1985 and M' Boob and Oers, 1994).

In SriLanka, *Axinoscymnus puttarudriahi* Kapur appeared to be a potential predator of the SWF and the parasitoid, *E. transvena* (Timberlake) was found feeding on *A. dispersus* (Wijesekara and Kudagamage, 1990).

E. guadeloupae parasitized the *A. dispersus* (Kumashiro and Polaszek, 1992) with the parasitism of more than 80 per cent in Malaysia (Kajita, 1991). *Euderomphale vittata* Dozier (Eulopidae) was found as parasitoid of *A. dispersus* in Florida (Bennett and Noyes, 1989). Eight species of predators namely, *Axinoscymnus* sp., *Cybocephalus* sp, *Coleophora inaequalis* Fab., *Harmonia sedecimnotata* Fab., *Cheilomenes sexmaculatus* Fab. (Coleoptera) *Paragus serratus* (Fab.) (Diptera), *Iridomyrmex anceps* (Roger) (Hymenoptera), *Chrysoperla* sp. (Neuroptera), were found attacking the *A. dispersus* on guava in Java but they failed to suppress the outbreaks of *A. dispersus* in Indonesia (Kajita *et al.*, 1991). Bennet and Noyes (1989) reared *E. vittata* as primary parasitoid from *A. dispersus*. Villacoris and Robin (1992) reported that *Curinus coeruleus* Mulsant, an introduced predator of *Heterpsylla cubana* Crawford feeds on all stages of *A. dispersus* on guava.

In India, the grubs and adults of Coccinellids, *Menochilus sexmaculatus* and *Scymnus coccivora* prey on the whitefly nymphs and pupae (Palaniswami *et al.*, 1995 and Mani and Krishnamoorthy, 1996). Eight predators were recorded on *A. dispersus* during surveys conducted in Bangalore (Karnataka), Coimbatore and Dharmapuri (Tamil Nadu). Among them *Cryptolaemus* montrouzieri Muls, *Mallada astur* (Banks) and *A. puttarudriahi* appeared in more numbers. The coccinellid predator, *Chilocorus nigrita* (Fab.) was found feeding on the spiralling whitefly on guava and *Pongamia glabra* in September - October 1996 around Coimbatore and Bangalore. All the stages of the predator were observed on the leaves infested with the whiteflies. In the laboratory, the predatory larvae completed its development exclusively on *A. dispersus*. *C. nigrita* along with

C. montrouzieri can suppress the whitefly population to some extent both on guava and *P. glabra* (Mani and Krishnamoorthy, 1999a and 1999b).

Beevi *et al.* (1999) reported the presence of the *Encarsia* parasitoid near to *E. meritoria* on *A. dispersus* in Kerala during January 1998. Srinivasa *et al.* (1999) also reported the *Encarsia* parasitoids of *A. dispersus* closely related to *E. haitiensis* and *E. meritoria* and higher parasitism was found on *Cassia siamea* Lamk. in Bangalore.

2.8. Population dynamics

2.8.1. Influence of host plants on *A. dispersus* population

Abiotic factors including temperature and rainfall, host plants, natural enemies may have an important role in regulating the *A. dispersus* population.

Adults of *A. dispersus* moved from infested perennial plants such as ornamentals, fruit trees and shade trees to newly planted annual crops successfully throughout the year (Kajita *et al.*, 1991).

2.8.2. Influence of weather factors on *A. dispersus* population

Heavy sporadic rains and cool temperature resulted in a temporary reduction in *A. dispersus* population which, however, rose again in warm dry weather in Hawaii. Mortality of immature stages increased significantly between 40 and 45°C and of adults between 35 and 40°C. Temperatures below 10°C also caused mortality (Cherry, 1979).

In Hawaii, significant positive correlation was obtained between temperature and whitefly abundance and negative correlation between the pest incidence and rainfall indicating that both temperature and rainfall played an important role in regulating the whitefly populations besides the natural enemies

(Kumashiro *et al.*, 1983). *A. dispersus* populations declined following the onset of the rainy season (Nechols, 1983).

Waterhouse and Norris (1989) reported that the whitefly was not recorded as an important pest until the end of 1987, but early in 1988, following on three month drought, whitefly populations increased rapidly. In Sri Lanka, the relative humidity had significant correlation with the whitefly population (Chandrasekara, 1990). In Southern Taiwan, *A. dispersus* occurred all round the year, its population build up rapidly in October, reaching a peak in November and declining gradually after December (Wen *et al.*, 1995). The population escalated in February and fall by April on tapioca (Palaniswami *et al.*, 1995). The whitefly had increased drastically in summer and decreased after the premonsoon showers in Kerala (Ranjith *et al.*, 1998). Higher the rainfall in the month, fewer *A. dispersus* were found. This was attributed to a washing off effect by rain as well as indirect influence mediated through the physiological condition of the host plants (D'Almeida *et al.*, 1998).

2.8.3. Influence of Natural enemies on *A. dispersus* population

A good correlation was established between decreasing densities of *A. dispersus* and increasing rates of parasitisation by *E. haitiensis* in Guam (Nechols, 1982). Kumashiro *et al.*, (1983) conducted studies on different climatic conditions and found that the density of the *A. dispersus* was at a peak (461.3 pupae) in May 1980 with declined population in the following months and reached 4.0 in November. The density of the predator *N. amnicola* reached a peak of 24.3 individuals in June 1980. Throughout 1981, *N. amnicola* remained at a very low level. The results indicated that there was a significant positive correlation between the predator and the *A. dispersus*. The parasitoid *E. haitiensis* increased in density to a peak of 16.3 pupae in October 1980, and then decreased to 2.7 pupae in the following months as the *A. dispersus* population subsided. In March 1981, parasite density increased as the *A. dispersus* population began to increase and thereafter fluctuated with the *A. dispersus* population through October. During November and December 1981, there was a substantial increase in parasite density to 61.3 pupae with a corresponding decline in the *A. dispersus* population.

D'Almeida *et al.* (1998), studied the impact of *Encarsia* species on population dynamics of *A. dispersus*. From 1993 to 1995, *A. dispersus* populations showed three peaks, mostly early in the dry season. Populations were lower during the second half of the dry season and during the wet seasons. Following the detection of *E. haitiensis* in August 1993, *A. dispersus* infestations became lower. A decline in *A. dispersus* populations was noted with increasing time of parasitoid presence. The annual peaks of *A. dispersus* population declined by 80 per cent between 1993 and 1996 with increased parasitism rates on guava. The predators, spiders and ants were more abundant on high *A. dispersus* population, than on low ones because they had been attracted to their food source.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

3.1. Survey for the host range and damage intensity of the spiralling whitefly, *A. dispersus*

Intensive survey was undertaken through out Tamil Nadu to study the host range, distribution pattern and rate of infestation of *A. dispersus* on various host plants. The details on location, crops infested, symptoms of damage, period of occurrence, stage of the crops attacked and population level of *A. dispersus* were collected using a structured questionnaire. *In situ* sampling was carried out on the per cent leaf area covered with egg spirals (<10%, 25%, 50%, 75% and 100%) and number of nymphs and adults per leaf were recorded on twenty randomly selected leaf samples from each host.) Survey was undertaken in five cassava growing districts of Tamil Nadu *viz.*, Coimbatore, Erode, Salem, Dharmapuri and Namakkal. Sampling units were selected randomly and survey was carried out on plant species along the road side, household ornamentals, kitchen garden and in field and horticultural crops of both urban and rural areas. A standard evaluation system was formulated based on the per cent damage intensity and the damage was categorised into six grades. The overall distribution map of the pest in Tamil Nadu was prepared.

Intensity of damage (%)	Damage category	Grade
0	Nil	1
1-10	Very low	2
11-25	Low	3
26-50	Moderate	4
51-75	High	5
76-100	Very high	6

3.2. Mass culturing of *A. dispersus*

Heavy infestation of *A. dispersus* on cassava (*Manihot esculenta* Crantz.) and guava (*Psidium guajava* L.) for the past two years from 1996 in Coimbatore showed their high preference as host plants (Plate 1). Hence, cassava was selected for mass culturing of this pest. Field collected adult population of *A. dispersus* was released on two months old cassava (ME 501) plants, which were raised in microplots (20 plants in 6 m^2) under screen house. Mass culturing was also done on potted plants of cassava to ensure the availability of uniform population of SWF, needed for various studies. A batch of ten numbers of two months old potted (30 x 26 cm) plants were kept in between the rows of cassava plants in microplots and allowed for egg laying for a period of one week. Then the plants with waxy egg spirals were tapped gently to remove the adults alighting on leaves and removed and covered with mylar film cages (110 x 25 cm) with the top open covered with muslin cloth (Plate 2a). When the population reached pupal stage (last nymphal instar), the leaves were covered individually with leaf cages (20 x 8 cm) for trapping the freshly emerged adults (Plate 2b). New batches of cassava plants were introduced in microplot for egg laying and culturing was continued.

3.3. Morphology of the *A. dispersus*

Morphometric observations were made on life stages of *A. dispersus* on *M. esculenta* and *P. guajava*. Leaf samples with freshly laid egg spirals were tagged and two leaves from each plant species were excised daily and examined under 40x binocular stereo microscope. Measurements on eggs, nymphal (I to IV) instars and adults were taken using stage and ocular micrometers on fifty samples for each stage. Morphology and changes in the nymphal instars from I to IV were studied. The ratio between the length and breadth of successive instars were calculated.

Plate 2. Studies on biology of *A. dispersus*

a. Mylar film cages for studying biology of nymphal stages

b. Leaf cages for studying biology of adults

3.4. Biology of the *A. dispersus*

Biology of *A. dispersus* was studied on various economically important and most preferred host plants from June 1998 to November 1999. The following observations were made:

i. Size (mm) and pattern of egg wax spirals
ii. Fecundity (numbers)
iii. Egg period (days)
iv. Nymphal duration (days)
v. Adult emergence (%)
vi. Adult longevity (days)
vii. Total life span (days)
viii. Sex ratio

3.4.1. Developmental period and longevity of *A. dispersus*

Egg and nymphal duration of SWF was studied on various host plants. In the case of *M. esculenta*, *Gossypium* spp., *Capsicum annuum* L., *Solanum melongena* L., *Abelmoschus esculentus* Moench., *Lycopersicon exculentum* Mill and *Cajanus cajan* L., the plants were raised in mud pots and the leaves were covered individually with a leaf cage (20 x 8 cm) made from mylar film with a window covered with muslin cloth. Both the top and bottom of the cage were covered with gada cloth and twenty pairs of SWF adults were released in each cage for egg laying. The leaves were examined on every 24 hours for the presence of egg spirals and twenty leaves with egg spirals were tagged with date of egg laying and the leaf cages were removed. The potted plants were covered with mylar film cage after counting the number of eggs in each spiral on each tagged leaf carefully using a hand magnifier (10x). Observations were made on the developmental stages of SWF. Studies were conducted at 28 to 31°C with relative humidity of 79 to 85 per cent.

In case of *P. guajava*, *Carica papaya* L., *Musa* spp. and *Manihot* sp., the leaves with fresh egg spirals were selected and caged after counting the total number of eggs in each leaf using a hand magnifier (10x). As the egg laying of SWF on fruits of *C. papaya* was noted for the first time, study was conducted to find out the suitability for *A. dispersus*. Five fruits with egg spirals were marked and the developmental periods of different life stages were studied. The leaves with late fourth instars were covered individually with leaf cages (20 x 8 cm) except the papaya fruits, which were covered with polythene bags (25 x 20 cm) to trap the adults emerged. Longevity was studied till the mortality of the adult.

3.4.2. Adult emergence, fecundity and egg hatchability

Leaf cages were removed along with the adults emerged daily and the number of adults emerged were counted. The emerged adults were released at the rate of 1:1 (male to female) for egg laying on the respective host plants covered with mylar film cages (110 x 25 cm). Leaves with egg spirals were collected and examined under 40x stereo microscope to count the number of eggs and first instar nymphs. The leaves were kept in plastic trays for the emergence of nymphs from the unhatched eggs and the numbers were counted, to work out the per cent hatchability of eggs

3.4.3. Size and pattern of egg wax spiral and trichome density

Twenty five leaf samples with freshly laid egg spirals were collected from various host plants and the shape, pattern and size of egg wax spirals were studied. The number of eggs per cm^2 area and the number of trichomes per cm^2 were counted in twenty samples using 40x binocular stereo microscope. Correlations between the number of eggs, size of the spiral and trichome density were worked out.

3.5. Spatial distribution pattern of *A. dispersus* in different crops

An experiment was conducted to study the spatial distribution pattern of *A. dispersus* on guava (5 months old) and cassava (3 and 6 months old) in Tamil Nadu Agricultural University (TNAU) Orchard, Coimbatore. Twenty numbers of heavily infested guava (Chittidar) shoots and cassava (ME 501) plants were selected for the study, in which each shoot/plant acted as a replication. Distribution pattern of immature stages and adults of *A. dispersus* were observed on 5 leaves each in top, middle and bottom position of leaves.

3.6. Damage potential of *A. dispersus* on *M. esculenta*

Study was conducted to find out the damage potential of *A. dispersus* at different population levels on *M. esculenta.* Genotype (ME 501) was raised in a micro plot of 3.5 x 3.5 m for each treatment at Insectary, TNAU, Coimbatore. The plants (9 numbers) were covered with nylon net cage of 3.5m x 3.5m x 3m (Plate 3a). Population build up and damage potential of SWF was studied on three months old crop by releasing freshly emerged adults at the rate of 50/plot and 250/plot in the caged plants. Another set of caged plants was maintained as control, without the infestation of *A. dispersus*. Observations on population build up, per cent leaf damage, plant height and number of leaves were recorded at monthly interval till the harvest and tuber yield was recorded both in the infested and control plots.

3.7. Cultural methods

Studies were conducted to find out the effect of cultural method like pruning on the population suppression of *A. dispersus.* Pruning of one-third of tree branches was done on 4 branches of guava heavily infested with *A. dispersus* (local-red flesh) at P.N.Pudur, Coimbatore, during September 1999. Observation on pest incidence on new shoots was recorded.

3.8. Physical control of *A. dispersus*

Studies were made on sticky traps and light traps as physical method of control of *A. dispersus.*

3.8.1. Usefulness of sticky traps in monitoring and management of *A. dispersus*

Experiments were carried out to study the utility of sticky traps using castor oil as sticker for monitoring and management of the *A. dispersus*. Cylindrical sticky traps (20.5 cm height and 16.5 cm diameter) were tested in plants of *M. esculenta, A. indica* and *Manihot glaziovii* M. Arg. (wild cassava or cera rubber). The traps were placed in different heights from the ground level to find out the optimum height to attract more number of adults.

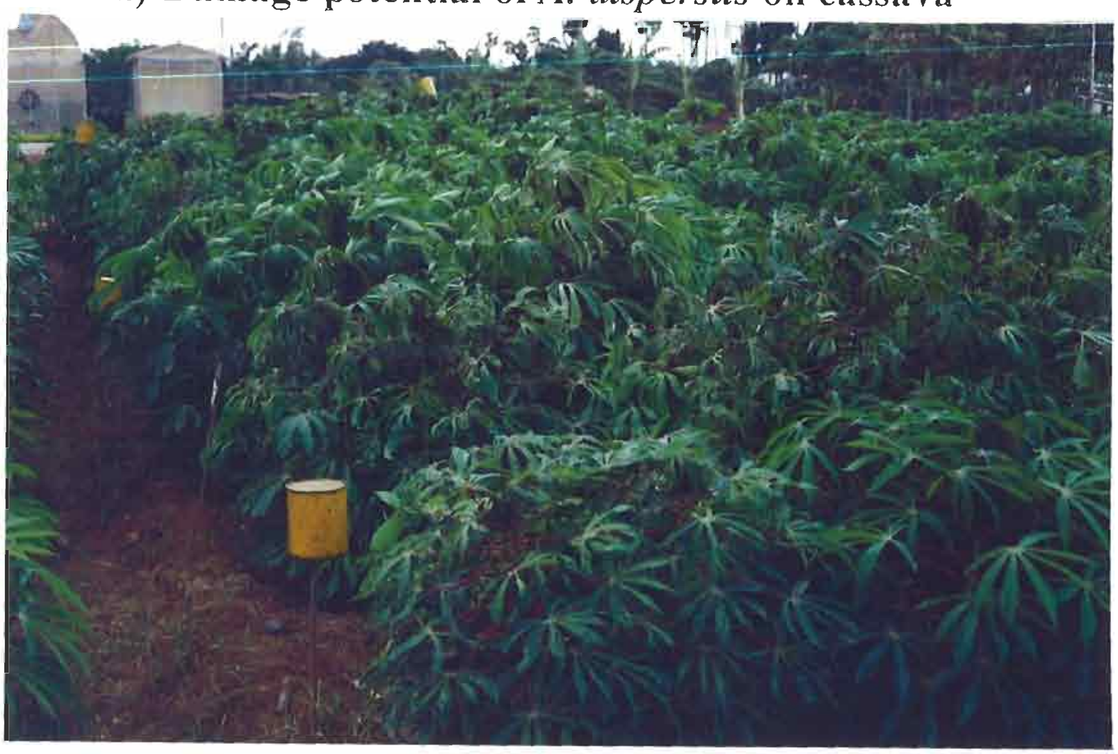
3.8.1.1. Yellow sticky trap catches of *A. dispersus* in *M. esculenta*

Cylindrical yellow sticky traps were installed equidistantly (at 5 m distance either way) in six months old cassava (ME 501) field at TNAU orchard. Traps were placed at three different heights *viz.* above crop canopy (200 to 220 cm), crop canopy (150 to 170 cm) and below crop canopy (100 to 120 cm) (Plate 3b).

The level of the traps at each crop phase was altered according to the crop height during the study period and the other two levels *viz.*, above and below crop canopy were also changed based on the height at crop. The experimental design was FRBD and the number of traps used per treatment was seven. Observations were recorded on the number of adults trapped on the sticky traps individually at weekly interval. The traps were thoroughly cleaned, smeared with castor oil as adhesive during the subsequent weeks before installation for further observation. The study was conducted for a period of four months from September 1998 to December 1998.

Plate 3.

a) Damage potential of *A. dispersus* on cassava



b) Cylindrical yellow sticky traps for *A. dispersus*

3.8.1.2. Yellow sticky trap catches of *A. dispersus* in *A. indica*

The traps were placed at three different height levels, *viz.*, below crop canopy (70 cm), crop canopy (90 cm) and above crop canopy (110 cm) from the ground level randomly at the rate of one trap per plant and totally 5 traps were used per treatment. The study was conducted for a period of four months from December 1998 to March 1999. The method of installation and observations were same as mentioned in 3.8.1.1.

3.8.1.3. Yellow sticky trap catches of *A. dispersus* in *M. glaziovii* (Wild cassava)

Totally 8 traps were placed in branches of the *M. glaziovii* at 4 m height from the ground level. The study was conducted from October 1998 to February 1999. Method of observation was same as mentioned in 3.8.1.1.

3.8.1.4. Coloured sticky traps

The whitefly adults exhibit differences in their attraction towards various colours. This was studied using rectangular (35 x 12 cm) sticky sheets of various colours as traps. Flourescent colour paper was sandwiched between the transparent plastic sheets and the edges of the sheets were pasted tightly. Commercial grade castor oil was smeared as adhesive on the outer surface of the trap and placed in stakes equidistantly (at 6 m distance either way) in the cassava (ME 501) field commencing from five months old crop to seven months at TNAU orchard (Plate 4). The colours tested were yellow, green, orange, red, black and white. Three traps were used for each colour. Observations on number of adults trapped were recorded at weekly interval. The study was conducted for a period of 8 weeks from October 1999 to November 1999.

3.8.2. Attractancy of light traps against *A. dispersus*

Studies were conducted to find the attractancy of light traps against SWF adults. A white fluorescent light trap consisting of a 2 feet tube light, in front of

Plate 4. Sticky traps for *A. dispersus*

Rectangular, coloured sticky sheets

Yellow light trap

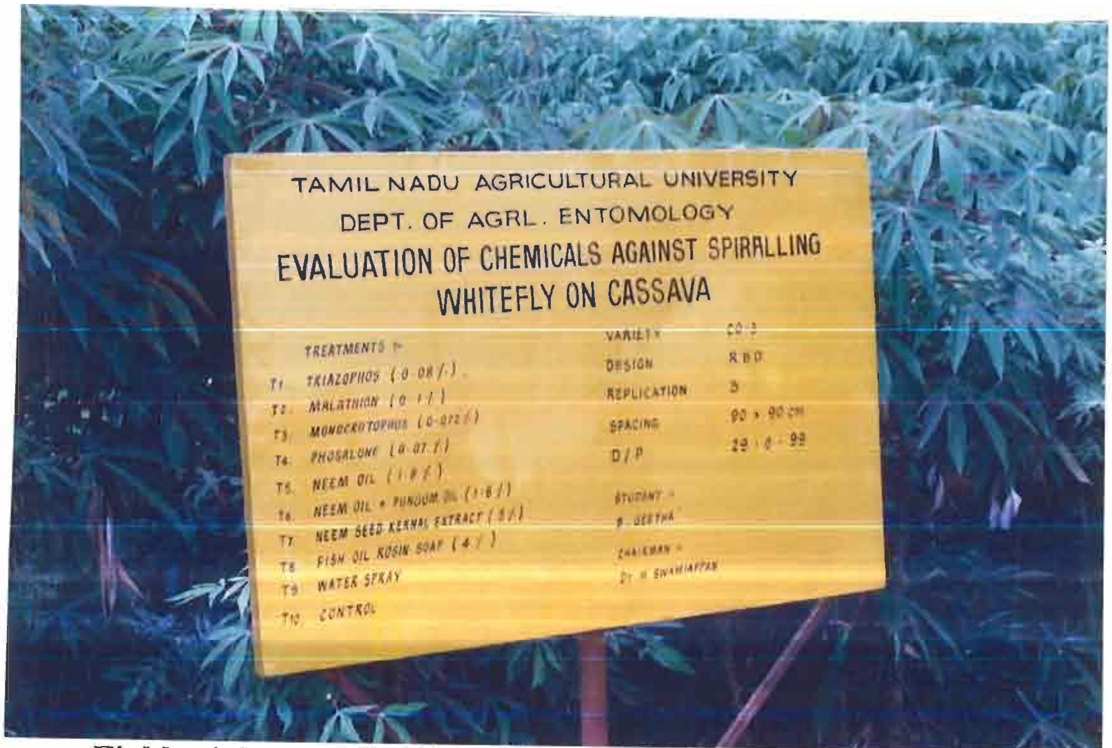
which a plastic plate of size 20 cm breadth and 75 cm height was placed using wooden frames. Transparent glossy sheet was fixed over the plastic sheet. The adhesive, castor oil was smeared on the sheet uniformly using a brush. Bihourly catches were studied from 6.00 p.m. to 6.00 a.m. at different time intervals to find out the peak period of activity of whiteflies towards light by removing the sheets. The sheet was cleaned and smeared with oil after each observation. The study was conducted for 10 days in May 1999 and 15 days in December 1999. In another study, the differences in attraction of SWF adults to various colours in light trap were tested. The glossy sheets of yellow, green and orange were tested as described earlier (Plate 4). The study was conducted for 7 days between 3.00 a.m. to 6.00 a.m. and observations were taken daily in the morning.

3.9. Chemical control of *A. dispersus*

3.9.1. Efficacy of various chemical insecticides and plant products against *A. dispersus* on cassava (*M. esculenta*)

To study the efficacy of certain chemicals and plant products against *A. dispersus,* two field trials were conducted on six months old cassava field at TNAU, Coimbatore. The first field trial was conducted during August to September, 1998 on cassava cultivar ME 501. Two insecticides, four plant products, dish wash soap solution (Vim bar soap) and fish oil rosin soap (FORS) were evaluated. The second trial was conducted during December 1999 to January 2000 on cassava (CO 3) (Plate 5a). Four chemical insecticides, three neem based products and FORS were evaluated. For all the trials water spray was maintained as control. Second spray was given 10 days after the first spray. The treatment details are as follows.

Plate 5



a. Field trial on evaluation of insecticides against *A. dispersus*

b. Leaf cages with parasitoid, *Encarsia* sp nr *meritoria* for studying parasitization potential

Field trial - I

	Treatments	Dose (ml/gm/lit.)
T_1	Triazophos 40 EC	2ml
T_2	Phosalone 35 EC	2ml
T_3	Dish wash soap solution	40gm
T_4	TNAU Neem (0.03 %)	1ml
T_5	TNAU Neem oil 60 EC (C)	30ml
T_6	TNAU Pungam oil + Neem oil 60 EC	30ml
T_7	Neem seed kernel extract	50gm
T_8	Fish Oil Rosin Soap	25gm
T_9	Control	-

Field trial - II

	Treatments	Dose (%)
T_1	Triazophos 40 EC	0.08
T_2	Malathion 50 EC	0.1
T_3	Monocrotophos 36 WSC	0.072
T_4	Phosalone 35 EC	0.07
T_5	TNAU Neem oil 60 EC (C)	1.8
T_6	TNAU NO + PO 60 EC (C)	1.8
T_7	Neem seed kernel extract	5.0
T_8	Fish oil Rosin Soap	4.0
T_9	Water spray	-
T_{10}	Control	-

A high volume rocker sprayer was used to spray the chemicals and spray swath was centered on the adaxial surface of the leaves. Each treatment was given in three plots and each plot consisted of three ridges with five plants per ridge in randomised block design. Observations on mortality of late instar nymphs and adults on ten leaves collected per plot were recorded before and 1, 3, 5, 7 and 10 days after application of chemicals. The leaves were collected randomly from top, middle and bottom of the plants and examined under microscope (40x) to detect the mortality of eggs and nymphs per 1 cm^2 area on 10 samples. The malformed, shrunken and discoloured eggs and nymphs from yellowish green to dark reddish brown were considered as dead ones. The mortality was worked out as corrected per cent mortality (Abbott, 1925).

3.10. Biological control of *A. dispersus*

3.10.1. Survey on natural enemies of *A. dispersus*

Natural enemies of SWF were recorded simultaneously while taking up the survey for the incidence of SWF on various host plants in Tamil Nadu from June 1997 to December 1999. *In situ* observations on predators were recorded randomly on twenty leaves infested with SWF on each host at each location. Predator specimens were collected in labeled screw cap vials for the identification and the most abundant predators were collected with host insects in polythene bags (30 x 19 cm) and brought to the laboratory for mass culturing. Leaves were also observed using hand magnifier (10x) for the presence of parasitoids. In each plant species ten leaves with late instar nymphs of SWF were collected randomly in polythene bags (30 x 19 cm) and examined under 40x binocular stereo microscope for the presence of parasitoids. After removing the waxy coats, the nymphal stages were scanned for the presence of pupal case with circular exit hole (parasitoid emergence) and black coloured parasitized pupae of SWF. The leaves with parasitized pupae were kept in glass tubes (12.5 cm length x 2.5 cm dia) for the emergence of parasitoids and the per cent parasitism and per cent parasitoid emergence were worked out.

3.10.2. Predators of *A. dispersus*

3.10.2.1. Predator fauna of *A.dispersus*

The predators collected during field surveys were identified at Project Directorate of Biological Control, Bangalore (Poorani, Pers. Comm. 2000).

3.10.2.2. Predator population of *A. dispersus* on various crops

Periodical observations on predator population of *A. dispersus* were made on 10 cassava plants (2 leaves/plant) at fortnightly intervals in TNAU Orchard and on guava at weekly intervals on 5 branches (4 leaves/branch) in Patchapalayam Milk Society Garden, Madampatti, Coimbatore.

3.10.2.3. Feeding potential and longevity of *A. dispersus* predators

Experiments were conducted to study the feeding potential and longevity of the predominant predators of *A. dispersus*, on cassava and guava. Feeding potential of both grubs and adults of *Cybocephalus* sp. and spiders was studied *insitu* on cassava plants for 10 individuals separately using leaf cages of 20 cm height and 8 cm dia. Predators were released at the rate of 1 per leaf after counting the *A. dispersus* population (egg to fourth instar nymphs) and examined daily. Predators were changed to fresh leaf in alternate days till mortality occurred. The used leaves were collected and examined under microscope for counting the number of *A. dispersus* fed by the predator.

Laboratory experiments were conducted to find out the feeding potential and longevity of the *coccenellid* predator, *Cryptolaemus montrouzieri* Muls. and *Chrysopids viz., Mallada astur* (Banks)and *Chrysoperla carnea* Stephens. The predators were housed individually in small plastic containers (20 x 10 cm) covered with gada cloth. Study was conducted for ten individuals for each predator, using the egg and nymphs of SWF separately. The predators were examined daily and fresh leaves with SWF population were provided in alternate days to ensure that the predators always had an excess of prey. The leaves used in the experiment were examined under microscope and the number of SWF population fed by the predator was counted. The study was continued till the mortality of the predator and the longevity was worked out.

3.10.2.4. Mass culturing of predators

Attempts on mass culturing of predators were made for *Cybocephalus* sp., *C. montrouzieri, C. carnea* and *M. astur*. Grape vine mealy bug reared on pumpkin and eggs of *C. cepholonica* were used for rearing of *C. montrouzieri* and chrysopid predators respectively (Anonymous, 1995). Attempts were initiated for mass culturing of *Cybocephalus* sp in the laboratory using *M. esculenta* leaves infested with SWF. The leaves were kept as a bouquet and the petioles were covered with absorbant cotton and immersed in a conical flask containing water. Ten pairs of *Cybocephalus* sp adults were released for egg laying under caged condition.

3.10.3. Parasitoids of *A. dispersus*

3.10.3.1. Collection and identification of the parasitoids of *A. dispersus*

Extensive field surveys were conducted throughout Tamil Nadu to collect the parasitoids of SWF as mentioned in 3.10.1. In guava and cassava regular sampling were made on 20 leaves for observing the presence of parasitoids. The leaf samples with parasitized pupae were cleaned off gently to remove other unwanted materials using a fine camel hair brush and kept in glass vials (12.5 x 2.5 cm) for the emergence of parasitoids. Few of the emerged parasitoids were preserved by mounting on microscopic slides using Hoyer's medium. The specimens were identified at Entomology laboratory, Aligarh Muslim University (Hayat, Pers. Comm. 1999).

3.10.3.2. Parasitization level of the newly recorded parasitoid of *A. dispersus*

Based on the first detection of parasitoids on guava, intensive survey and periodical sampling were done on guava at Patchapalayam Milk Society, Madampatti, Coimbatore to find out the parasitization level. Twenty leaf samples with late instar nymphs of *A.dispersus* were collected randomly in polythene bags (30 x 19 cm) and examined under microscope for counting the number of adults, fourth instar nymphs, puparia with parasitoid emergence hole, and parasitized pupae. The leaves with parasitoid pupae were kept in polythene bags for the emergence of parasitoid. The duration of parasitoid emergence, and the number of parasitoids emerged were recorded.

3.10.3.3. Morphology of the parasitoid of *A.dispersus*

Morphological features of the parasitoid of *A.dispersus* collected from guava leaves were studied on 20 individuals as follows.

- i) body size and colour
- ii) antennae type and segments
- iii) wing type and colour
- iv) leg type and tarsal segments

3.10.3.4. Biology of the parasitoid of *A. dispersus*

The parasitized pupae of *A.dispersus* in guava leaves were taken in petriplates (9 cm dia) on moistened filter paper. Observations were recorded on the time of emergence and activities of the parasitoid after emergence. Attempts were also made to study the longevity and level of parasitization of the parasitoid on potted guava seedlings of 5 months old. The leaves with late instar nymphs (third and fourth instar) were covered with leaf cages (15 x 8 cm) where top and bottom of the cages were covered with muslin cloth (Plate 5b). Parasitoids were released on ten leaves at the rate of 2 per leaf. The parasitoids were observed daily using hand magnifier (10x) and adult longevity was recorded. The waxy coat of few fourth instar nymphs were brushed off gently to find colour change of the nymph if any. Observations were made daily and the day on which the pupae changed to black colour was noted. Observations were continued till the emergence of the adults and the number of parasitoids emerged was recorded.

3.10.3.5. Periodical release and recovery of parasitoids of *A. dispersus*

Attempts were initiated to establish the parasitoid culture by periodical release of parasitoids and recovery on trees of guava at Insectary and Orchard. Guava leaves with parasitized pupae of *A.dispersus* collected from Patchapalayam, Coimbatore were stapled on the under surface of the leaves having third and fourth instar nymphs of *A. dispersus*. In Insectary totally 3 releases were made, first on October first week with five number of parasitoid pupae, second and third releases were made with 10 numbers of parasitized pupae on October third week and November first week. In orchard 3 releases were made, first on October first week, second on November first week and third on November fourth week with 15 numbers of parasitized pupae at each release. Leaves at released spots were tagged and examined periodically using a hand magnifier (10x) for the presence of any colour change of the pupae. Leaf samples were also collected at fortnightly intervals, and examined under microscope for the presence of parasitoid, puparia with parasitoid emergence hole and parasitized pupae.

3.10.4. Parasitic mite on *A.dispersus*

During field surveys on natural enemy complex of *A. dispersus* in TNAU campus a parasitic mite species was found feeding on nymphal stages of *A. dispersus*. Hence surveys were intensified on various host plants of *A. dispersus* and the mites were identified at the Department of Agricultural Entomology, TNAU, Coimbatore (Ramaraju, Pers. Comm. 1999).

3.11. Evaluation of crop varieties for *A. dispersus* infestation

3.11.1. Field reaction of cassava (*M. esculenta*) accessions against *A. dispersus* infestation

A field trial was conducted during April to August, 1999 at TNAU Orchard, Coimbatore to evaluate the cassava germplasms for their reaction to *A.dispersus.* Totally 94 accessions were screened initially and the damage intensity was evaluated for 35 accessions for a period from 2 months to 6 months. Each accession was planted in a ridge with five plants. In each accession, three plants were selected randomly and tagged which acted as replications. The grading of accessions for *A. dispersus* infestation was done on 3 leaves per replication as follows:

Damage category	Grade	Damage intensity
Free	0	No damage
Very low	1	10% leaf area damaged with egg wax spirals, 1-10 nymphs and adults.
Low	2	25% leaf area damaged with egg wax spirals, 11-25 nymphs and adults.
Medium	3	50% leaf area damaged with egg wax spirals, 26-50 nymphs and adults with yellow speckling.
High	4	75% leaf area damaged egg wax spirals, 51-75 nymphs and adults with slight leaf crinkling.
Very high	5	100% leaf area damaged with egg wax spirals, 76-100 nymphs and adults with leaf crinkling.
Extreme	6	100% leaf area with egg wax spirals, >100 nymphs and adults with sooty mould.

Observations were recorded at monthly intervals on the incidence of *A. dispersus* and grading was done based on leaf area damaged with spirals, nymphs and adults and symptom of damage *viz.,* yellowing, crinkling and sooty mould on three leaves per plant (Plate 6 and 7). Based on the infestation of *A. dispersus*, the cassava accessions were categorised. The damage intensity of all the accessions under low and moderate population and damage category selected accessions from high, very high and extreme category were statistically analysed to find out the accessions resistance to *A. dispersus* infestation for further screening studies.

3.11.2. Reaction of *P. guajava* varieties against *A. dispersus*

Evaluation of guava varieties for the infestation of *A. dispersus* was done on ten guava varieties of 15 years old at TNAU Orchard, Coimbatore. Observations on leaf area with egg spirals, nymphs and adults of *A. dispersus* were recorded for four months from July to October 1999 on 10 leaves per tree and three trees were maintained as replication for each variety.

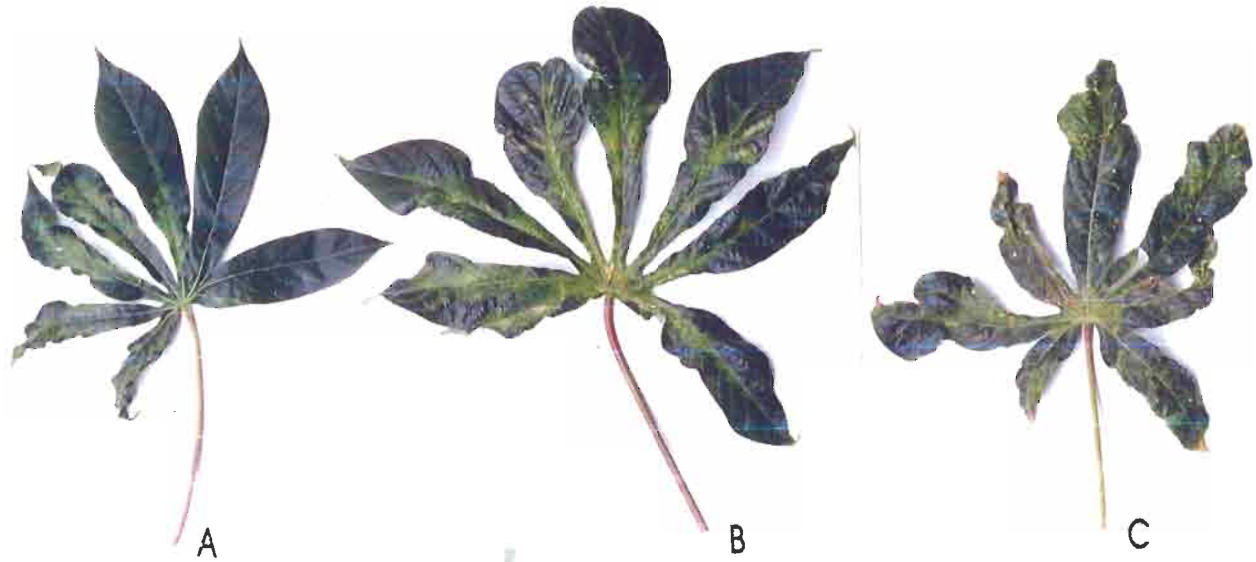
3.11.3. Reaction of *Gossypium* spp. genotypes against *A. dispersus*

Evaluation of cotton genotypes for the infestation of *A. dispersus* was done at Cotton Breeding Station, TNAU, Coimbatore on 6 wild species and 12 cultivated species. Each cultivated species was raised in 5 rows. Observations were made on leaf area with egg spiral, number of nymphs and adults on five leaves per plant for three plants. In case of wild species, observations were taken on three branches. Totally three observations were taken on population build up at fortnightly intervals from October to November 1999.

3.12. Population dynamics of *A. dispersus*

Studies were conducted to find out the impact of natural enemies and weather parameters on population dynamics of *A.dispersus* on cassava at TNAU Orchard and guava at Patchapalayam Milk Society, Madampatti, Coimbatore. The

Plate 6. Symptoms of damage by *A. dispersus* on cassava



A. Yellow speckling on leaf
B. Moderate yellowing of leaf
C. Yellowing with slight crinkling of leaf

D. Yellowing and crinkling of the entire leaf
E. Crinkling with slight blackening of leaf
F. Blackening of the entire leaf due to sooty mould

Plate 7. Sooty mould on cassava

A. Under surface of leaves with black spots due to fungal growth

B. Severe infestation of *A. dispersus* on cassava leads to complete blackening of plant due to dense growth of sooty mould study was made during May 1999 to March 2000 at weekly intervals on guava and August 1998 to March 2000 at fortnightly intervals on cassava.

Observations on pest population and natural enemies were made from 5 branches, 4 leaves each and totally in 20 leaves on guava and in 10 plants of cassava at 2 leaves per plant. Correlation and multiple regression analysis were made between the population of *A. dispersus* and natural enemies (parasitoids and predators) and weather parameters *viz.*, maximum temperature (°C), minimum temperature (°C) maximum relative humidity (forenoon) (%), minimum relative humidity (afternoon) (%), rainfall (mm) and wind velocity (kmph). Weather data were collected from the Department of Meteorology, TNAU, Coimbatore.

3.13. Statistical analysis

The data collected from various experiments were statistically analysed using Completely Randomised Block Design (CRBD) for field experiments and Randomised Block Design (RBD) and split plot designs for pot culture and laboratory experiments as described by Panse and Sukhatme (1981). The data were transformed to sqr (x + 0.5) and Arc sine wherever required as per the method described by Poisson for statistical analysis (Snedcor and Cochran, 1967). Duncans Multiple Range Test (DMRT) was applied for comparing treatment means (Duncan, 1955). Linear and multiple regression analyses were carried out following the method of Snedcor and Cochran (1967) to find out the influence of different variables on population dynamics of *A. dispersus*.

RESULTS

CHAPTER 1V
RESULTS

Survey was conducted to know the population level, distribution of spiralling whitefly among crop species and its natural enemy complex in different districts of Tamil Nadu during 1997-1998. Laboratory and field trials were carried out on the biology, varietal reaction and management practices for *A. dispersus*. The results are presented in this chapter.

4.1. Host range and intensity of damage by spiralling whitefly in Tamil Nadu

4.1.1. Distribution of *A. dispersus* in Tamil Nadu

The results on distribution and damage intensity of *A. dispersus* in Tamil Nadu are presented in Table 1. *A. dispersus* was found in all the districts of Tamil Nadu, except Udhagamandalam (Fig.1). The damage intensity was very high in Coimbatore, Dharmapuri, Namakkal, Salem, Erode, Kanyakumari and Tuticorin, which ranged from 76.04 to 94.17 per cent. In northern districts of Tamil Nadu, the intensity ranged from very low to low. Central Tamil Nadu and Southern Tamil Nadu showed the highest incidence of *A. dispersus*.

4.1.2. Incidence and population density of *A. dispersus* among different crops at city and villages in Coimbatore

Significant differences were observed in population density of *A. dispersus* on various host plants at city (home, kitchen garden, Institutions and road sides) and in villages (homes and fields) (Tables 2 and 3). The incidence was high (>90%) on *M. escuenta*, *P. guajava* (Plate 1), *C. papaya*, *Musa* spp., *Annona squamosa* L., *Terminalia catappa* L., *Thespesia populnea* Soland., *Manihot glaziovii* M. Arg. and *Manihot* sp.. The incidence on crops at city and roadsides ranged from 31.18 to 99.83 per cent with an average of 80.12 per cent whereas it

Table 1. Damage intensity of spiralling whitefly among different districts of Tamil Nadu

Sl. No.	District	Damage intensity (%)	Grade	Category of damage
1.	Chennai	15.07	3	Low
2.	Coimbatore	94.17	6	Very high
3.	Dharmapuri	79.34	6	Very high
4.	Dindigul	23.65	3	Low
5.	Erode	79.15	6	Very high
6.	Namakkal	82.71	6	Very high
7.	Salem	87.89	6	Very high
8.	Udhagamandalam	0.0	1	Nil
9.	Vellore	21.40	3	Low
10.	Tiruvallur	17.21	3	Low
11.	Kanchipuram	10.42	2	Very low
12.	Thiruvannamalai	13.22	3	Low
13.	Viluppuram	8.92	2	Very low
14.	Cuddalore	12.06	3	Low
15.	Peramabalur	18.04	3	Low
16.	Tiruchchirappali	21.74	3	Low
17.	Karur	21.06	3	Low
18.	Nagapattinam	20.11	3	Low
19.	Thiruvarur	8.13	2	Very low
20.	Thanjavur	17.15	3	Low
21.	Pudukkottai	7.49	2	Very low
22.	Sivaganga	10.02	2	Very low
23.	Madurai	68.59	5	High
24.	Theni	47.35	4	Moderate
25.	Virudunagar	16.93	3	Low
26.	Ramanathapuram	8.16	2	Very low
27.	Tuticorin	76.04	6	Very high
28.	Tirunelveli	52.35	5	High
29.	Kanyakumari	78.21	6	Very high

Fig.1. Damage intensity of spiralling whitefly among various districts of Tamil Nadu

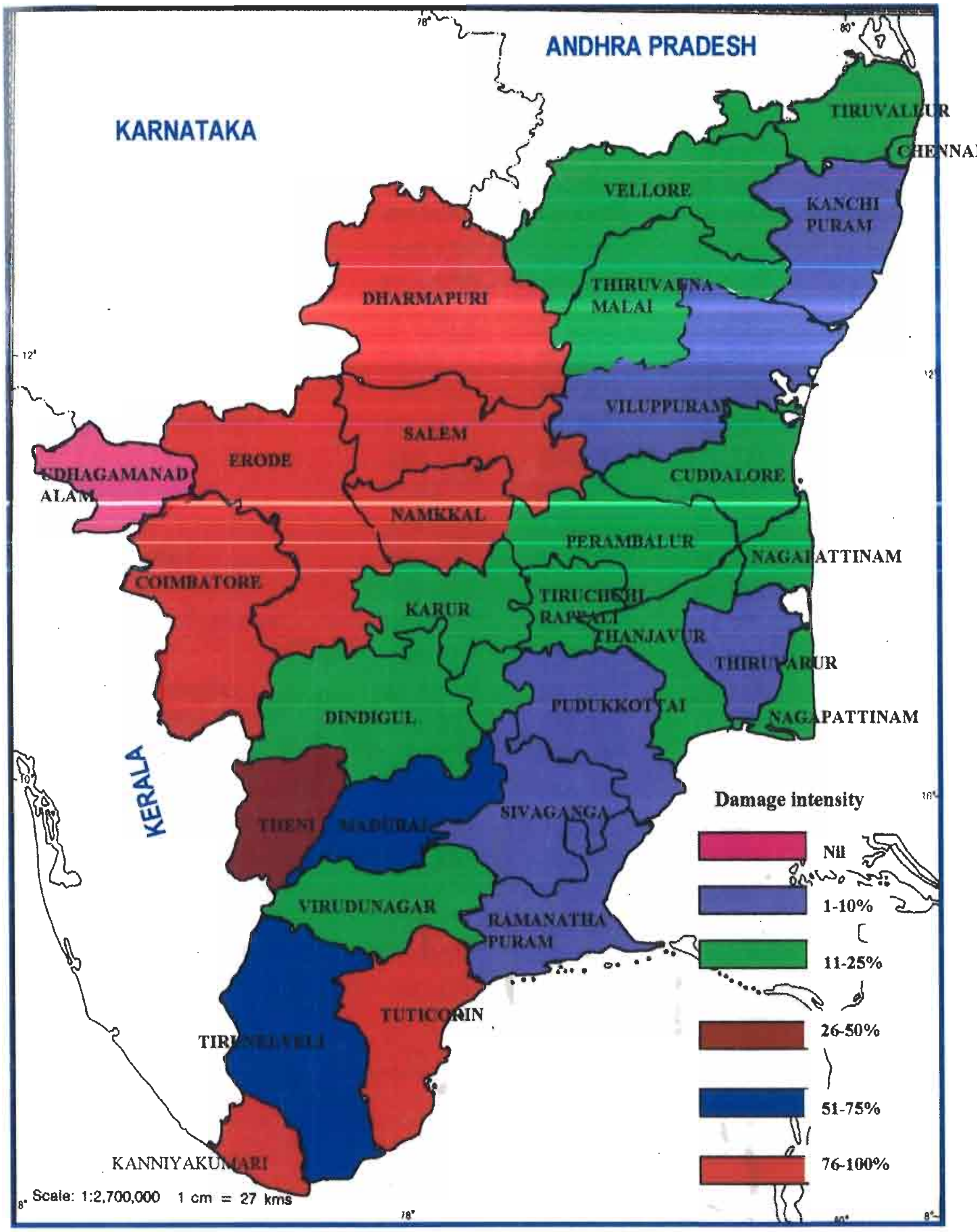


Table 2. Incidence of *A. dispersus* among different crops at city and road sides

Sl. No.	Crops	Incidence (%)*	Leaf area damage (%)*	No. of nymphs / leaf*	No. of adults / leaf*
1.	*Manihot esculenta*	99.83^{a} (88.97)	98.00^{a} (87.91)	154.90^{b} (2.19)	198.06^{b} (2.30)
2.	*Psidium guajava.*	99.17^{ab} (86.89)	97.00^{ab} (83.92)	103.70^{c} (2.02)	139.40^{cd} (2.15)
3.	*Gossypium hirsutum*	62.46^{hij} (52.22)	67.50^{def} (57.94)	10.21^{hi} (1.05)	18.30^{hi} (1.29)
4.	*Abelmoschus esculentus*	80.39^{fgh} (65.72)	62.50^{def} (52.25)	11.72^{hi} (1.10)	16.40^{j} (1.24)
5.	*Solanum melongena.*	88.89^{efgh} (71.91)	89.00^{bc} (72.63)	28.00^{gh} (1.46)	39.20^{fg} (1.60)
6.	*Lycopersicon esculentum*	92.59^{cdef} (80.92)	85.00^{cd} (67.21)	14.75^{hi} (1.20)	9.70^{jk} (1.03)
7.	*Capsicum annuum*	98.93^{abc} (86.12)	97.50^{ab} (84.91)	15.70^{hi} (1.22)	11.70^{j} (1.10)
8.	*Cajanus cajan*	97.43^{abcd} (84.25)	87.50^{bcd} (70.29)	12.64^{hi} (1.13)	15.70^{hj} (1.22)
9.	*Glycine max*	54.47^{ijk} (47.85)	41.00^{fghi} (38.82)	9.40^{ij} (1.02)	16.20^{k} (1.24)
10.	*Solanum trilobatum*	84.88^{efgh} (68.12)	57.50^{fgh} (50.31)	11.2^{hi} (1.09)	14.20^{hij} (1.18)
11.	*Amorphophallus compoanulatus*	88.57^{defg} (74.59)	89.75^{abc} (75.29)	29.14^{g} (1.48)	42.57^{ef} (1.63)
12.	*Ricinus communis*	64.18^{hij} (52.94)	49.50^{fghi} (46.72)	10.43^{hi} (1.06)	15.30^{hij} (1.21)
13.	*Arachis hypogea*	79.21^{fghi} (66.85)	75.50^{de} (62.19)	8.70^{hi} (0.99)	10.40^{j} (1.06)
14.	*Carica papaya* (leaf)	93.13^{cdef} (78.71)	87.50^{bcd} (69.99)	82.90^{cd} (1.92)	96.17^{cd} (1.99)
15.	*Carica papaya* (fruit)	43.42^{kl} (40.61)	42.00^{fghi} (40.13)	9.92^{ij} (1.04)	17.2^{hi} (0.91)
16.	*Musa* spp.	92.70^{cdef} (75.32)	85.00^{cd} (69.84)	62.40^{de} (1.80)	8712^{e} (1.95)

Contd....

Sl. No.	Crops	Incidence (%)	Leaf area damage (%)*	No. of nymphs / leaf*	No. of adults / leaf*
17.	*Punica granatum*	68.83^{hi} (59.06)	63.50^{def} (52.83)	4.60^{ij} (0.75)	5.21^{kl} (0.79)
18.	*Annona squamosa*	96.05^{bcd} (81.26)	90.00^{abc} (74.16)	28.00^{gh} (1.46)	34.02^{gh} (1.54)
19.	*Ficus carica*	40.86^{nop} (43.18)	23.75^{kl} (27.76)	8.17^{ij} (0.96)	14.87^{kl} (1.20)
20.	*Terminalia catappa*	96.43^{bcd} (81.98)	90.75^{abc} (76.29)	54.10^{def} (1.74)	86.42^{e} (1.94)
21.	*Cocos nucifera*	31.41^{lm} (34.09)	25.00^{ij} (31.02)	7.28^{hi} (0.92)	19.38^{hi} (1.31)
22.	*Thespesia populnea*	99.92^{a} (88.34)	98.25^{a} (86.93)	79.80^{de} (1.91)	162.10^{c} (2.01)
23.	*Manihot glaziovii*	99.05^{ab} (87.15)	96.75^{abc} (85.14)	188.20^{a} (2.28)	215.20^{a} (2.34)
24.	*Manihot* sp.	99.12^{ab} (87.94)	96.00^{abc} (84.92)	109.0^{c} (2.04)	$143\ 14^{cd}$ (2.06)
25.	*Pongamia glabra*	31.18^{lm} (33.95)	24.00^{jk} (30.19)	6.60^{ij} (0.88)	13.90^{hij} (1.17)
26.	*Ficus bengalensis*	60.14^{hij} (52.85)	70.50^{def} (57.10)	23.02^{gh} (1.38)	41.31^{fg} (1.63)
27.	*Bauhinia purpurea*	49.69^{klm} (41.63)	38.00^{ij} (38.06)	6.02^{hij} (0.85)	19.07^{hi} (1.30)
28.	*Plumeria alba*	58.03^{ijk} (50.46)	47.00^{fghi} (44.21)	17.80^{ghi} (1.27)	22.37^{hi} (1.13)
29.	*Poinsettia pulcherrima*	94.09^{cde} (83.59)	89.25^{bc} (72.86)	61.80^{de} (1.80)	79.17^{e} (1.91)
30.	*Dombia spectabilis*	91.02^{defg} (81.90)	72.50^{de} (59.37)	18.79^{gh} (1.30)	23.12^{hi} (1.38)
31.	*Acalypha indica*	98.74^{abc} (86.54)	97.25^{ab} (83.45)	49.58^{ef} (1.71)	76.30^{ef} (1.89)

*Figures in parentheses are Arc sine transformed values .
Means followed by small letters in common within columns are not significantly different at 5 % level DMRT.

Table 3. Incidence of *A. dispersus* among different crops at village level

Sl. No.	Crops	Incidence (%)*	Leaf area damaged (%)*	No. of nymphs / leaf **	No. of adults / leaf **
1.	*Manihot esculenta*	48.00^{a}	38.25^{b}	27.70^{a}	29.08^{a}
		(43.78)	(38.05)	(5.24)	(5.43)
2.	*Psidium guajava*	45.43^{a}	41.00^{b}	12.80^{bc}	14.73^{bcd}
		(42.28)	(39.62)	(3.51)	(3.85)
3.	*Gossypium hirsutum*	17.86^{def}	8.50^{efgh}	2.05^{e}	10.35^{de}
		(24.12)	(16.85)	(1.53)	(3.09)
4.	*Abelmoschus esculentus*	18.05^{cde}	15.65^{def}	2.40^{e}	4.28^{fgh}
		(24.22)	(23.16)	(1.70)	(2.16)
5.	*Solanum melongena*	15.45^{def}	8.63^{efgh}	2.67^{de}	7.00^{efg}
		(22.47)	(17.05)	(1.76)	(2.71)
6.	*Lycopersicon esculentum*	14.95^{efg}	15.50^{def}	2.75^{e}	6.78^{efg}
		(22.65)	(22.91)	(1.75)	(2.66)
7.	*Capsicum annuum*	29.68^{b}	26.25^{c}	2.68^{de}	6.65^{efg}
		(32.17)	(29.96)	(1.77)	(2.63)
8.	*Ricinus communis*	8.68^{fg}	11.75^{efgh}	4.00^{de}	4.60^{fgh}
		(16.89)	(19.95)	(2.07)	(2.17)
9.	*Arachis hypogea*	16.35^{def}	12.50^{efg}	2.95^{de}	10.18^{de}
		(23.74)	(20.42)	(1.83)	(3.09)
10.	*Cajanus cajan*	19.65^{cde}	14.75^{efg}	1.60^{e}	8.60^{def}
		(26.07)	(22.14)	(1.40)	(2.99)
11.	*Glycine max*	13.58^{efg}	8.75^{efgh}	1.00^{e}	1.30^{j}
		(21.21)	(17.15)	(1.21)	(1.34)
12.	*Carica papaya*	27.68^{bc}	15.88^{def}	3.45^{de}	10.10^{de}
		(31.64)	(23.20)	(1.97)	(3.19)
13.	*Musa* spp.	19.05^{cde}	18.38^{de}	3.55^{de}	8.23^{def}
		(25. 86)	(25.05)	(1.99)	(2.88)
14.	*Punica granatum*	11.70^{efg}	10.63^{efgh}	2.65^{de}	3.30^{ghi}
		(19.88)	(18.95)	(1.77)	(1.95)

Contd....

Sl. No.	Crops	Incidence (%)*	Leaf area damaged (%)*	No. of nymphs / leaf **	No. of adults / leaf **
15.	*Annona squamosa*	22.50^{cd}	5.38^{gh}	3.08^{de}	3.50^{ghi}
		(28.09)	(12.89)	(1.88)	(1.96)
16.	*Cocos nucifera*	20.98^{cd}	17.88^{de}	4.65^{de}	6.08^{efg}
		(27.04)	(24.72)	(2.18)	(2.51)
17.	*Lablab typicus*	16.03^{def}	21.63^{cd}	1.98^{e}	3.00^{hij}
		(23.41)	(27.61)	(1.58)	(1.86)
18.	*Vitis vinifera*	19.68^{cde}	11.25^{efgh}	2.10^{e}	1.45^{j}
		(25.61)	(19.55)	(1.58)	(1.38)
19.	*Tectona grandis*	14.48^{efg}	8.88^{efgh}	1.98^{e}	2.05^{ij}
		(21.21)	(77.27)	(1.54)	(1.57)
20.	*Acalypha indica*	28.30^{bc}	45.38^{ab}	13.00^{bc}	29.13^{a}
		(31.67)	(42.27)	(3.50)	(5.26)
21.	*Thespesia populnea*	44.58^{a}	56.50^{a}	19.75^{b}	16.58^{bc}
		(41.82)	(48.99)	(4.14)	(4.12)
22.	*Emblica officinalis*	12.50^{efg}	6.75^{fgh}	1.35^{e}	4.83^{fgh}
		(20.56)	(14.83)	(1.35)	(2.29)
23.	*Ficus bengalensis*	6.50^{fgh}	3.50^{h}	8.30^{cd}	21.15^{ab}
		(14.48)	(10.69)	(2.91)	(4.50)
24.	*Plumeria alba*	8.75^{fg}	7.50^{efgh}	1.70^{e}	13.45^{cd}
		(16.72)	(15.71)	(1.43)	(3.71)

* Figures in parentheses are Arc sine transformed values

** Figures in parentheses are sqr. (x+0.5) transformed values

Means followed by small letters in common within columns are not significantly different at 5% level (DMRT).

was less and it ranged from 6.50 to 48.00 per cent among different crops at village level (Table 3). The per cent leaf damage was high (>90) on crops *viz.*, *M. esculenta, P. guajava, C. annuum* L. (Plate 8), *T. catappa* (Plate 9), *A. squamosa, A.indica, T. populnea, M. glaziovii* and *Manihot* sp. which ranged from 96.00 to 98.00 in city and roadsides (Plates 8 and 9). Nymphal population was significantly high (188.20 per leaf) on *M. glaziovii* followed by *M. esculenta* (154.90), *T. populnea* (79.80) and *P. guajava* (103.70). The same trend was noted in adult population (Table 3) on crops found in city. The per cent leaf area damage, nymph and adult population on crops at village level ranged from 3.5 to 56.50, 1.00 to 27.70 and 1.3 to 29.13 respectively. Incidence and population density of SWF were also high on *M. esculenta* and *P. guajava* followed by *C. cajan* L. and vegetable crops. From the results, it was clearly evident that population load was high on crops at homes, road side and bus stands in city than fields at village.

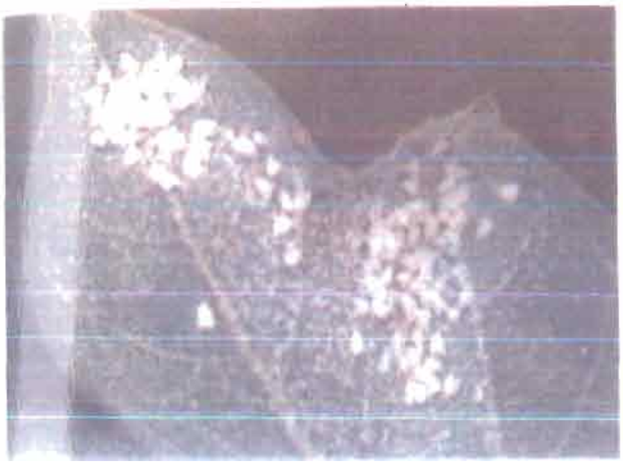
4.1.3. Incidence of *A. dispersus* on various crop families

The data on survey carried out during 1997 to 1999 in Tamil Nadu showed the occurrence of *A. dispersus* on 128 crop species belonging to 52 families (Appendix I). The crop families with high incidence of *A. dispersus* is set out in Table 4. Incidence was very high on crops of Euphorbiaceae family with the maximum of 99.83 per cent and leaf area damage was 90.00 per cent. The next preferred crop families as host were Malvaceae, Myrtaceae and Solanaceae with > 90 per cent of incidence and leaf area damage.

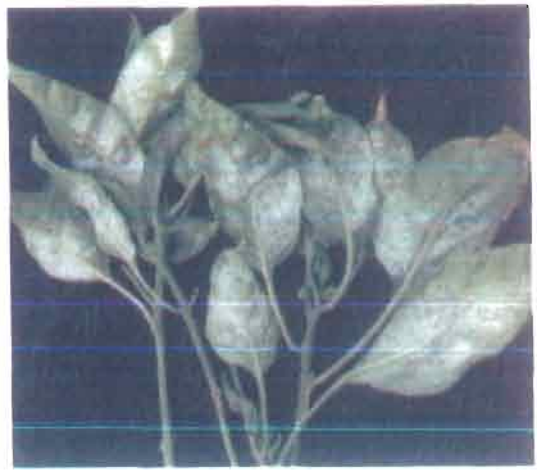
4.1.4. Alternate weed hosts of *A. dispersus*

The occurrence of *A. dispersus* was recorded on 25 weeds belonging to 12 families in Coimbatore (Tables 5 and 6). The per cent incidence was highest on *Corchorus capsularis* L. (99.80), *Euphorbia heterophylla* L. (99.76) and *Euphorbia hirta* L. (99.24) and all the three weed specie were statistically on par.

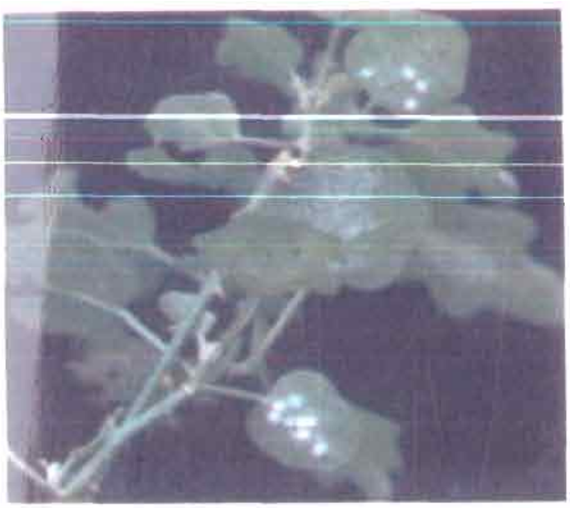
Plate 8. Host plants of spiralling whitefly



Gossypium sp.



Capsicum annuum



Solanum trilobatum

Lycopersicon esculentum

Arachis hypogea

Glycine max

Plate 9. Fruit crops as host plants for *A. dispersus*

Musa sp.

Terminalia catappa

Leaf

Fruit

Carica papaya

Table 4. Incidence of spiralling whitefly among crop families

Sl. No.	Crop family	Total crop species with SWF incidence	Incidence % (Range)	Leaf area damage % (Range)
1.	*Euphorbiaceae*	14	26.3 - 99.83	10.0 - 98.0
2.	*Malvaceae*	7	22.76 -99.92	18.50 - 98.25
3.	*Myrtaceae*	3	31.00 - 99.17	10.00 - 97.00
4.	*Solanaceae*	5	20.40 - 98.93	85.00 - 97.50
5.	*Fabaceae*	20	1.93 - 98.22	10.00 - 96.50
6.	*Annonaceae*	3	5.00 - 96.05	4.00 - 90.00
7	*Araceae*	1	27.42 - 88.57	40.00 - 99.75
8.	*Caricaceae*	1	43.42 - 93.13	42.00 - 87.50
9.	*Musaceae*	1	16.62 - 92.70	12.50 - 85.00
10.	*Punicaceae*	1	20.41 - 68.83	24.30 -63.50
11.	*Moraceae*	7	40.86 - 60.14	3.00 - 62.00
12.	*Combretaceae*	1	20.72 - 98.00	80.00 - 99.00

Table 5. Spiralling whitefly population on different weeds

Sl. No.	Weeds	Incidence (%)*	Leaf area damage (%)*	No. of egg per cm^{2}**
1.	*Euphorbia heterophylla*	99.76^{a} (88.80)	97.50^{a} (86.11)	60.05^{a} (7.78)
2.	*Euphorbia hirta*	99.24^{a} (87.51)	95.00^{a} (83.17)	32.60^{e} (5.68)
3.	*Corchorus capsularis*	99.80^{a} (88.85)	100.00^{a} (90.00)	37.95^{ed} (6.13)
4.	*Corchorus olitorius*	96.94^{b} (81.85)	96.25^{a} (81.32)	34.90^{de} (5.89)
5.	*Eclipta alba*	92.32^{c} (77.65)	95.00^{a} (83.17)	41.00^{c} (6.39)
6.	*Vernonia cineraria*	85.64^{d} (68.71)	92.50^{a} (79.91)	24.80^{f} (4.92)
7.	*Vicoa indica*	41.27^{ij} (39.92)	29.00^{fg} (34.19)	11.20^{k} (3.32)
8.	*Acalypha indica*	69.90^{e} (56.84)	96.25^{a} (81.10)	54.60^{b} (7.42)
9.	*Rungia repens*	62.21^{f} (52.13)	51.25^{cd} (45.78)	21.65^{fg} (4.63)
10.	*Ruellia tuberosa*	82.42^{d} (66.00)	34.25^{efg} (35.18)	19.10^{gh} (4.35)
11.	*Commelina bengalensis*	51.14^{gh} (45.65)	44.25^{de} (41.52)	12.05^{jk} (3.43)
12.	*Alternanthra triandra*	55.79^{fg} (48.35)	76.25^{b} (61.11)	23.20^{f} (4.81)
13.	*Amaranthus tricolor*	56.51^{fg} (48.76)	77.50^{b} (70.21)	60.20^{a} (7.71)
14.	*Sonchus arvensis*	40.85^{ij} (39.70)	55.00^{c} (48.07)	11.80^{jk} (3.42)
15.	*Convolvulus* sp.	51.27^{gh} (45.75)	50.00^{ed} (42.12)	11.45^{k} (3.37)

Contd…

Sl. No.	Weeds	Incidence (%)*	Leaf area damage (%)*	No. of egg per cm^2**
16.	*Aristolachia bracteata*	35.96^{j} (36.75)	42.25^{de} (39.13)	7.65^{l} (2.72)
17.	*Abutilon indicum*	41.87^{ij} (40.31)	52.50^{cd} (46.98)	16.90^{hi} (4.05)
18.	*Trianthema portulacastrum*	20.72^{k} (27.03)	37.75^{ef} (37.21)	7.65^{l} (2.74)
19.	*Amaranthus viridis*	44.37^{hi} (41.74)	58.75^{c} (50.17)	33.80^{de} (5.79)
20.	*Tridax procumbens*	11.47^{l} (19.64)	12.25^{i} (20.72)	4.05^{m} (1.99)
21.	*Solanum elaegnifolium*	25.49^{k} (30.19)	25.25^{gh} (29.12)	14.45^{ij} (3.76)
22.	*Datura metal*	10.39^{l} (18.79)	16.00^{hi} (24.46)	6.90^{l} (2.59)
23.	*Parthenium hysterophorus*	8.98^{l} (17.34)	10.00^{i} (18.21)	4.00^{m} (1.92)

* Figures in parentheses are Arc sine transformed values

** Figures in parentheses are Sqr (x + 0.5) transformed values

Means followed by small letters in common within columns are not significantly different at 5% level (DMRT)

Table 6. Nymphal and adult population of SWF on different weeds

Sl. No.	Weeds	No.of early instar nymph / cm^2*	No.of late instar nymph / leaf*	No. of adult / leaf*
1.	*Euphorbia heterophylla*	49.40^{a} (7.00)	62.05^{a} (7.86)	34.90^{a} (5.67)
2.	*Euphorbia hirta*	15.35^{fghi} (3.87)	19.05^{d} (4.35)	4.80^{cd} (2.11)
3.	*Corchorus capsularis*	32.90^{c} (5.71)	45.95^{b} (6.75)	8.80^{b} (2.89)
4.	*Corchorus olitorius*	16.75^{fg} (4.06)	26.05^{c} (5.08)	8.90^{b} (2.97)
5.	*Eclipta alba*	21.25^{e} (4.51)	17.70^{d} (4.19)	8.35^{b} (2.80)
6.	*Vernonia cineraria*	14.15^{ghij} (3.72)	25.25^{c} (5.00)	5.40^{c} (2.21)
7.	*Vicoa indica*	6.15^{l} (2.45)	4.50^{h} (2.06)	2.85^{efgh} (1.67)
8.	*Acalypha indica*	14.50^{fghij} (3.75)	8.25^{g} (2.79)	4.10^{cde} (1.98)
9.	*Rungia repens*	13.25^{hij} (3.59)	11.00^{f} (3.28)	3.10^{defg} (1.72)
10.	*Ruellia tuberosa*	12.30^{ij} (3.48)	3.00^{i} (1.70)	2.05^{fghij} (1.40)
11.	*Commelina bengalensis*	11.60^{j} (3.39)	12.95^{e} (3.59)	1.60^{ij} (1.23)
12.	*Alternanthra triandra*	25.80^{d} (5.01)	7.80^{g} (2.74)	1.70^{hij} (1.28)
13.	*Amaranthus tricolor*	44.20^{b} (6.63)	10.70^{f} (3.26)	10.05^{b} (2.96)
14.	*Sonchus arvensis*	17.60^{ef} (4.14)	14.10^{e} (3.74)	1.75^{hij} (1.30)
15.	*Convolvulus* sp.	6.85^{l} (2.59)	5.00^{h} (2.20)	2.75^{efghi} (1.63)

Contd....

Sl. No.	Weeds	No.of early instar nymph / cm^{2}*	No.of late instar nymph / leaf*	No. of adult / leaf*
16.	*Aristolachia bracteata*	9.15^{k} (2.98)	2.20^{ijk} (1.44)	2.10^{ghij} (1.38)
17.	*Abutilon indicum*	20.30^{e} (4.48)	2.80^{ij} (1.64)	3.30^{def} (1.80)
18.	*Trianthema portulacastrum*	15.80^{fgh} (3.94)	2.40^{ij} (1.50)	1.70^{hij} (1.28)
19.	*Amaranthus viridis*	30.70^{c} (5.53)	8.20^{g} (2.84)	3.40^{cde} (1.83)
20.	*Tridax procumbens*	4.15^{m} (1.98)	2.00^{jk} (1.39)	1.45^{j} (1.18)
21.	*Solanum elaegnifolium*	8.20^{kl} (2.79)	3.00^{I} (1.71)	1.50^{j} (1.21)
22.	*Datura metal*	2.95^{m} (1.69)	1.40^{kl} (1.20)	1.20^{j} (1.09)
23.	*Parthenium hysterophorus*	1.45^{n} (1.18)	1.20^{l} (1.09)	1.20^{j} (1.09)

* Figures in parentheses are Sqr.(x + 0.5) transformed values
Means followed by small letters in common within columns are not significantly different at 5% level (DMRT)

Leaf area damage was high on *E. heterophylla, E. hirta, C. capsularis, C. olitorius, Eclipta alba* L., *Vernonia cineraria* Bioss and Bal, and *Acalypha indica* L. which ranged from 92.50 to 100 per cent (Plate 10). Number of eggs per cm^2 was high on *E. heterophylla* (60.05) followed by *A. indica* (54.60). Early and late instar nymphal population ranged from 1.45 to 49.40 and 1.20 to 62.05 respectively. Adult population ranged from 1.20 to 34.90 on all the weeds surveyed (Table 6). The population was lowest on *Tridox procumbens* L., *Solanum elaegnifolium* Cav., *Datura metal* L. and *Parthenium hysterophorus* L. In general, the incidence and population density of *A. dispersus* were high on weeds belonging to the families Euphorbiaceae and Teliaceae followed by Compositae and Amaranthaceae (Appendix 11).

4.1.5. Host range and incidence of *A. dispersus* in cassava (*M. esculenta*) growing districts

Occurrence of *A.dispersus* was found on 22 crop species in Erode. The incidence was high on *M. esculenta* (85.95 per cent) followed by *A.indica* (65.22 per cent) and *T. populnea* (46.78 per cent) (Table 7). Nineteen plant species were recorded as host plants for *A.dispersus* in Salem (Table 8). Among them, the highest incidence was found on *M. esculenta* (77.09 per cent) followed by *P. guajava* (66.24 per cent), *Crossandrum undulaefolia* Salisb. (63.58 per cent), *Lycopersicon esculentum* Mill. (60.30 per cent) and *T. catappa* (59.58 per cent) which were on par. The occurrence of *A.dispersus* in Dharmapuri and Namakkal was noted on 19 and 13 crop species respectively (Tables 9 and 10). In Namakkal high level of incidence was recorded on *M. esculenta* (88.75 per cent) and *Punica granatum* L.(80.43 per cent), which was on par followed by *Musa* spp. (65.55 per cent). In all the four districts, *A. dispersus* incidence, leaf area damage, nymph and adult population were significantly higher on *M. esculenta* than on other crops.

Plate 10. Weeds as hosts plants for *A. dispersus*

Euphorbia heterophylla

Euphorbia hirta

Corchorus sp.

Corchorus capsularis

Corchorus olitorius

Vernonia cineraria

Table 7. Occurrence of *A. dispersus* on various plant species in Erode

Sl. No.	Host plants	Incidence (%)*	Leaf area damage (%)*	No.of nymph/ leaf**	No. of adult/leaf**
1.	*Psidium guajava*	41.62[cd] (40.05)	21.10[cde] (26.80)	4.63[def] (2.23)	11.00[cde] (3.29)
2.	*Carica papaya*	41.34[cd] (39.58)	17.80[cdef] (24.71)	5.64[cdef] (2.30)	12.56[bcde] (3.42)
3.	*Capsicum annuum*	42.62[cd] (40.73)	29.70[bc] (31.88)	4.60[cdef] (2.21)	7.84[efg] (2.86)
4.	*Acalypha indica*	65.22[b] (53.88)	32.90[b] (34.99)	6.622[bcde] (2.66)	10.13[def] (3.09)
5.	*Pisonia alba*	9.67[e] (18.14)	5.00[hi] (12.80)	1.64[efg] (1.466)	1.62[hij] (1.46)
6.	*Tectona grandis*	10.45[e] (18.32)	3.38[ij] (10.20)	1.30[fh] (1.29)	3.08[hij] (1.80)
7.	*Lycopersicon esculentum*	36.77[cd] (37.25)	26.60[bcd] (29.54)	18.06[b] (3.69)	5.70[efgh] (2.46)
8.	*Rosa chinensis*	10.63[e] (19.01)	5.10[hi] (13.01)	1.86[defg] (1.53)	3.28[ghi] (1.94)
9.	*Thespesia populnea*	46.78[c] (42.96)	30.20[bc] (32.80)	12.22[b] (3.51)	15.48[bcd] (3.87)
10.	*Manihot esculenta*	85.95[a] (68.00)	54.00[a] (47.37)	49.88[a] (7.02)	42.54[a] (6.52)
11.	*Punica granatum*	10.77[e] (19.14)	3.60[ij] (10.81)	1.68[efg] (1.47)	4.26 [fghi] (12.18)
12.	*Cocos nucifera*	4.56[e] (12.32)	3.80[hij] (11.15)	0.98[fg] (1.21)	1.70 [hij] (1.48)
13.	*Musa* spp.	33.61[d] (34.76)	11.50 4[efgh] (19.47)	10.04[bcd] (12.75)	20.00[bc] (4.19)
14.	*Nephelium lappaceum*	10.52[e] (18.90)	5.50[ghi] (13.52)	0.90[fg] (1.17)	3.04[hij] (1.87)

Contd ...

Sl. No.	Host plants	Incidence (%)*	Leaf area damage (%)*	No.of nymph/ leaf**	No. of adult/leaf**
15.	*Zizyphus jujuba*	11.06 (19.41)	9.30^{fghi} (17.74)	1.40^{fg} (1.37)	1.54^{ij} (1.43)
16.	*Plumeria alba*	9.30^{e} (17.74)	21.50^{bcde} (27.62)	1.48^{fh} (1.41)	0.70^{j} (1.09)
17.	*Solanum melongena*	42.49^{cd} (40.68)	16.50^{def} (22.76)	8.14^{bc} (2.94)	16.39^{bc} (4.11)
18.	*Ricinus communis*	37.96^{cd} (37.85)	17.40^{cdef} (24.61)	9.39^{bc} (2.89)	9.07^{def} (3.04)
19.	*Albizzia lebbeck*	40.77^{cd} (39.68)	4.40^{hij} (12.08)	4.54^{cdef} (2.24)	18.08^{b} (4.31)
20.	*Terminalia catappa*	8.32^{e} (16.75)	13.20^{defg} (21.30)	2.92^{cdefg} (1.84)	0.68^{j} (1.08)
21.	*Curcuma longa*	28.33^{c} (36.04)	4.00^{hij} (11.46)	1.26^{cdef} (1.33)	2.43^{fghi} (1.71)
22.	*Embilica officinàlis*	5.31^{e} (13.22)	0.56^{j} (4.23)	0.62^{fg} (1.06)	1.61^{hij} (1.45)

* Figures in parentheses are Arc sine transformed values.

** Figures in parentheses are Sqr. (x + 0.5) transformed values.

Means followed by small letters in common within columns are not significantly different at 5% level (DMRT)

Table 8. Occurrence of *A. dispersus* on various plant species in Salem

Sl. No.	Host plants	Incidence (%)*	Leaf area damage (%)*	No.of nymph/ leaf **	No.of adult/ leaf**
1.	*Psidium guajava*	66.24[a] (55.19)	47.10[b] (43.40)	29.60[b] (5.45)	22.64[b] (4.72)
2.	*Solanum melongena*	23.34[bcd] (28.87)	21.34[cd] (27.48)	1.26[fg] (1.32)	2.56[fg] (1.74)
3.	*Musa* spp.	24.70[bcd] (29.77)	23.41[c] (28.26)	7.46[c] (2.76)	2.96[fg] (1.83)
4.	*Carica papaya*	18.54[bcd] (24.89)	12.15[cdef] (19.61)	2.80[def] (1.73)	4.12[f] (2.09)
5.	*Manihot esculenta*	77.09[a] (62.20)	69.40[a] (57.22)	42.04[a] (6.52)	32.66[a] (5.73)
6.	*Capsicum annuum*	25.02[bcd] (29.98)	14.50[cdef] (21.91)	3.00[def] (1.86)	10.64[c] (3.34)
7.	*Vigna mungo*	17.54[cd] (24.76)	7.70[ef] (16.80)	0.30[g] (0.89)	0.64[g] (1.07)
8.	*Tectona grandis*	20.17[bcd] (26.35)	11.20[cdef] (19.50)	1.34[fg] (1.35)	3.82[f] (2.08)
9.	*Annona squamosa*	23.16[bcd] (28.75)	17.75[cde] (24.91)	1.16[fg] (1.29)	2.87[fg] (1.83)
10.	*Crossandrum undulaefolia*	63.58[a] (44.76)	10.26[cdef] (18.67)	1.24[fgh] (1.32)	3.40[f] (1.97)
11.	*Rosa chinensis*	10.91[d] (19.28)	5.72[f] (13.73)	1.56[efg] (1.43)	0.84[g] (1.15)
12.	*Albizzia lebbeck*	33.76[bc] (35.52)	16.89[cde] (24.26)	2.48[def] (1.72)	3.76[f] (2.06)

Contd ....

Sl. No.	Host plants	Incidence (%)*	Leaf area damage (%)*	No.of nymph/ leaf**	No.of adult/ leaf**
13.	*Ter minalia catappa*	59.58^{a} (52.02)	46.80^{b} (42.30)	4.38^{de} (1.95)	10.56^{cde} (2.91)
14.	*Abelmoschus esculentus*	27.28^{bcd} (31.48)	20.21^{cd} (26.69)	2.50^{def} (1.73)	538^{def} (2.42)
15.	*Vigna radiata*	11.83^{cd} (20.10)	9.18^{def} (17.61)	0.60^{g} (1.07)	3.66^{f} (2.04)
16.	*Lycopersicon esculentum*	60.30^{a} (50.98)	37.41^{b} (37.70)	3.86^{d} (2.09)	9.73^{cd} (3.20)
17.	*Punica granatum*	23.97^{bcd} (29.31)	14.20^{cdef} (22.00)	4.21^{d} (2.17)	9.23^{cd} (3.12)
18.	*Plumeria alba*	15.32^{cd} (23.02)	16.60^{cdef} (23.18)	0.51^{g} (1.02)	4.24^{ef} (2.17)
19.	*Acalypha indica*	39.87^{b} (38.90)	44.00^{b} (41.47)	1.62^{efg} (1.46)	10.82^{c} (3.29)

* Figures in parentheses are Arc sine transformed values

** Figures in parentheses are Sqr. (x + 0.5) transformed values

Means followed by small letters in common within columns are not significantly different at 5% level (DMRT)

Table 9. Occurrence of *A. dispersus* on various host plants in Dharmapuri

Sl. No.	Host plants	Incidence (%)*	Leaf area damage (%)*	No.of nymph /leaf**	No.of adult/ leaf**
1.	*Manihot esculenta*	80.01[a] (67.02)	46.40[b] (42.96)	11.90[a] (3.49)	20.68[abc] (4.52)
2.	*Psidium guajava*	82.43[a] (66.01)	64.80[a] (55.19)	7.72[bc] (2.75)	23.94[a] (4.89)
3.	*Carica papaya*	41.45[bcd] (39.83)	15.55[defg] (23.03)	7.54[bc] (2.73)	11.08[de] (3.40)
4.	*Musa* spp.	43.71[bc] (41.36)	20.80[de] (26.90)	2.20[efg] (1.53)	15.20[bcd] (3.93)
5.	*Capsicum annuum*	31.61[cd] (33.10)	13.30[defg] (22.84)	4.36[cde] (2.17)	11.62[de] (3.44)
6.	*Abelmoschus esculentus*	16.38[ef] (23.87)	11.95[efgh] (20.15)	2.20[efg] (1.58)	1.74[hi] (1.44)
7.	*Glycine max*	26.99[de] (30.76)	12.63[efgh] (20.61)	3.18[def] (1.86)	6.42[fgh] (2.48)
8.	*Vigna mungo*	9.83[fgh] (17.96)	8.50[ghi] (16.92)	0.90[g] (1.18)	1.92[ghi] (1.55)
9.	*Lycopersicon esculentum*	33.85[cd] (34.84)	9.75[fgh] (18.17)	10.62[ab] (3.33)	9.06[ef] (2.95)
10.	*Gossypium hirsutum*	28.50[de] (31.97)	17.50[defg] (23.67)	2.34[efg] (1.61)	5.34[fgh] (2.31)
11.	*Embilica officinalis*	11.35[fg] (19.66)	3.20[ij] (10.27)	1.24[g] (1.10)	1.49[hi] (1.41)
12.	*Hibiscus rosa sinensis*	26.22[de] (30.79)	17.40[def] (24.64)	6.78[bc] (2.70)	1.72[hi] (1.49)
13.	*Acalypha indica*	40.80[bcd] (39.68)	24.70[cd] (29.80)	7.20[bc] (2.77)	14.52[cde] (3.77)
14.	*Thespesia populnea*	54.71[b] (47.77)	31.70[c] (34.15)	3.00 [def] (1.87)	23.88[ab] (4.78)
15.	*Tectona grandis*	11.54[fg] (19.85)	6.70[hij] (14.77)	1.00[fg] (1.20)	2.90[ghi] (1.84)
16.	*Albizzia lebbeck*	40.51[bcd] (39.53)	16.68[defg] (24.10)	4.70[cd] (2.28)	16.56[abcd] (4.08)
17.	*Piper betel*	6.56[g] (14.83)	2.80[j] (9.59)	0.72[g] (1.09)	0.62[i] (1.06)
18.	*Rosa chinensis*	6.93[g] (13.49)	2.50[j] (9.00)	0.78[g] (1.12)	1.70[hi] (1.48)
19.	*Jasminum auriculatum*	5.14[g] (12.44)	1.90[j] (7.89)	0.42[g] (0.96)	1.86[ghi] (1.53)

* Figures in parentheses are Arc sine transformed values

** Figures in parentheses are Sqr (x + 0.5) transformed values

Means followed by small letters in common within columns are not significantly different at 5% level (DMRT)

Table 10. Occurrence of *A. dispersus* on various host plant in Namakkal

Sl. No.	Host plants	Incidence (%)*	Leaf area damage (%)*	No.of nymph/ leaf**	No.of adult/ leaf**
1.	*Manihot esculenta*	88.75^{a} (71.68)	79.90^{a} (64.89)	16.58^{a} (4.11)	16.66^{bc} (4.05)
2.	*Psidium guajava*	52.46^{bc} (46.87)	48.80^{bc} (47.21)	13.94^{ab} (3.76)	5.66^{c} (3.98)
3.	*Punica granatum*	80.43^{a} (64.54)	57.40^{b} (49.47)	7.46^{cd} (2.66)	5.76^{ef} (2.40)
4.	*Carica papaya*	34.25^{def} (35.47)	34.20^{bcd} (35.45)	6.74^{cd} (2.61)	11.84^{cd} (3.45)
5.	*Musa* spp.	65.55^{b} (54.77)	58.60^{b} (49.95)	10.84^{b} (3.37)	36.34^{a} (6.07)
6.	*Lycopersicon esculentum*	21.14^{fh} (26.29)	31.60^{cdef} (33.58)	3.62^{de} (1.99)	6.00^{ef} (2.41)
7.	*Capsicum annuum*	32.03^{ef} (34.23)	41.05^{bcd} (38.55)	5.42^{de} (2.39)	2.32^{g} (1.66)
8.	*Abelmoschus esculentus*	50.26^{bcd} (45.15)	21.25^{def} (27.45)	5.00^{de} (2.34)	7.60^{de} (2.84)
9.	*Solanum nigrum*	39.69^{cde} (39.05)	35.70^{bcd} (36.69)	2.62^{e} (1.77)	3.76^{fg} (2.06)
10.	*Solanum tarvum*	10.80^{g} (19.17)	13.09^{ef} (21.18)	4.24^{de} (2.17)	1.96^{g} (1.56)
11.	*Ricinus communis*	27.15^{ef} (31.40)	12.00^{f} (20.22)	4.54^{de} (2.24)	11.25^{cd} (3.43)
12.	*Thespesia populnea*	41.06^{cde} (39.85)	30.20^{cdef} (33.28)	10.50^{bc} (3.22)	21.28^{b} (4.67)
13.	*Hibiscus rosa sinensis*	20.95^{fg} (27.24)	24.26^{def} (29.49)	2.74^{e} (1.80)	2.26^{g} (1.66)

* Figures in parentheses are Arc sine transformed values

** Figures in parentheses are Sqr. (x + 0.5) transformed values

Means followed by small letters in common within columns are not significantly different at 5% level (DMRT)

4.2. Biology

4.2.1. Description of bio-stages of *A. dispersus*

4.2.1.1. Egg

Eggs were smooth surfaced, elliptical,yellow with translucent and deposited mainly on the adaxial surface of the leaves. They were 0.310 ± 0.011 mm long and 0.119 ± 0.01 mm broad (Table 11). They had a very short stalk. The matured eggs had mycetomes, which appeared yellow coloured at its proximal end (Plate 12). Eggs were laid in characteristic spiral manner covered with waxy coat. Egg wax laying pattern was found in regular and irregular manner (Plate 11).

4.2.1.2. Nymph

There were four distinct nymphal instars. The first instar nymph, the crawlers had functional walking legs and antennae. They were translucent yellowish green,elliptical, with a convex dorsum. They were 0.351 ± 0.041 mm long and 0.168 ± 0.027 mm broad. They found on the leaf surface parallel to vein or veinlet. They had meagre deposits of white powdery wax. The second instar appeared oval and translucent. They had many marginal fringes of wax which covered the body on dorsum. They were 0.517 ± 0.032 mm long and 0.294 ± 0.019 mm broad. A pair of mycetomes appeared clearly in the centre of the body (Table 11) (Plate 12).

Third instar nymphs were oval with 0.641± 0.021 mm long and 0.431 ± 0.022 mm broad. They had numerous evenly spaced glassy wax rods, on the margin of the body produced from abdominal pores with more wax secretion covering the body (Plate 12). Fourth instar nymphs were 1.237 ± 0.042 mm long and 0.795 ± 0.033 mm broad. The body was entirely covered with copious amounts of white waxy material (Plate 13). They secrete numerous number of glassy rod like filaments from the compound pores. The fourth instar, which are

Table 11. Biometrical characters of *A. dispersus*

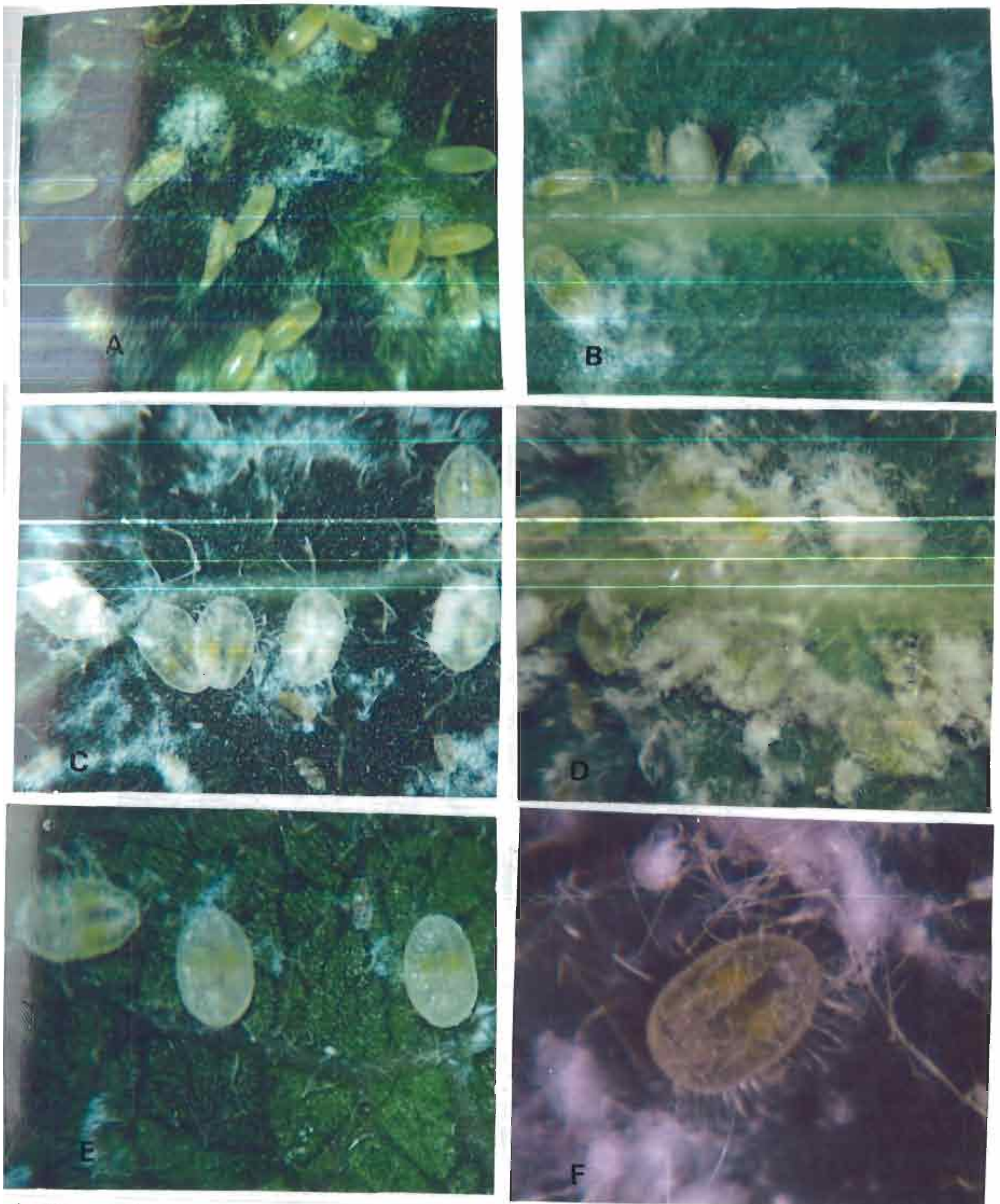
Stage	Length (mm)	Breadth (mm)	Ratio		
			Length	:	Breadth
Egg	0.310 ± 0.011	0.119 ± 0.01			
I instar	0.351 ± 0.041	0.168 ± 0.027	1.132	:	1.412
II instar	0.517 ± 0.032	0.294 ± 0.019	1.473	:	1.75
III instar	0.641 ± 0.021	0.431 ± 0.022	1.24	:	1.466
IV instar	1.237 ± 0.042	0.795 ± 0.033	1.930	:	1.845
Adults					
Male Body	2.410 ± 0.086	1.201 ± 0.031			
Female Body	1.892 ± 0.062	1.069 ± 0.038			

Plate 11. Egg wax pattern of *A. dispersus*

A. Regular spirals

B. Irregular pattern

Plate 12. Bio-stages of *A. dispersus* (Egg and early instar nymphal stages)



A. Eggs (40x)

C . Second instar nymphs (30x)

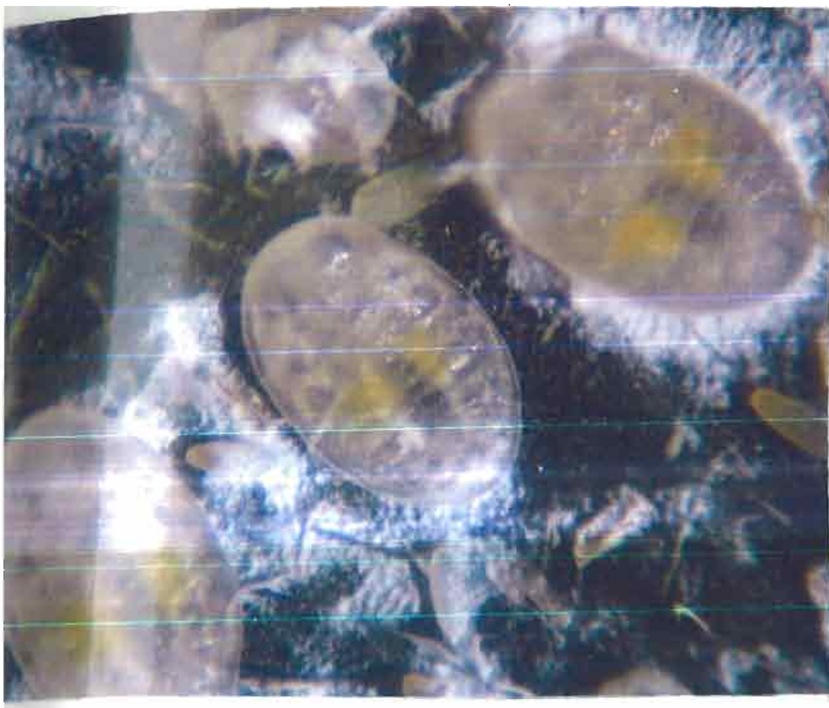
E. Third instar nymphs (30x)

B. Crawler (25x) (lie parallel to vein and Second instar nymphs (25x) [perpendicular to vein]

D. Second and third instar nymphs (30x)

F. Third instar nymphs with evenly spaced glassy rods (40x)

Plate 13. Late instar nymphs of *A. dispersus*



a. Early fourth instar nymphs (40x) (dewaxed)

b. Fourth instar nymphs with white waxy flocculence and glassy rods (40x)

c. Pupae with two red eye spots in the cephalic region (40x) generally called as pupa, were differentiated by the presence of two red eye spots in the cephalic region. This stage is often termed as red eyed nymph (REN) stage (Plate 13).

4.2.1.3. Adult

Adults emerged from the puparia through a 'T' shape exit slit on the dorsal surface of the puparia (Plate 14). The wings of newly emerged adults were clear after unfurling, later covered with a coat of white waxy powder. The eyes were dark reddish brown and the forewings each had two characteristic dark spots. Males were bigger than females. Body length of adults was 2.410 ± 0.086 mm in males and 1.892 ± 0.062 mm in females with breadth of 1.201± 0.031 mm and 1.069 ± 0.038 mm in males and females respectively. Males could be easily distinguished by their elongated claspers, which were exposed from the distal end of the abdomen in between the wings (Table 11) (Plate 14).

4.2.2. Developmental period and longevity of *A. dispersus*

The developmental periods of each instars and adult longevity of *A.dispersus* on various host plants are presented in Tables 12 to 14. Incubation period on various host plants was ranging from 5.2 to 7.9 days. The eggs hatched after 6.4 to 6.7 days on *M. esculenta,* and *P. guajava* and 5.2 to 5.6 days on *S.melongena* and *Gossypium hirsutum.* The crawlers lived for 4.25 to 4.11 days on. *M.esculenta and P. guajava..* Crawler period was shorter (2.15 to 3.5 days) on *S.melongena* , *L. esculentum* and *C. cajan and* longer (5.11 to 6.50 days) on *C. papaya* fruit and leaf.

The developmental period of second instar ranged from 2.7 to 5.00 on various crops. Longer period of 5.00 and 4.91 days were noted on *P. guajava* and *M. esculenta.* The third instar period registered 2.90 to 5.96 days on various hosts tested, with the longer period on *Musa* spp. (5.96) and *A. esculentus*(5.10).

Plate 14. *A. dispersus* adults

A. Puparia with 'T' shape adult emergence exit slit

B. Adults with white powdery coat
a. Female
b. Male with elongated claspers

Table 12: Egg period of *A. dispersus* on various host plants

Host plants	Period (days)	
	Mean $\pm$ SEd	Range
Manihot esculenta	6.40 ± 0.91^{de}	6-9
Psidium guajava	6.70 ± 2.01^{d}	4-9
Gossypium hirsutum	5.60 ± 1.15^{f}	4-8
Capsicum annuum	7.40 ± 1.41^{b}	6-9
Lycopersicon esculentum	6.20 ± 0.91^{e}	4-7
Solanum melongena	5.20 ± 2.17^{g}	4-9
Abelmoschus esculentus	7.90 ± 1.33^{a}	7-10
Cajanus cajan	7.20 ± 1.19^{bc}	5-9
Musa spp.	7.14 ± 1.40^{bc}	6-8
Carica papaya (L.)	7.60 ± 2.67^{a}	5-9
Carica papaya (F)	7.10 ± 1.97^{bc}	4-8

Means followed by small letters in common within columns are not significantly different at 5% level (DMRT)

Table 13: Developmental period of nymphs of *A. dispersus* on various host plants

Host plants	Developmental period / Instar (days)				Total nymphal period (days)
	I	II	III	IV	
Manihot esculenta	4.25 ± 0.83^{cd}	4.91 ± 0.72^{a}	3.85 ± 0.81^{ef}	6.75 ± 1.02^{fg}	19.76 ± 2.06^{c}
Psidium guajava	4.11 ± 1.00^{de}	5.00 ± 1.04^{a}	4.40 ± 1.63^{bc}	6.80 ± 1.16^{ef}	20.31 ± 5.83^{bc}
Gossypium hirsutum	4.45 ± 1.64^{c}	2.80 ± 2.00^{de}	4.00 ± 1.21^{cd}	6.80 ± 2.13^{e}	18.65 ± 2.89^{de}
Capsicum annuum	4.10 ± 0.85^{de}	2.70 ± 0.64^{e}	4.60 ± 1.20^{bc}	7.30 ± 1.91^{b}	18.75 ± 4.93^{cd}
Lycopersicon esculentum	2.40 ± 0.46^{g}	4.75 ± 0.83^{ab}	3.00 ± 1.21^{g}	6.90 ± 1.88^{de}	17.10 ± 4.52^{ef}
Solanum melongena	2.15 ± 0.13^{g}	2.70 ± 1.27^{e}	4.35 ± 0.35^{bc}	8.10 ± 5.31^{a}	17.30 ± 2.75^{ef}
Abelmoschus esculentus	4.65 ± 0.88^{bc}	3.20 ± 0.83^{cd}	5.10 ± 0.72^{ab}	6.65 ± 0.98^{fg}	21.55 ± 4.57^{ab}
Cajanus cajan	3.50 ± 1.47^{f}	2.80 ± 0.80^{de}	2.90 ± 0.94^{g}	7.00 ± 2.11^{cd}	16.20 ± 4.80^{g}
Musa spp.	4.21 ± 1.08^{cd}	4.33 ± 0.62^{b}	5.96 ± 1.20^{a}	7.92 ± 1.00^{ab}	23.97 ± 4.60^{a}
Carica papaya (L.)	6.50 ± 1.31^{a}	3.80 ± 0.59^{c}	3.75 ± 1.04^{ef}	7.20 ± 3.96^{bc}	21.25 ± 4.22^{ab}
Carica papaya (F)	5.11 ± 1.20^{b}	3.00 ± 1.72^{de}	3.90 ± 1.32^{de}	6.50 ± 2.95^{g}	18.51 ± 4.90^{de}

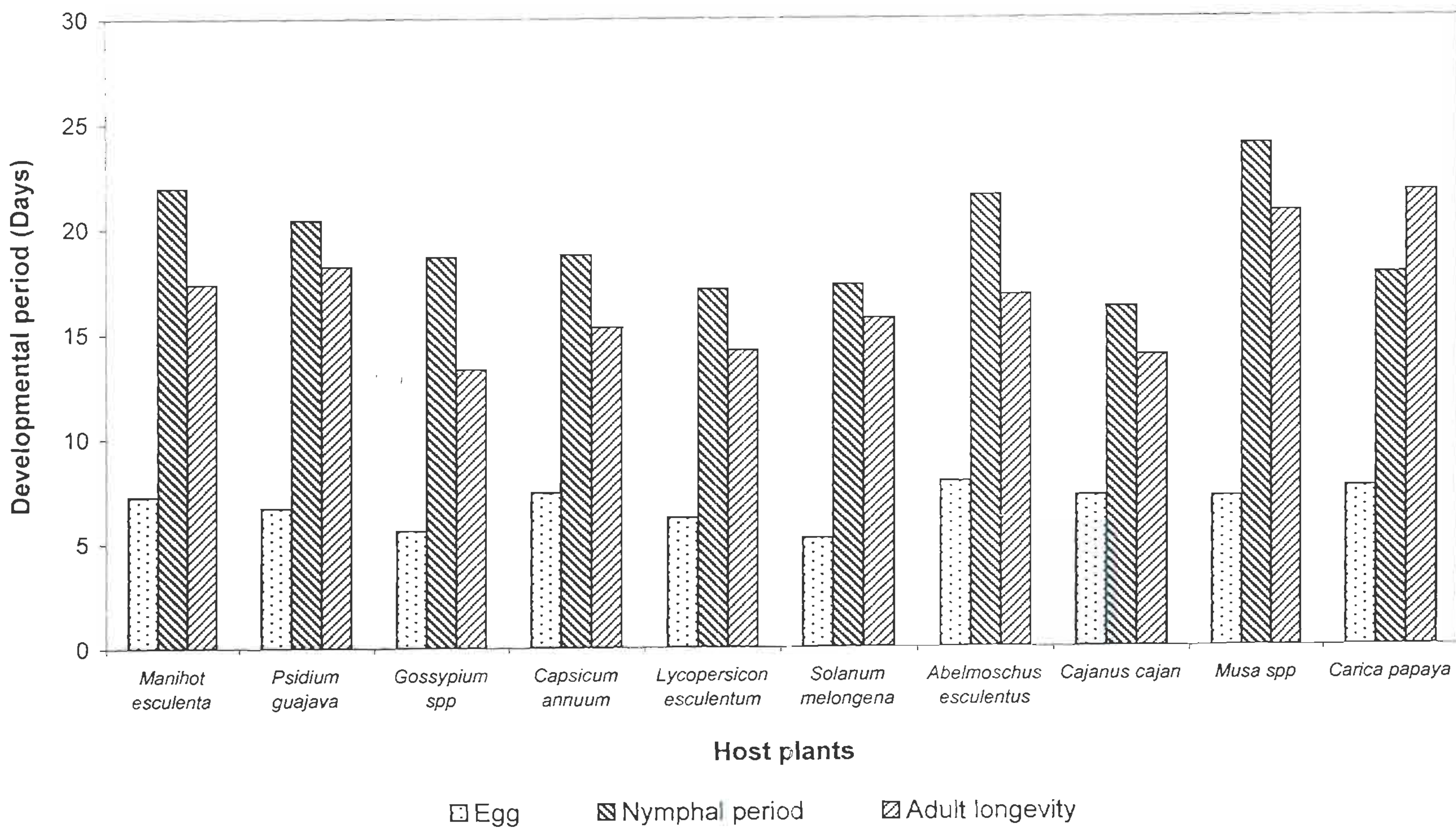
Means followed by small letters in common within columns are not significantly different at 5% level (DMRT)

Table 14: Total developmental period and adult longevity of *A. dispersus* on various host plants

Host plants	Period (days)	
	Mean ± SEd	**Range**
Manihot esculenta	17.36 ± 4.93[bc]	16-27
Psidium guajava	18.20 ± 21.22[b]	12-27
Gossypium hirsutum	13.30 ± 4.88[f]	7-26
Capsicum annuum	15.30 ± 23.80[cd]	7-21
Lycopersicon esculentum	14.20 ± 27.33[e]	9-24
Solanum melongena	15.70 ± 15.80[cd]	10-22
Abelmoschus esculentus	16.8 ± 23.12[c]	10-26
Cajanus cajan	13.90 ± 11.36[f]	8-19
Musa spp.	20.72 ± 14.26[a]	12-32
Carica papaya (L.)	21.70 ± 11.91[a]	14-26
Carica papaya (F)	14.21 ± 7.21[e]	12-29

Means followed by small letters in common within columns are not significantly different at 5% level (DMRT)

Fig. 2. Developmental period of *A.dispersus* on various host plants



The fourth instar required 6.75 to 8.1 days for completion of development before adult eclosion. The total developmental period from egg to nymph was ranging from 22.50 to 29.66 on various host plants. In *M. esculenta* and *P. guajava, A. dispersus* took on an average of 26.16 to 27.01 days respectively for its egg and nymphal development. Adults lived for longer period on *C. papaya* (21.70) and *Musa* spp. (20.72 days). On *M. esculenta* and *P. guajava* adult longevity was 17.36 and 18.20 days respectively. Total life period from egg to adult was longest on *C.papaya* leaf (50.55 days) followed by *P. guajava* (45.21 days) (Fig. 2).

4.2.3. Adult emergence, fecundity and egg hatchability

The per cent adult emergence was higher when reared on *Gossypium* spp. (97.31) and on other crops, it ranged from 85.60 to 96.94 (Table 15). Fecundity showed great deal of variations among different hosts. *M. esculenta* recorded highest number (27.25), followed by *P. guajava* (25.62) and *Musa* spp. (25.99). Apparent different was not noticed in egg hatchability among various hosts which ranged from 92.09 to 98.73 per cent.

4.2.4. Egg spiral pattern

A.dispersus female laid eggs covered in a waxy deposition, in characteristic spirals with zig-zag centre. Wax spirals were formed in regular (circular and elliptical spirals) and irregular pattern (Plate 11). Regular pattern of spirals were more on all the hosts except *Musa* sp during initial stage of infestation which had more of irregular pattern of egg spirals (65.92 per cent). Regular spiral patterns were found more on *C. annuum* (78.92 %) and *Manihot* sp. (76.22%) followed by *A. esculentus* (70.00 %). The per cent irregular spirals on various hosts during initial stage of infestation ranged from 23.78 to 65.92. During the later stage of infestation, irregular pattern of egg laying was more on all the hosts tested which ranged from 60.44 to 100 per cent (Table 16). In *M. esculenta*, regular spirals were found to be more (69.85%) during the initial stage of infestation whereas

Table 15. Adult emergence, fecundity and egg hatchability of *A. dispersus*

Sl. No.	Crops	Adult emergence (%)	Fecundity (No.of eggs/female)**	Egg hatchability (%)*
1	*Manihot esculenta*	96.40 ab (81.57)	27.25 ab (5.01)	95.89 ab (9.80)
2.	*Psidium guajava*	96.90 ab (82.01)	25.62 bc (4.75)	94.92 ab (9.74)
3.	*Gossypium* spp.	97.31 a (84.04)	12.38 e (3.51)	98.13 a (9.91)
4.	*Capsicum annuum*	96.94 ab (81.75)	13.03 de (3.60)	97.39 a (9.87)
5.	*Lycopersicon esculentum*	85.60 c (69.26)	13.08 de (3.61)	93.78 ab (9.68)
6.	*Solanum melongena*	96.67 ab (81.40)	15.27 d (3.90)	93.85 ab (0.69)
7.	*Abelmoschus esculentus*	93.06 bc (74.81)	7.34 f (2.71)	92.09 b (9.59)
8.	*Cajanus cajan*	93.53 abc (75.47)	12.76 de (3.57)	95.34 ab (9.76)
9.	*Musa* spp	94.30 abc (76.41)	25.99 a (5.09)	95.60 ab (9.78)
10.	*Carica papaya* (leaf)	96.65 ab (80.39)	24.69 ab (4.97)	98.74 a (9.94)
11	*Carica papaya* (fruit)	92.52 bc (74.31)	15.15 d (3.63)	96.14 (9.81)
12.	*Thespesia populnea*	96.66 ab (80.36)	15.15 d (3.89)	96.08 ab (9.80)
13.	*Manihot* sp.	94.28 abc (76.21)	20.06 bc (4.48)	96.46ab (9.82)

*Figures in parentheses are Arc sine transformed values.
**Figures in parentheses are Sqr. (x + 0.05) transformed values.
Means followed by small letters in common within columns and capital letters in common within rows are not significantly different at 5% level (DMRT).

Table 16. Egg spiral pattern of *A. dispersus* on various host plants

Sl. No.	Crop	Egg laying pattern			
		Initial stage of infestation		Later stage of infestation	
		Regular spirals (%)	Irregular (%)	Regular spirals (%)	Irregular (%)
1	*Manihot esculenta*	69.85 ^{Ab} (56.74)	30.15 ^{Be} (33.30)	0.0 ^{Bg} (0.0)	100.00 ^{Aa} (90.00)
2.	*Psidium guajava*	60.73 ^{Ac} (51.21)	39.07 ^{Bd} (38.69)	4.00 ^{Be} (11.54)	96.00 ^{Aa} (78.46)
3.	*Gossypium* spp.	62.18 ^{Ac} (52.06)	37.82 ^{Bd} (37.95)	7.40 ^{Bd} (15.78)	92.60 ^{Aa} (75.22)
4.	*Solanum melongena*	55.24 ^{Ad} (48.02)	44.76 ^{Bc} (41.99)	3.76 ^{Be} (11.18)	96.24 ^{Aa} (78.82)
5.	*Abelmoschus esculentus*	70.00 ^{Ab} (56.80)	30.00 ^{Be} (33.21)	39.56 ^{Ba} (38.97)	60.44 ^{Ad} (51.03)
6.	*Cajanus cajan*	68.52 ^{Ab} (55.89)	31.48 ^{Be} (34.11)	21.79 ^{Bb} (27.84)	78.21 ^{Ac} (62.17)
7.	*Musa* spp.	34.08 ^{Bf} (35.72)	65.92 ^{Aa} (54.28)	0.0 ^{Bg} (0.0)	100.00 ^{Aa} (90.00)
8.	*Carica papaya*	47.03 ^{Ae} (43.29)	52.97 ^{Ab} (46.71)	0.0 ^{Bg} (0.0)	100.00 ^{Aa} (90.00)
9.	*Capsicum annuum*	78.92 ^{Aa} (62.74)	21.08 ^{Bf} (27.27)	9.98 ^{Bd} (18.42)	90.02 ^{Aa} (74.58)
10.	*Lycopersicon esculentum*	63.86 ^{Ac} (53.05)	36.14 ^{Bd} (36.95)	12.86 ^{Bc} (21.02)	87.14 ^{Ab} (68.98)
11	*Thespesia populnea*	61.44 ^{Ac} (51.62)	38.56 ^{Bd} (38.38)	0.0 ^{Bg} (0.0)	100.00 ^{Aa} (90.00)
12.	*Manihot* sp.	76.22 ^{Aa} (61.00)	23.78 ^{Bf} (29.00)	1.86 ^{Bf} (7.84)	98.14 ^{Aa} (82.16)

Figures in parentheses are Arc sine transformed values.
Means followed by small letters in common within columns and capital letters in common within rows are not significantly different at 5% level (DMRT)

Plate 15. Egg laying pattern of *A. dispersus* on cassava

Regular spiralling pattern during initial stage of infestation

Irregular pattern during later stage of infestation

Entire leaf surface covered with egg wax irregular pattern of egg laying was cent per cent during the later stage of infestation (Plate 15).

4.2.5. Effect of trichome density on eggs and spiral size of *A. dispersus*

The trichome density per cm^2 leaf area was higher on *A. triandra* (649.2) followed by *S. melongena* (502) and *E. heterophylla* (446.4) with egg density of 27.0 to 48.0 per cm^2 (Table 17). *C. annuum* and *Musa* spp. recorded 86.4 and 38.2 eggs per cm^2 with no trichomes. The spiral size was larger (2.37 cm^2) on *Musa* spp., which had no trichomes followed by *M. esculenta* (2.24 cm^2), *S. melongena* (2.13 cm^2) and *P. guajava* (2.10 cm^2) with trichomes of 42.8, 502 and 317.4 per cm^2 respectively. The spiral size was very small (0.39 cm^2) on *A. triandra*, which had highest number of trichomes. There was no significance in correlation between egg density and trichome density ($r = -0.01^{NS}$) and spiral size with trichome density ($r = 0.004^{NS}$) implying that variations in trichome densities did not alter the egg density and spiral size of *A. dispersus*. However the study indicated the non-existence of significant relationship between trichome density, eggs/unit area and spiral area.

4.3. Spatial distribution of *A. dispersus*

4.3.1. Spatial distribution of *A. dispersus* on *M. esculenta*

The results on spatial distribution of *M. esculenta* revealed that there were significant differences in distribution pattern of different stages of *A. dispersus* on top, middle and bottom position of leaves at 3 and 6 months old crop. During the initial period of infestation, egg laying was more on bottom leaves. Egg spirals were more (78.00%) during the initial stage of infestation on 3 month old crop. Both nymphs and adults of *A. dispersus* were crowded on bottom leaves (47.82 and 93.80 respectively). Nearly 40 per cent of egg spirals were found on middle leaves with the nymph and adult population of 11.69 and 7.22 respectively (Table 18) (Fig. 3).

Table 17. Relationship between trichome density and egg wax spirals of *A.dispersus*

Sl. No.	Crop	No. of Trichome/cm^2	No. of Egg/cm^2	Spiral size (cm^2)
1.	*Manihot esculenta*	42.8	59.2	2.236
2.	*Psidium guajava*	317.4	51.0	2.096
3.	*Gossypium hirsutum*	230.8	36.8	1.838
4.	*Solanum melongena*	502.0	48.0	2.128
5.	*Abelmoschus esculentus*	128.0	32.2	0.70
6.	*Cajanus cajan*	77.4	34.8	0.77
7.	*Musa* spp.	00.0	38.2	2.37
8.	*Carica papaya*	70.4	57.6	1.90
9.	*Capsicum annuum*	00.0	86.4	0.72
10.	*Lycopersicon esculentum*	306.6	33.4	0.50
11.	*Plumeria alba*	21.2	36.6	1.45
12.	*Poinsettia pulcherrima*	47.2	48.0	1.71
13.	*Thespesia populnea*	68.8	47.8	1.43
14.	*Manihot* sp	29.2	56.2	1.69
15.	*Amaranthus tricolor*	1.8	59.6	1.71
16.	*Sesbania grandiflora*	23.8	10.6	1.00
17.	*Sesbania trilobatum*	00.0	30.0	1.68
18.	*Euphorbia heterophylla*	446.4	46.2	1.62
19.	*Euphorbia hirta*	406.0	31.8	0.72
20.	*Corchorus capasularis*	136.4	80.6	0.72
21.	*Alternanthra triandra*	649.2	27.0	0.39
22.	*Acalypha indica*	352.6	45.0	1.17

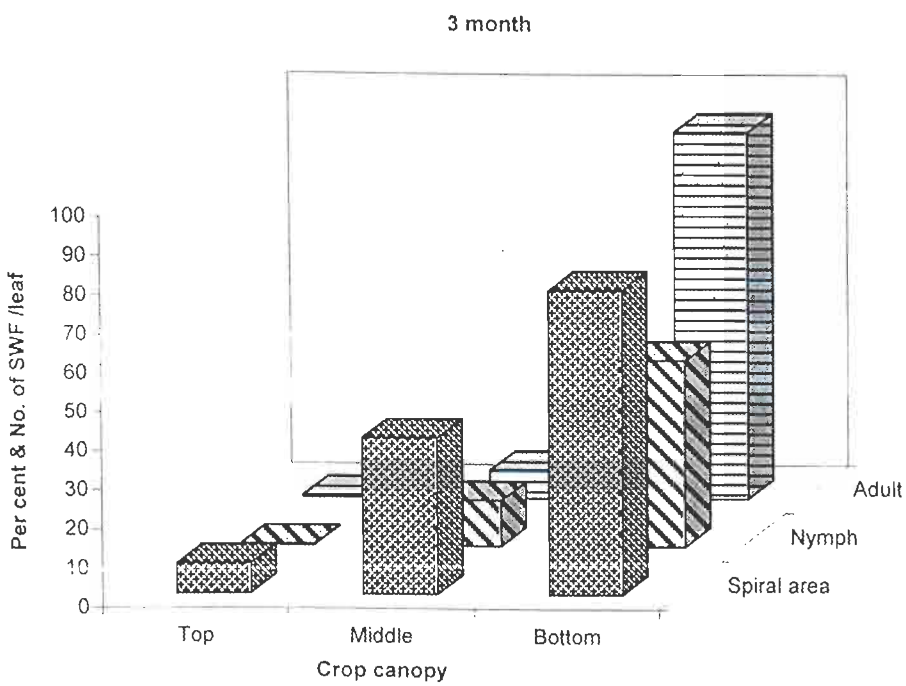
Variable X	Trichomes	Trichomes
Variable Y	Number of eggs	Size of spirals
'r' value	-0.01^{NS}	0.004^{NS}
'r^2' value	0.03^{NS}	0.047^{NS}
Regression equation :	$Y = 48.20 - 0.02X$	$Y = 1.519 - 0.001X$

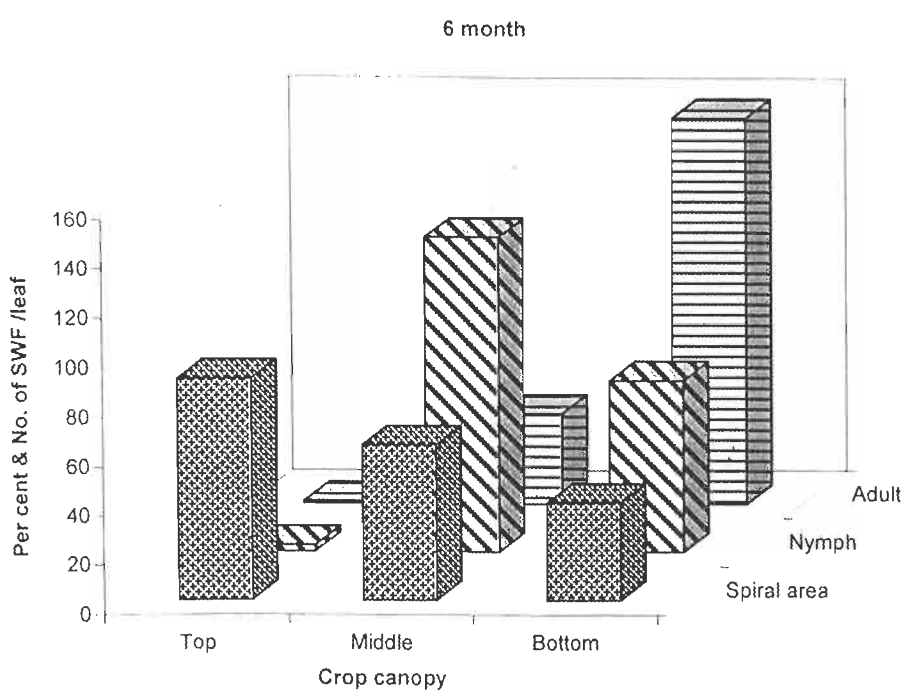
Table 18. Spatial distribution of *A. dispersus* on *M. esculenta*

Leaf position	3 Months			6 Months		
	Spiral area (%)*	No. of Nymph/leaf**	No. of Adult/leaf**	Spiral area (%)*	No. of Nymph/leaf**	No. of Adult/leaf**
Top	7.60[c]	0.22[c]	0.52[c]	90.00[a]	2.64[c]	1.02[c]
	(14.86)	(0.84)	(0.99)	(76.88)	(1.72)	(1.22)
Middle	40.00[b]	11.69[b]	7.22[b]	63.50[b]	128.09[a]	36.90[b]
	(38.98)	(3.34)	(2.54)	(54.72)	(11.23)	(5.97)
Bottom	78.00[a]	47.82[a]	93.80[a]	40.00[c]	70.03[b]	157.45[a]
	(66.43)	(6.91)	(9.58)	(38.66)	(8.27)	(12.43)

*Figures in parentheses are Arc sine transformed values
**Figures in parentheses are Sqr. (x+0.5) transformed values
Means followed by small letters in common within columns are not significantly different at 5% level (DMRT).

Fig. 3. Spatial distribution of SWF on cassava





The results indicated that the distribution of whitefly stages was least on top leaves during the initial period of infestation. On 6 months old crop, the per cent distribution of egg spiral was more on top leaves (90.00) followed by middle (63.50) and bottom leaves (40.00). More number of nymphs (128.09) were found on middle leaves followed by bottom leaves (70.03). Adults were found to congregate on bottom leaves (157.45), which was significantly higher than other two positions. In top leaves, egg laying was predominant, which indicated that adults prefer tender leaves for egg laying at 6 months old crop.

4.3.2. Spatial distribution of *A. dispersus* on *P. guajava*

The per cent distribution of egg spirals was significantly more on both top (85.00) and middle (73.00) leaves. Only fewer spirals were found on bottom (matured) leaves (17.02). Nymphal population was significantly higher on middle leaves (92.71 leaf) followed by bottom leaves (61.22). Significantly larger number of adults per leaf was observed on bottom leaves (103.37). Though most of the adults could be found on the matured leaves, nearly 85.00 per cent of the egg spirals was found on the tender leaves in the top position (Table 19).

This study clearly indicated that *A. dispersus* population and spiral area was more on bottom leaves when the crop was young (3 months old). In grown up plants, adults preferred tender leaves for egg laying and more number of nymphs and adults were found on matured leaves.

4.4. Damage potential of *A. dispersus* and its effect on plant growth and yield in *M. esculenta*

The extent of leaf damage, population density of *A. dispersus* on cassava plants initially released with whiteflies at the rate of 50 and 250/plot showed significant differences on growth and yield (Tables 20 to 22).

Table 19. Spatial distribution of *A. dispersus* on *P. guajava*

Crop canopy	Spiral area (%)*	No. of Nymph/leaf**	No. of Adult/leaf**
Top	85.00[a] (71.17)	1.00[c] (1.20)	1.22[c] (1.30)
Middle	73.00[a] (64.82)	92.71[a] (9.40)	28.94[b] (5.35)
Bottom	17.20[b] (24.03)	61.22[b] (7.64)	103.37[a] (10.05)

*Figures in parentheses are Arc sine transformed values.
**Figures in parentheses are sqr (x+0.5) transformed values
Means followed by small letters in common within columns are not significantly different at 5% level (DMRT).

4.4.1. Effect on the height of the plants

Upto five months of crop period there was no significant difference in respect of height of the plants between whiteflies infested and healthier plants. From the sixth month onwards significant differences existed between infested and uninfested plants. At tenth month, the average height of the infested plants was 238.24 cm (50 SWF/plot) and 246.40 cm (250 SWF/plot) whereas it was 280.20 cm in uninfested plants (Table 20).

4.4.2. Effect on number of leaves

There was no significant difference in number of leaves per plant infested with SWF and uninfested plants till the sixth month of the growth period. From seventh to eighth months, there was no significant difference between the uninfested and infested plants with 50 SWF/plot, the number of leaves per plants ranged from 114.20 to 126.40 and 102.20 to 118.0 respectively. Thereafter, there was a significant differences in plants infested with 250 SWF/plot (119.40 to 139.80) and 50 SWF/plot (127.2 to 146.8) when compared to uninfested plants (172.80 leaves/plant) (Table 20).

4.4.3. Damage intensity and population level of *A. dispersus*

The leaf area damage by *A. dispersus* in plants released with 50 SWF/plot was meagre (6.0 per cent) at one month after release whereas it was 18.50 per cent on plants released with 250 SWF/plot. Whitefly population build up was poor on plants released with 50 SWF/plot till the period of sixth months, which were 12.2 nymphs/leaf and 21.0 adults/leaf, whereas it was 30.2 nymphs and 38.70 adults per leaf in plants released with 250 SWF/plot. From seventh month onwards, population build up was high on plants released with 50 SWF/plot. On ninth and tenth months the population load of SWF was very high in both the plots released with 50 and 250 SWF adults. This increased population caused leaf area

Table 20. Effect of *A. dispersus* infestation on plant growth of *M. esculenta*

Month	Plant height (cm)			Leaves / branch (Numbers)*		
	Infested (No. of *A.dispersus* released/plot)		Uninfested	Infested (No.of *A.dispersus* released/plot)		Uninfested
	50	250		50	250	
1.	15.20^{Ai}	14.90^{Aj}	14.60^{Aj}	7.20^{Aj} (0.89)	7.31^{Ai} (0.89)	7.40^{Aj} (0.89)
2.	45.60^{Ah}	46.96^{Ai}	46.80^{Ai}	17.90^{Ai} (1.26)	19.20^{Ah} (1.29)	17.40^{Ai} (1.25)
3.	89.25^{Ag}	88.25^{Ah}	88.80^{Ah}	42.70^{Ah} (1.64)	40.90^{Ag} (1.62)	46.40^{Ah} (1.67)
4.	126.42^{Af}	136.50^{Ag}	134.00^{Ag}	73.80^{Ag} (1.87)	75.60^{Af} (1.88)	74.00^{Ag} (1.87)
5.	166.70^{Ae}	162.00^{Af}	171.40^{Af}	82.20^{Af} (1.91)	81.20^{Ae} (1.91)	85.00^{Af} (1.93)
6.	178.14^{Ad}	170.12^{Be}	186.40^{Ae}	94.60^{Ae} (1.98)	91.30^{Ad} (1.96)	97.20^{Ae} (1.98)
7.	202.16^{Ac}	185.40^{Bd}	204.20^{Ad}	102.20^{Ad} (2.01)	97.20^{Bc} (1.99)	114.20^{Ad} (2.05)
8.	209.11^{Bc}	201.56^{Bc}	236.00^{Ac}	118.0^{Ac} (2.07)	102.10^{Bc} (2.01)	126.40^{Ac} (2.10)
9.	22.800^{Bb}	219.00^{Bb}	256.00^{Ab}	127.2^{Bb} (2.11)	119.40^{Bb} (2.08)	146.60^{Ab} (2.17)
10.	246.40^{Ba}	238.24^{Ba}	280.20^{Aa}	146.80^{Ba} (2.17)	139.80^{Ba} (2.14)	172.80^{Aa} (2.24)

*Figures in parentheses are log (x+0.5) transformed values

Means followed by small letters in common within columns and capital letters in common with in rows are not significantly different at 5% level (DMRT).

Table 21. Damage level and population density of *A. dispersus* on *M. esculenta*

Month	Leaf area damage(%)*		No. of Nymph/leaf**		No. of Adult/leaf**	
	No. of whitefly released					
	50/plot	250/plot	50/plot	250/plot	50/plot	250/plot
3	6.0^{Bc}	18.50^{Af}	2.0^{Bf}	15.90^{Ag}	1.70^{Af}	6.80^{Af}
	(13.18)	(24.47)	(0.39)	(1.21)	(0.34)	(0.86)
4	10.50^{Be}	26.50^{Ae}	7.20^{Bef}	19.20^{Afg}	3.0^{Bf}	18.80^{Ae}
	(17.91)	(31.98)	(0.89)	(1.29)	(0.54)	(1.28)
5	23.20^{Bd}	56.00^{Ad}	10.4^{Be}	22.7^{Af}	15.0^{Ae}	20.20^{Ae}
	(29.79)	(49.44)	(1.03)	(1.36)	(1.19)	(1.31)
6	40.50^{Bc}	74.00^{Ac}	12.2^{Be}	30.2^{Ae}	21.0^{Be}	38.70^{Ad}
	(38.52)	(62.66)	(1.10)	(1.49)	(1.33)	(1.59)
7.	40.75^{Bc}	70.50^{Ac}	35.8^{Bd}	49.7^{Ad}	46.20^{Ad}	41.00^{Ad}
	(38.68)	(59.10)	(1.55)	(1.70)	(1.67)	(1.62)
8.	62.00^{Bb}	81.50^{Ab}	62.6^{Bc}	80.4^{Ac}	69.00^{Ac}	72.0^{Ac}
	(53.94)	(66.53)	(1.80)	(1.90)	(1.84)	(1.86)
9.	91.00^{Aa}	96.00^{Aa}	83.4^{Bb}	95.25^{Ab}	91.80^{Bb}	115.7^{Ab}
	(74.54)	(80.46)	(1.92)	(1.98)	(1.96)	(2.06)
10.	96.50^{Aa}	97.50^{Aa}	107.90^{Ba}	122.50^{Aa}	121.70^{Ba}	149.30^{Aa}
	(81.22)	(82.90)	(2.03)	(2.09)	(2.09)	(2.18)

* Figures in parentheses are Arc sine transformed values

** Figures in parentheses are log (x+0.05) transformed values

Means followed by the small letters in common within rows and capital letters in common within columns are not significantly different at 5% level (DMRT).

damage ranged from 91.00 to 96.50 and 96.00 to 97.50 in the corresponding plots released with 50 and 250 SWF/plot (Table 21).

4.4.4. Effect on yield

Both foliage weight and tuber yield of the plants infested with SWF had significant differences when compared to uninfested plants (Table 22). Foliage biomass per plant was 2.36 and 2.10 kg in plants released with 50 and 250 SWF/plot whereas in uninfested plot, it was 3.05 kg. Average tuber yield was higher (2.96 kg) from uninfested plants whereas it was 2.07 kg in plants infested with 50 SWF/plot and 1.39 kg in plants released with 250 SWF/plot. The per cent reduction in yield were 53.10 and 30.07 in plants released with 250 and 50 SWF/plot respectively.

4.5. Cultural control

4.5.1. Effect of pruning on incidence of *A. dispersus* on *P. guajava*

In *P. guajava*, the young shoots one month after pruning attracted whitefly adults for egg laying. Egg spiral occupied 20.5 per cent of the leaf area with nymphs and adult population of 3.3 and 4.7 per cent respectively. Population in the subsequent months rapidly increased and the entire lamina i.e. 97.5 to 100.00 per cent was covered with eggs. Nymphal population was 96.9 to 106.0 per leaf with 96.2 to 143.7 adults per leaf in 4 to 5 months after pruning (January to February, 2000) (Table 23).

4.6. Physical control using sticky traps

4.6.1. Yellow sticky trap catches of *A. dispersus* in *M. esculenta*

The result on yellow sticky trap catches of SWF showed significant variations among the three different heights of traps tested (Table 24). More number of adults were attracted on trap placed at crop canopy (150 to 170 cm), followed by below crop canopy (100 to 120 cm). The mean number of adults

Table 22. Effect of *A. dispersus* infestation on foliage and tuber yield in cassava (*M. esculenta*).

	Foliage weight (Kg)	Foliage reduction over control (%)	Tuber yield (Kg/plant)	Yield reduction over control (%)
Infested plants (Whiteflies/Plot)				
50	2.36^{b}	22.62	2.07^{b}	30.07
250	2.10^{c}	31.15	1.39^{c}	53.04
Uninfested	3.05^{a}	-	2.96^{a}	-

Table 23. Effect of pruning on the population build up of *A. dispersus* on guava (*P. guajava*)

	Month	Egg spiral area (%)*	No. of Nymph/leaf**	No. of Adult/leaf**
1.	October 1999	20.5^{d} (24.92)	3.3^{e} (0.58)	4.7^{e} (1.01)
2.	November	66.5^{c} (38.17)	39.6^{d} (1.60)	59.7^{d} (1.78)
3.	December	92.5^{b} (76.11)	72.1^{c} (1.86)	77.9^{c} (1.89)
4.	January 2000	97.5^{a} (87.95)	96.9^{b} (1.99)	96.2^{b} (1.99)
5.	February 2000	100.0^{a} (90.00)	106.0^{a} (2.03)	143.7^{a} (21.59)

Pruning period in Guava - September 1999
*Figures in parentheses are Arc Sine transformed values
**Figures in parentheses are log (x + 0.5) transformed values
Means followed by small letters in common within columns are not significantly different at 5% level by DMRT.

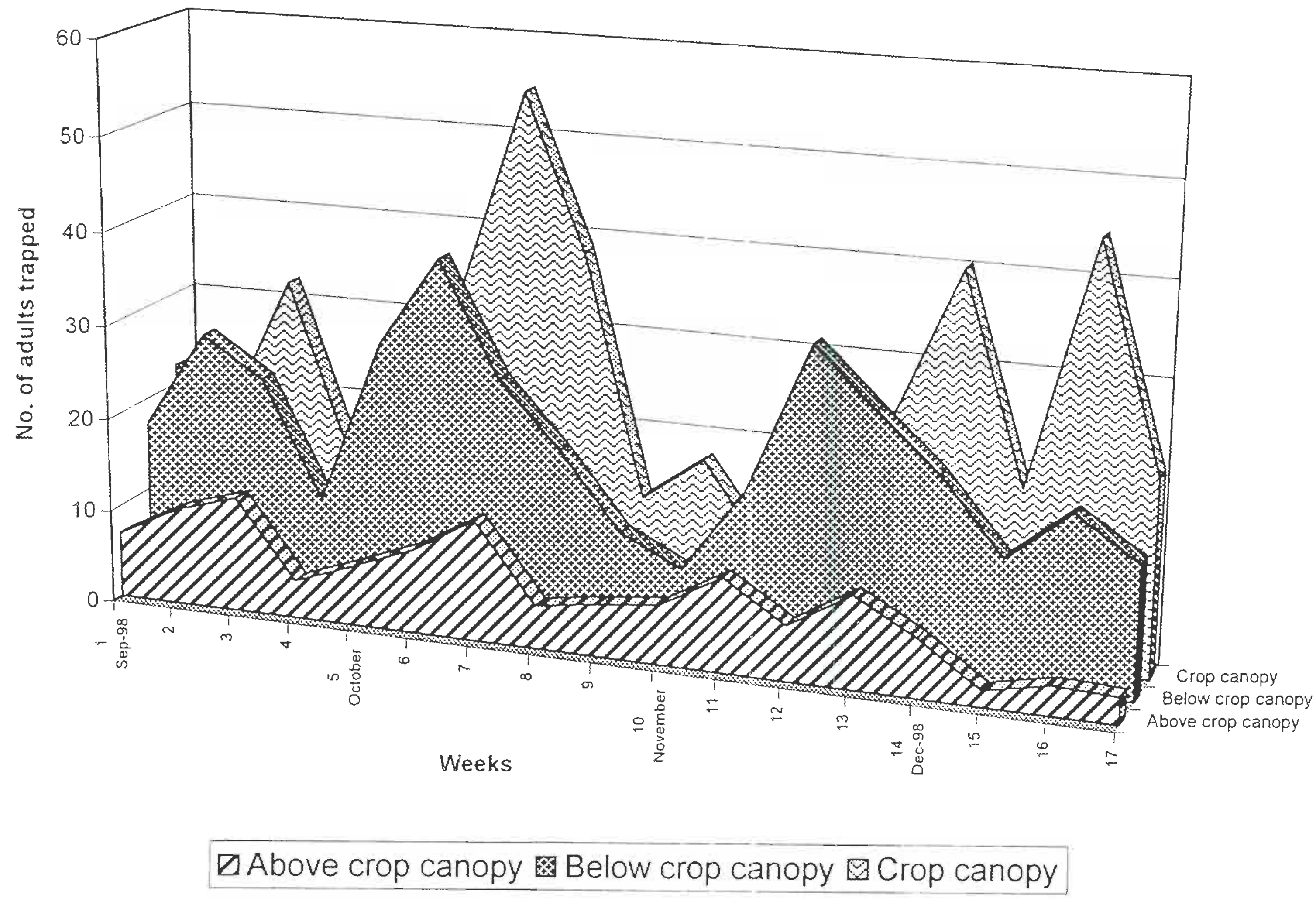
Table 24. Yellow sticky trap catches of SWF in cassava (*M. esculenta*).

Month	Week	No. of whitefly trapped		
		Trap height from ground level (cm) *		
		Below crop canopy (100-120)	Crop canopy (150-170)	Above crop canopy (200-220)
Sep' 98	1	17.29 $^{A\ cdef}$	22.00 ^{Adefgh}	7.00 ^{Bbcd}
		(4.22)	(4.74)	(2.74)
	2	27.57 $^{A\ abc}$	18.43 $^{B\ fgh}$	10.29 $^{C\ ab}$
		(5.30)	(4.35)	(3.28)
	3	23.43 $^{A\ bcd}$	32.29 $^{A\ bcde}$	12.29 $^{B\ a}$
		(4.89)	(5.73)	(3.58)
	4	11.00 $^{A\ fg}$	14.57 $^{A\ ghi}$	4.00 $^{B\ cde}$
		(3.39)	(3.88)	(2.12)
Oct.	5	28.43 $^{A\ abc}$	26.29 $^{A\ cdef}$	6.43 $^{B\ cde}$
		(5.38)	(5.18)	(2.63)
	6	38.14 $^{A\ a}$	34.14 $^{A\ bcd}$	9.00 $^{B\ abc}$
		(6.22)	(5.89)	(3.08)
	7	26.00 $^{B\ abc}$	54.67 $^{A\ a}$	12.86 $^{C\ a}$
		(5.15)	(7.42)	(3.66)
	8	19.14 $^{B\ cdef}$	38.57 $^{A\ bc}$	4.57 $^{C\ cde}$
		(4.43)	(6.25)	(2.25)
	9	11.14 $^{A\ fg}$	13.00 $^{A\ hi}$	5.57 $^{B\ cde}$
		(3.41)	(3.67)	(2.46)
Nov	10	8.00 $^{B\ g}$	17.72 $^{A\ fgh}$	6.29 $^{B\ cde}$
		(2.92)	(4.27)	(2.61)
	11	17.00 $^{A\ cdef}$	8.86 $^{B\ I}$	10.00 $^{AB\ ab}$
		(4.18)	(3.06)	(3.24)
	12	33.00 $^{A\ ab}$	19.00 $^{B\ fgh}$	5.86 $^{C\ cde}$
		(5.79)	(4.47)	(2.52)
	13	26.86 $^{A\ abc}$	25.00 $^{A\ defg}$	9.86 $^{B\ abc}$
		(5.23)	(5.05)	(3.22)
Dec' 98	14	21.00 $^{B\ bcde}$	40.29 $^{A\ bc}$	6.29 $^{C\ cde}$
		(4.64)	(6.39)	(2.61)
	15	13.14 $^{A\ efg}$	18.43 $^{A\ fgh}$	1.71 $^{B\ e}$
		(3.69)	(4.35)	(1.49)
	16	18.57 $^{B\ cdef}$	44.57 $^{A\ ab}$	3.14 $^{C\ cde}$
		(4.37)	(6.71)	(2.60)
	17	14.14 $^{A\ defg}$	21.00 $^{A\ efgh}$	2.86 $^{B\ de}$
		(3.83)	(4.64)	(1.83)
	Mean	20.82 ^{A}	26.40 ^{A}	6.95 ^{B}
		(4.62)	(5.19)	(2.73)

*Figures in parentheses are Sqr.(x + 0.5) transformed values.

Means followed by small letters in common within columns and capital letters in common within rows are not significantly different at 5% level (DMRT).

Fig.4. Yellow sticky trap catches of *A. dispersus* in cassava



attracted to traps placed at crop canopy was significantly more during October third week (54.67), followed by third week of December (44.57) and first week of December (40.29). Adult catches were more during second week of October (38.14) followed by third week of November (33.00) and fourth week of November (26.86) on traps at below crop canopy. The traps kept at above crop canopy (200 to 220 cm) attracted least number of SWF adults than other two heights which ranged from 1.71 to 12.86 (Fig. 4).

4.6.2. Yellow sticky trap catches of *A. dispersus* in *A. indica*

The mean number of SWF adults attracted to yellow sticky trap was significantly more on traps at crop canopy (43.73). The peak attraction was observed during fourth week of February (68.43) followed by second week of February (61.00) and third week of December (57.43) on traps at crop canopy. The attraction of whiteflies was significantly poor on traps kept at above and below crop canopy. The number of whiteflies trapped on traps placed at below was found to be more during first week of January (29.71) and December (28.43), which were statistically on par (Table 25) (Fig. 5).

4.6.3. Yellow sticky trap catches of *A. dispersus* in wild cassava (*Manihot glaziovii*)

The mean number of SWF adults trapped using yellow sticky traps in *M. glaziovii* ranged from 102.00 to 325.88. Significantly more number of adults were trapped from second week of November '98 to fourth week of February. On an average 211.86 adults were trapped per week during the study period (Table 26) .

Table 25. Yellow sticky trap catches of SWF in *Acalypha indica*

Month	Week	No. of whitefly trapped — Trap height from ground level (cm)*		
		Below crop canopy (100-120)	Crop canopy (150-170)	Above crop canopy (200-220)
Dec' 98	1	28.43 Ba (5.38)	46.86 A bcde (6.88)	4.29 C def (2.19)
	2	26.57 A ab (5.20)	20.00 A h (4.53)	4.00 B def (2.12)
	3	19.72 B bcde (4.44)	57.43 A ab (7.61)	5.29 C cdef (2.41)
	4	10.86 B def (3.37)	44.86 A bcde (6.73)	9.00 B bcde (3.08)
Jan' 99	5	29.71 A a (5.50)	35.43 A defg (5.99)	11.71 B abc (3.49)
	6	17.43 B bcde (4.74)	43.29 A bcdef (6.62)	5.72 C cdef (2.49)
	7	12.86 B cdef (3.65)	54.14 A abc (7.39)	15.29 B ab (3.97)
	8	12.57 B cdef (3.62)	37.57 A cdefg (6.17)	13.00 B abc (3.74)
	9	9.57 B ef (3.17)	27.43 A gh (5.28)	9.00 B bcde (3.08)
Feb	10	18.00 B bcde (4.30)	30.00 A fgh (5.52)	11.43 B abcd (3.45)
	11	20.71 B abcd (4.61)	61.00 A ab (7.84)	19.14 B a (4.43)
	12	12.00 B cdef (3.54)	49.57 A abcd (7.08)	6.14 C cdef (2.58)
	13	7.14 B f (3.48)	68.43 A a (8.30)	4.57 B def (2.25)
March	14	17.00 B bcde (4.18)	37.71 A defg (6.18)	3.14 C ef (1.91)
	15	22.86 B abc (4.83)	45.29 A bcde (6.77)	2.29 C f (1.67)
	16	17.71 B bcde (4.27)	55.71 A abc (7.50)	5.43 C cdef (2.44)
	17	20.43 A abcd (4.57)	30.57 A efgh (5.57)	3.14 B ef (1.91)
April	18	16.00 B bcde (4.06)	41.86 A bcdefg (6.51)	2.72 C ef (1.79)
	Mean	17.75 B (4.27)	43.73 A (6.65)	7.52 C (2.83)

* Figures in parentheses are Sqr. (x + 0.5) values.
Means followed by small letters in common within columns and capital letters in common within rows are not significantly different at 5% level (DMRT).

Fig. 5. Yellow sticky trap catches of SWF in Acalypha

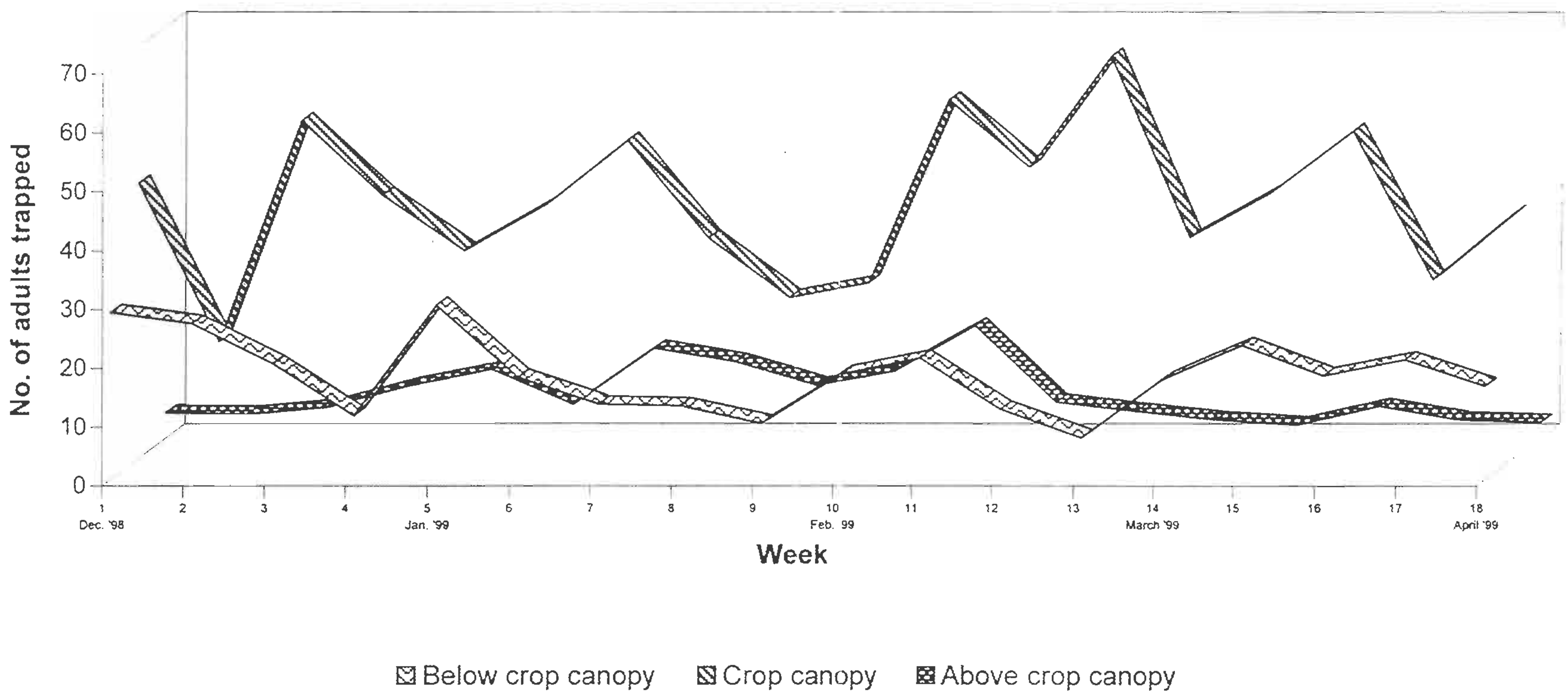


Table 26. Yellow sticky trap catches of *A. dispersus* in wild cassava (*M. glaziovii*)

Month	Week	No. of adult / trap*	Month	Week	No. of adult / trap*
Oct' 98	1	121.00 [d] (11.00)	Jan' 99	12	221.75 [b] (14.91)
	2	217.63 [b] (14.76)		13	235.38 [ab] (15.36)
	3	102.25 [d] (10.14)		14	270. 63 [ab] (16.47)
Nov.	4	135.00 [cd] (11.64)		15	227.38 [b] (14.10)
	5	247.75 [ab] (15.76)		16	199.50 [b] (14.14)
	6	325.88 [a] (18.07)	Feb' 99	17	209.88 [b] (14.50)
	7	219.63 [b] (14.84)		18	195.25 [b] (13.99)
Dec.	8	273.38 [ab] (16.55)		19	217.00 [b] (14.75)
	9	122.00 [d] (11.07)		20	239.38 [ab] (15.49)
	10	232.38 [ab] (15.26)		Mean	211.86 (14.57)
	11	224.25 [b] (14.99)			

* Figures in parentheses are sqr (x + 0.5) transformed values

Means followed by small letters in common within columns are not significantly different at 5% level (DMRT)

4.6.4. Efficiency of coloured sticky traps for *A. dispersus* catches in *M. esculenta*

Among the various coloured sticky traps tested, the mean number of adults trapped was significantly more on yellow coloured traps (226.25). This was followed by green coloured trap (169.08). Next to these two colours, orange coloured sticky trap attracted adults at moderate level in all the weeks except second week, where the trap catches on yellow, green and orange coloured sticky traps were statistically on par. Red, black and white coloured traps attracted only few whitefly adults which ranged from 3.13 to 23.63 (Table 27).

4.6.5. Bihourly attraction of whitefly in light trap

Results on the use of light traps at different time intervals for attraction of SWF adults revealed that more number of adults (468.29) were attracted at early morning hours (4 to 6 a.m.), which was significantly higher than other periods tested. The catch at 4 to 6 a.m. accounted to 82.87 per cent of total catch. The trap catches at 2 to 4 a.m. was moderate (59.00) which accounted to 11.42 per cent. The mean number of whiteflies trapped from 6 p.m. to 2 a.m. was least which accounted to only 0.38 to 2.90 per cent of total catch (Table 28).

4.6.6. Colour light traps

Results on the attractancy of different coloured light traps showed that the yellow coloured light trap attracted more number of adults (668.9 per day) which was statistically higher than other traps tested. Next to yellow, white coloured light trap performed better, with an average catch of 454.4 adults per day followed by green coloured light trap (308.7). Comparatively orange coloured light trap, attracted fewer number of adults (146.2 per day) than other colours tested (Table 29).

Table 27. Efficacy of different coloured sticky traps in attraction of *A. dispersus*

Colours	Adults trapped (Number / Trap / Week)*								
	1	2	3	4	5	6	7	8	Mean
Yellow	238.67^{a} (2.37)	197.67^{a} (2.28)	151.33^{a} (2.16)	229.00^{a} (2.34)	191.33^{a} (2.28)	307.67^{a} (2.47)	235.00^{a} (2.35)	259.33^{a} (2.40)	226.25^{a} (2.35)
Green	169.33^{ab} (2.22)	182.33^{a} (2.26)	134.67^{a} (2.09)	99.33^{ab} (1.99)	196.33^{a} (2.28)	212.33^{ab} (2.32)	163.67^{ab} (2.21)	194.67^{a} (2.27)	169.08^{a} (2.22)
Orange	100.00^{b} (1.98)	12.00^{a} (1.90)	68.67^{ab} (1.82)	41.33^{bc} (1.60)	48.67^{b} (1.67)	109.00^{bc} (2.04)	86.67^{b} (1.93)	58.67^{b} (1.73)	80.63^{b} (1.88)
Red	28.33^{c} (1.42)	18.00^{b} (1.23)	14.67^{c} (1.11)	18.00^{cd} (1.17)	20.33^{c} (1.30)	62.67^{c} (1.78)	7.67^{c} (0.91)	19.33^{c} (1.29)	23.63^{d} (1.33)
Black	8.67^{d} (0.95)	5.00^{bc} (0.74)	9.33^{cd} (1.01)	7.67^{de} (0.85)	2.33^{c} (0.52)	8.33^{d} (0.95)	2.00^{c} (0.48)	4.00^{d} (0.69)	8.54^{d} (0.97)
White	2.67^{e} (0.55)	3.00^{c} (0.54)	5.00^{d} (0.73)	3.00^{e} (0.59)	2.67^{c} (0.55)	3.33^{e} (0.62)	3.67^{c} (0.66)	1.67^{e} (0.42)	3.13^{c} (0.61)
Mean	85.57 (1.59)	88.24 (1.55)	62.14 (1.52)	62.71 (1.44)	78.24 (1.57)	104.95 (1.67)	77.52 (1.51)	85.43 (1.54)	80.60 (1.58)

*Figures in parentheses are log (x+1) transformed values
Means followed by small letter in common within columns are not significantly different at 5% level (DMRT)

Table 28. Bihourly attraction of *A. dispersus* in light trap

Hour	No. of adults trapped/day*	Percentage to total adult catches **
6-8 p.m.	2.43 [e]	0.38 [e]
	(0.28)	(1.84)
8-10 p.m.	3.29 [de]	0.66 [de]
	(0.44)	(3.34)
10-12 p.m.	8.86 [d]	2.65 [cd]
	(0.72)	(8.33)
12-2 a.m.	15.71 [c]	2.90 [c]
	(1.21)	(9.65)
2-4 a.m.	59.00 [b]	11.42 [b]
	(1.73)	(18.97)
4-6 a.m.	468.29 [a]	82.87 [a]
	(2.66)	(66.06)

*Figures in parentheses are log (x + 1) transformed values.
**Figures in parentheses are Arc sine transformed values.
Means followed by small letters in common within columns are not significantly different at 5% level (DMRT)

Table 29. Effect of different coloured light on the attractancy of *A. dispersus*

Colour	No. of adults trapped/day*	Percentage to total adult catches **
White	454.4[b]	28.80[b]
	(21.33)	(31.46)
Yellow	668.6[a]	42.37[a]
	(25.87)	(40.61)
Green	308.7[c]	19.56[c]
	(17.58)	(25.25)
Orange	146.2[d]	9.27[d]
	(12.11)	(16.73)

*Figures in parentheses are Sqr (x + 0.5) transformed values.
**Figures in parentheses are ArcSine transformed values.
Means followed by small letters in common within columns are not significantly different at 5% level (DMRT).

4.7. Evaluation of certain chemicals and neem products against *A.dispersus* on cassava (*M. esculenta*)

Two field trials were carried out on cassava at TNAU Orchard, to evaluate synthetic chemicals and neem products for management of *A. dispersus.*

4.7.1. Field trial I

The results from the first trial showed that there were significant differences in the efficacy of insecticides tested (Tables 30 to 32). Egg mortality at 3 days after spraying (DAS) was high in all the chemicals than on 1 DAS. The insecticides triazophos and phosalone had more ovicidal effect which caused 99.73 and 92.04 per cent egg mortality at 3 DAS. The next best insecticides with ovicidal effect were neem oil 60 EC and TNAU Neem which recorded 89.14 and 81.14 per cent egg mortality respectively. FORS, dish wash soap solution (4%) and NOPO (1.8%) were equally effective but inferior to above said chemicals, recording 66.31 to 68.13 per cent egg mortality. In NSKE treated plot, mortality was only 47.10 per cent which was significantly lower than all other treatments (Table 30) (Fig. 6).

4.7.1.1. Early instar nymphal mortality

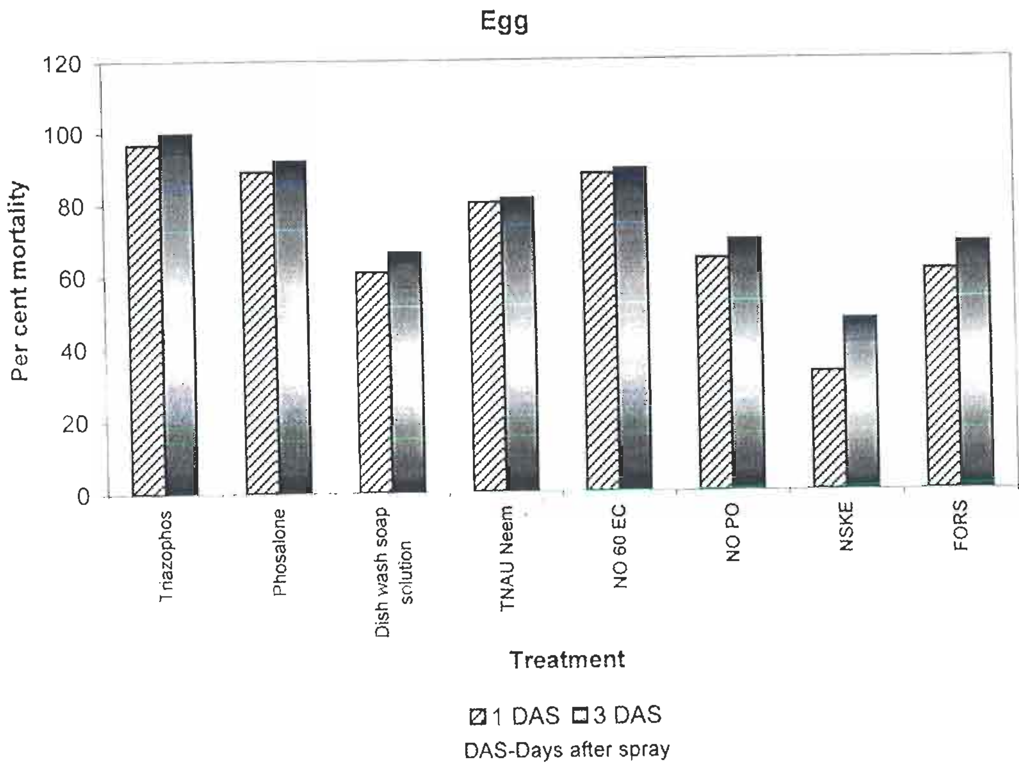
Triazophos spray was significantly effective in early instar (first and second instar) nymphal mortality followed by neem products which recorded 87.67 to 88.21 per cent at 1 DAS (Table 30). Phosalone, dish wash and soap solution were next best chemicals causing 82.08 to 84.11 per cent nymphal mortality at 1 DAS. All the chemicals tested performed better till 5 DAS, thereafter notable reduction was observed. At 10 DAS, triazophos recorded 70.30 per cent nymphal mortality which was significantly higher than other chemicals tested (Fig. 6).

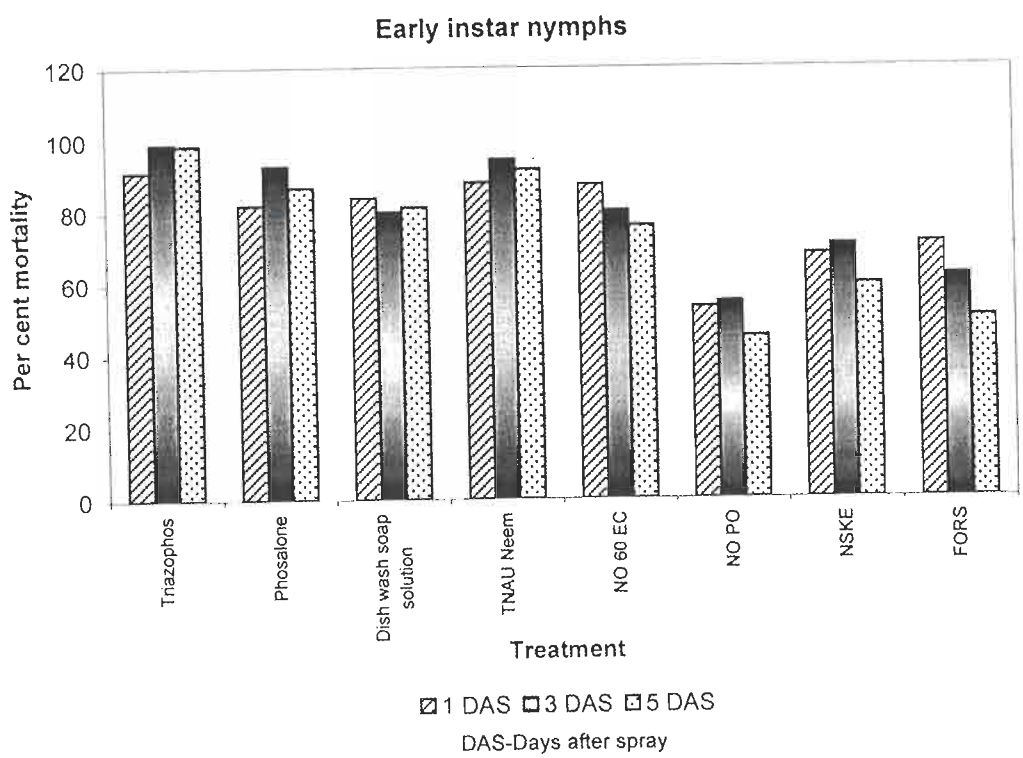
Table 30. Mortality of eggs and early instar nymphs of *A. dispersus* following insecticide application on *M. esculenta* (Field trial - I)

Treatments	Dose (ml/gm/lit)	Egg mortality (%) (DAS)*		Early instar nymphal mortality (%) (DAS) *				
		1	3	1	3	5	7	10
Triazophos	2 ml	96.70 [a] (82.54)	99.73 [a] (88.94)	91.48 [a] (74.15)	99.21 [a] (84.90)	98.74 [a] (85.56)	82.62 [a] (67.36)	70.30 [a] (58.98)
Phosalone	2 ml	89.11 [a] (73.70)	92.04 [b] (75.62)	82.08 [b] (66.95)	93.07 [a] (76.73)	87.03 [ab] (70.89)	69.04 [b] (56.25)	39.96 [b] (40.21)
Dish wash soap solution	40 gm	60.80 [d] (55.29)	66.31 [d] (57.52)	84.11 [b] (68.51)	80.11 [b] (63.60)	81.43 [bc] (64.64)	56.70 [cd] (48.86)	31.08 [c] (33.85)
TNAU Neem (0.03% azadirachtin)	1 ml	80.22 [bc] (65.69)	81.14 [c] (68.00)	88.21 [ab] (72.92)	94.62 [a] (77.35)	91.92 [a] (74.28)	62.72 [bc] (52.39)	37.23 [b] (31.44)
TNAU NO 60 EC (C)	30 ml	87.92 [ab] (71.96)	89.14 [b] (65.05)	87.67 [ab] (72.44)	80.14 [b] (63.75)	76.02 [c] (60.73)	51.78 [d] (46.02)	26.33 [d] (30.84)
TNAU NO + PO 60 EC	30 ml	64.02 [d] (58.14)	69.17 [d] (59.27)	53.28 [d] (44.82)	54.72 [d] (47.77)	45.09 [e] (42.10)	39.72 [f] (33.61)	16.89 [e] (24.22)
NSKE	50 gm	32.64 [e] (36.84)	47.10 [e] (46.34)	68.07 [c] (58.59)	70.66 [c] (57.49)	59.71 [d] (50.62)	40.66 [ef] (39.61)	20.37 [d] (26.75)
FORS	25 gm	60.63 [d] (54.14)	68.13 [d] (58.63)	71.14 [d] (60.14)	62.08 [c] (53.99)	50.37 [de] (40.02)	48.91 [e] (44.99)	30.82 [c] (34.11)

* Figures in parentheses are Arc sine transformed values
Means followed by small letters in common within columns are not significantly different at 5% level (DMRT)
DAS - Day after spraying

Fig. 6. Mortality of eggs and nymphs of SWF due to insecticide application on cassava (Field trail - I)





4.7.1.2. Late instar nymphal mortality

At one day after spraying triazophos, phosalone and neem oil 60 EC were statistically on par in reducing late instar nymphal population which ranged from 80.72 to 82.14 per cent. TNAU neem, dish wash soap solution were the next best, causing 69.33 to 74.60 per cent mortality (Table 31). Reduction in nymphal mortality was found in all the treatments from 7 DAS. Ten days after spraying mortality rate was poor in all the treatments. A maximum of 21.96 per cent mortality was recorded in triazophos followed by phosalone. In other treatments it ranged from 3.04 to 18.15 per cent.

4.7.1.3. Reduction of adult population

Significant adulticide action was noticed in triazophos treatment with 97.28 per cent mortality. This was followed by TNAU Neem formulation (92.66) and phosalone (92.65) which were equally effective at 1 DAS (Table 32). Population reduction at 3 and 5 DAS in triazophos treated plot were 92.97 and 70.68 per cent respectively. Gradual reduction in population reduction was noted in all the treatments tested. At 10 DAS, population reduction in triazophos, TNAU neem, phosalone, NO60EC and FORS was ranging from 24.60 to 40.65 per cent.

4.7.2. Field trial II

4.7.2.1. Egg mortality

All the chemical insecticides exerted ovicidal action which ranged from 90.03 to 98.68 per cent at 3 DAS. Triazophos and malathion had more ovicidal effect which recorded 98.68 and 97.13 per cent respectively at 3 DAS (Table 33). Neem oil 60 EC and FORS recorded 70.02 to 85.82 per cent mortality. Water spray also contributed 9.62 and 13.43 per cent egg mortality at 1 and 3 DAS respectively (Fig. 7).

Table 31. Mortality of late instar nymphs of *A. dispersus* due to insecticide application (Field trial-I)

Treatment	Dose (ml/gm/ lit.)	Mortality (%) DAS				
		1	3	5	7	10
Triazophos	2ml	80.72[a] (64.21)	63.76[a] (53.01)	68.23[a] (55.73)	49.45[a] (44.68)	21.96[a] (27.82)
Phosalone	2ml	82.14[a] (65.04)	60.97[a] (51.37)	52.06[b] (46.19)	48.76[a] (44.29)	20.0[a] (26.59)
Dish wash soap solution	40gm	69.33[bc] (56.48)	51.08[b] (45.62)	41.99[c] (40.38)	32.07[c] (34.49)	12.69[b] (20.82)
TNAU Neem (0.03%)	1ml	74.60[ab] (59.80)	68.21[a] (55.72)	50.02[b] (45.01)	33.72[c] (35.49)	10.22[bc] (18.62)
TNAU NO 60 EC (C)	30ml	81.92[a] (64.87)	63.49[a] (52.93)	51.17[b] (45.07)	40.26[b] (38.38)	18.15[a] (25.14)
TNAU NO + PO 60 EC(C)	30ml	54.28[d] (47.48)	50.06[b] (45.03)	32.98[d] (35.04)	22.63[d] (28.40)	7.21[cd] (15.36)
NSKE	50gm	60.99[cd] (51.36)	50.02[b] (45.01)	40.72[c] (39.65)	10.02[e] (19.81)	8.41[bcd] (16.79)
FORS	25gm	50.61[d] (45.35)	32.79[c] (34.90)	34.07[d] (35.70)	32.65[c] (34.84)	5.96[d] (14.02)

Figures in parentheses are Arc sine transformed values.
Means followed by small letters in common within columns are not significantly different at 5% level DMRT.

Table 32. Per cent reduction in adult population of *A. dispersus* following insecticide application (Field trial I)

Treatment	Dose (ml/gm/lit.)	Adult reduction (%) DAS				
		1	3	5	7	10
Triazophos	2ml	97.28 a (80.60)	92.97 a (75.34)	70.68 a (57.26)	61.26 a (53.51)	40.65 a (39.61)
Phosalone	2ml	92.65 b (75.27)	86.33 b (69.30)	54.38 bc (47.53)	60.11 a (50.85)	35.03 b (36.29)
Dish wash soap solution	40gm	71.37 e (58.65)	70.64 cd (58.03)	56.24 b (48.50)	52.92 b (46.68)	16.24 c (23.76)
TNAU Neem (0.03%)	1ml	92.66 b (74.28)	84.16 b (66.57)	52.45 c (48.40)	41.20 c (40.93)	24.60 b (29.73)
TNAU NO 60 EC (C)	30ml	82.69 c (65.45)	73.69 c (59.21)	48.22 cd (43.98)	54.72 b (47.73)	42.30 a (40.57)
TNAU NO + PO 60 EC(C)	30ml	80.62 d (64.13)	66.11 e (54.43)	32.68 e (34.85)	42.03 c (40.40)	16.97 d (24.33)
NSKE	50gm	86.33 c (68.57)	72.02 c (58.12)	46.42 d (42.94)	40.07 cd (39.23)	15.61 d (23.27)
FORS	25gm	73.24 e (58.89)	53.08 f (46.77)	39.11 e (38.71)	35.11 d (36.32)	27.05 b (31.34)

Figures in parentheses are Arc sine transformed values.
Means followed by small letters in common within columns are not significantly different at 5% level (DMRT).

4.7.2.2. Early instar nymphal mortality

Triazophos spray inflicted significant mortality to the early instar nymphs of *A. dispersus* (94.87 to 96.33%) at 1 to 5 DAS (Table 33). Next to triazophos, malathion was found superior in reducing crawler and second instar nymphs, which ranged from 88.22 to 90.21 per cent. FORS and neem oil caused the nymphal mortality by 69.22 and 66.11 per cent respectively at 1 DAS. Mere water spray lowered the population by 10.21 per cent at 1 DAS. Notable reduction in nymphal mortality was found from 7 DAS in all the treatments (Fig. 7).

4.7.2.3. Late instar nymphal morality

Triazophos significantly reduced the late instar nymphal population by 84.71 per cent at 1 DAS, followed by malathion (71.08), neem oil (71.33), FORS (64.92) and Phosalone (64.88), which were statistically on par (Table 34). Water spray reduced the population by 5.38 per cent. Decrease in nymphal mortality was recorded from 5 DAS in all the treatments. Triazophos recorded low mortality (41.96%) at 10 DAS, which was significantly higher than other treatments tested.

4.7.2.4. Adult mortality

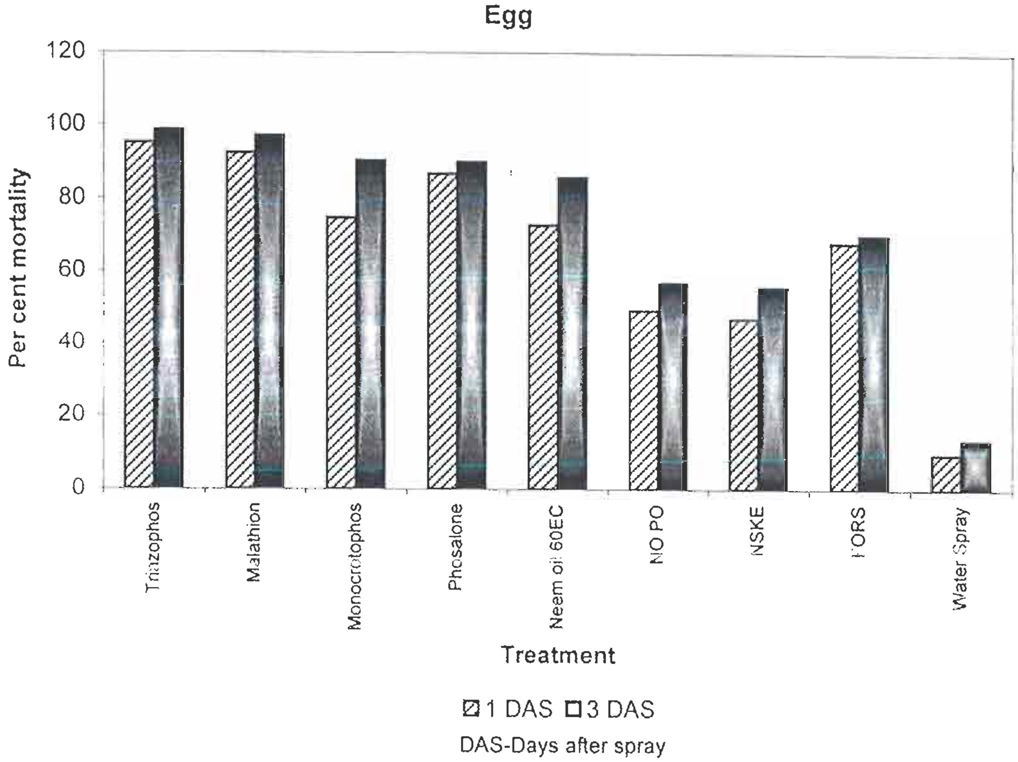
Triazophos was highly effective in its knock down effect. A reduction of 98.61 per cent adult population was noticed. This was followed by malathion (83.58%), monocrotophos (82.21%) and phosalone (80.84%) which were equally effective (Table 35). Next to chemical pesticides, neem oil and FORS reduced the adult population to 72.04 and 68.20 per cent respectively. Water spray also reduced the adult population by 12.06% at 1 DAS. The same trend was observed at 3 and 5 DAS. Population reduction of adults was less from 7 DAS in all the treatments.

Table 33. Mortality of eggs and early instar nymphs of *A. dispersus* following insecticidal application on cassava on *M. esculenta* (Field Trial - II)

Treatments	Dose	Egg mortality (%) (DAS)*		Early instar nymphal mortality (%) (DAS) *				
		1	3	1	3	5	7	10
Triazophos	0.08	95.26 a (78.42)	98.68 a (83.40)	95.65 a (78.45)	96.33 a (79.75)	94.87 a (77.91)	86.28 a (68.26)	65.14 a (54.81)
Malathion	0.1	92.54 b (75.15)	97.13 a (81.25)	89.31 b (70.91)	90.21 b (72.55)	88.22 b (70.93)	63.67 b (53.93)	49.06 b (44.46)
Monocrotophos	0.072	74.69 c (60.79)	90.44 b (72.99)	79.40 cd (63.01)	74.60 cd (59.74)	68.86 c (56.11)	59.73 d (51.61)	47.03 d (43.30)
Phosalone	0.07	86.86 b (69.75)	90.03 b (72.59)	86.11 bc (69.12)	76.17 c (61.02)	79.24 bc (63.89)	60.83 c (51.27)	33.72 c (38.11)
Neem oil 60 EC	1.8	72.74 d (60.53)	85.82 c (68.88)	66.11 d (55.40)	62.48 de (52.24)	60.11 cd (50.84)	43.28 d (41.13)	26.14 d (34.75)
NOPO	1.8	49.32 e (45.61)	56.92 e (50.98)	51.76e (46.01)	58.17e (49.71)	54.28 d (47.46)	38.72 d (38.46)	20.07 e (27.62)
NSKE	5	46.92 e (43.23)	55.74 e (49.30)	48.32 e (44.04)	55.07 e (47.92)	54.47 d (47.57)	40.39 d (39.46)	11.72 f (20.04)
FORS	4	67.98 c (56.54)	70.02 d (57.80)	69.22 d (56.33)	71.67 d (57.85)	66.38 c (54.59)	43.01 d (41.62)	20.14 e (27.66)
Water spray	-	9.62 f (18.07)	13.43 f (21.49)	10.21 f (18.63)	9.37 f (17.82)	6.27 e (14.50)	2.38 e (8.87)	1.24 g (6.39)

* Figures in parentheses are Arc sine transformed values
Means followed by small letters in common within columns are not significantly different at 5% level (DMRT)

Fig. 7. Mortality of eggs and nymphs of SWF due to insecticide application on cassava (Field trail - II)



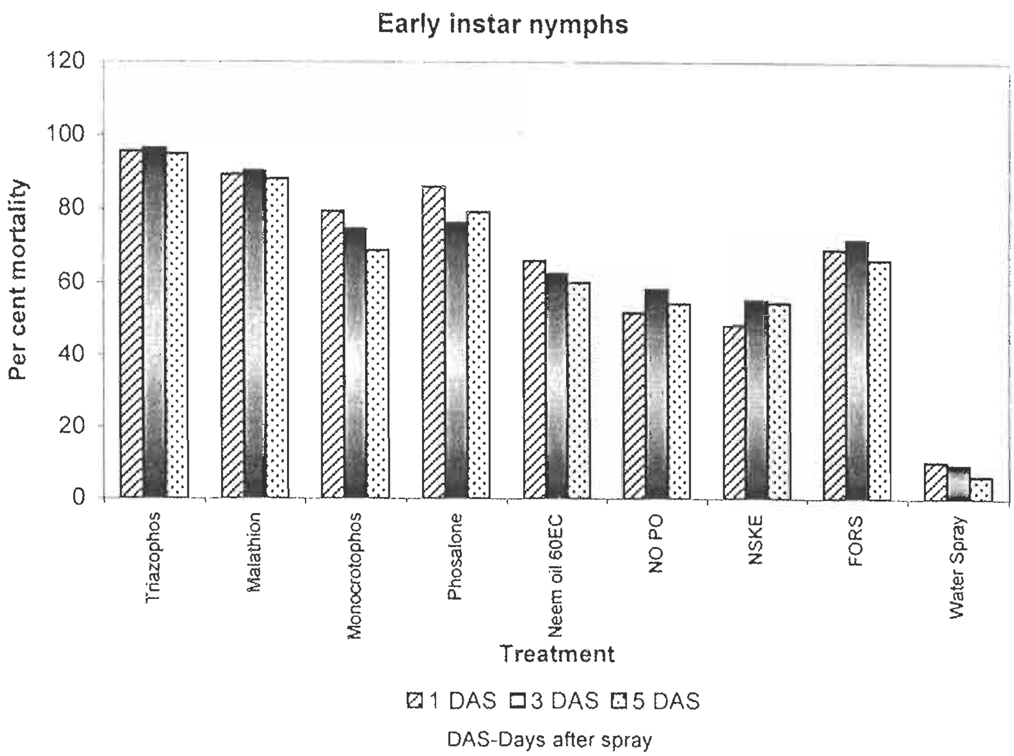


Table 34. Mortality of late instar nymphs of SWF following insecticide application on cassava (*M. esculenta*) (Field Trial II)

Treatment	Dose (%)	Mortality (%) DAS				
		1	3	5	7	10
Triazophos	0.08	84.71 [a] (67.35)	72.04 [a] (58.09)	70.81 [a] (57.47)	60.32 [a] (50.98)	41.96 [a] (40.21)
Malathion	0.1	71.08 [b] (57.75)	71.33 [a] (57.93)	63.27 [a] (52.70)	40.11 [b] (39.26)	16.98 [c] (26.32)
Monocrotophos	0.072	62.54 [b] (52.29)	54.21 [b] (47.42)	48.92 [b] (44.38)	36.21 [bc] (36.97)	12.06 [d] (22.21)
Phosalone	0.07	64.88 [b] (53.71)	50.73 [b] (45.42)	44.31 [bc] (41.72)	35.71 [bc] (36.68)	30.22 [b] (34.35)
Neem oil	1.8	71.33 [b] (58.79)	58.88 [b] (52.11)	40.79 [bcd] (39.65)	40.03 [d] (39.23)	14.26 [cd] (21.14)
NO + PO	1.8	48.29 [c] (44.02)	40.07 [c] (39.26)	32.62 [cd] (34.81)	29.48 [cd] (32.88)	7.21 [e] (14.29)
NSKE	5	40.03 [c] (39.21)	36.22 [c] (36.95)	30.06 [d] (33.23)	18.39 [e] (25.36)	5.96 [e] (14.13)
FORS	4	64.92 [b] (54.85)	60.73 [b] (51.21)	41.33 [bcd] (39.99)	24.43 [d] (29.62)	6.23 [e] (15.02)
Water spray	-	5.38 [d] (13.36)	4.11 [d] (11.46)	1.06 [e] (3.42)	0.03 [f] (0.19)	0.70 [f] (4.65)

Figures in parentheses are Arc sine transformed values.
Means followed by small letters in common within columns are not significantly different at 5% level (DMRT).

Table 35. Per cent reduction in adult population of *A. dispersus* on cassava (*M. esculenta)* following insecticide application (Field trial II)

Treatments	Dose (%)	Adult reduction (%) DAS				
		1	3	5	7	10
Triazophos	0.08	98.61[a]	86.42[a]	74.41[a]	53.11[a]	46.19[a]
		(84.23)	(68.53)	(59.75)	(46.81)	(42.81)
Malathion	0.1	83.58[b]	70.09[b]	61.38[b]	39.17[b]	20.24[c]
		(67.09)	(56.98)	(51.60)	(38.74)	(26.73)
Monocrotophos	0.072	82.21[b]	64.23[bc]	44.10[c]	29.49[c]	19.09[c]
		(65.05)	(53.29)	(41.60)	(32.89)	(25.91)
Phosalone	0.07	80.84[b]	62.11[bc]	49.88[c]	30.07[c]	22.06[b]
		(64.04)	(52.04)	(44.93)	(33.16)	(28.01)
Neem oil	1.8	72.04[c]	66.32[b]	56.34[b]	34.86[b]	26.09[b]
		(59.08)	(54.52)	(48.64)	(36.19)	(27.15)
NO + PO	1.8	58.23[b]	35.84[d]	36.02[d]	19.14[d]	14.11[d]
		(50.74)	(36.70)	(36.86)	(25.88)	(21.37)
NSKE	5	43.17[e]	30.07[d]	25.17[de]	16.28[d]	13.21[d]
		(41.07)	(33.20)	(30.02)	(23.79)	(20.94)
FORS	4	68.20[cd]	60.12[c]	52.67[bc]	26.08[c]	19.22[c]
		(55.71)	(52.83)	(46.53)	(26.50)	(26.00)[c]
Water spray	-	12.06[f]	5.14[e]	2.83[f]	1.24[e]	2.14[e]
		(20.32)	(13.08)	(7.63)	(3.71)	(7.02)

Figures in parentheses are Arc sine transformed values.
Means followed by small letters in common within columns are not significantly different at 5% level (DMRT).

4.8. Biological Control

4.8.1. Survey on natural enemy complex of *A. dispersus*

Extensive survey to record the occurrence of natural enemies of *A. dispersus* indicated the association of several species of predators *viz.*, cybocephalid, coccinellids, chrysopids and spiders and a hymenopteran parasitoid and a parasitic mite. Among the natural enemies, predators were more abundant in most of the localities surveyed where as parasitoids were found only in few localities, mostly in Coimbatore and nearby districts.

4.8.2. Predators

Predator fauna of *A. dispersus* including coccinellids, cybocephalid, chrysopids and spiders was found during surveys (Table 36).

4.8.2.1. Coleopteran predators

Totally eleven coleopteran species belonging to two families *viz.*, Nitidulidae and Coccinellidae were found to prey on *A. dispersus*. It was interesting to note that the *Cybocephalus* sp. (Nitidulidae : Coleoptera) found more abundant among the predators, was recorded for the first time in Tamil Nadu, on *A. dispersus*. Both the grubs and adults preyed on eggs and larvae of the whitefly. Among the members of the family Coccinellidae, the species, *Cryptolaemus montrouzieri* Mulst, *Axinoscymnus puttarudriahi* Kapur and Munshi, *Chilocorus nigritus* (Fab.) and *Scymnus coccivora* Ayyar were abundant than other species throughout the study period (Plate 16). The survey report on coccinellids on various hosts harbouring *A. dispersus* at Coimbatore district showed the abundance of *Cybocephalus* sp on *M. esculenta* (1408) *M. glaziovii* (862) *Manihot* sp. (719) and *P. guajava* (352) Table 37. *C. montrouzieri* was found predominant on *P. guajava* (241) followed by *T. populnea* (230) and *M. glaziovii* (109). *A. puttarudriahi* was found more in numbers on *M. esculenta* (49)

Table 36. Predator fauna of *A. dispersus*

Predators	Order	Family	Species
Cybocephalid	Coleoptera	Nitidulidae	*Cybocephalus* sp.
Coccinellids		Coccinellidae	*Axinoscymnus puttarudriahi* Kapur and Munshi
			Scymus coccivora Ayyar
			Cryptolaemus montrouzieri Mulsant
			Chilocorus nigritus (Fab.)
			Jauravia sp.
			Rodolia breviuscula Weise
			Cheilomenes sexmaculata (Fabricius)
			Illeis cincta (Fabricius)
			Anegleis cardoni (Weise)
			Micraspis discolor (Fab.)
Chrysopids	Neuroptera	Chrysopidae	*Apertochrya* sp
			Mallada astur (Banks)
			Chrysoperla carnea Stephens
Spiders	Acari	Oxyopidae	*Oxyopes* sp.

Table 37. Coleopteran predators of SWF on various plant species in Coimbatore (Jan.-Dec.'99)

Sl. No.	Species	*Cybocephalus* sp.	*Cryptolaemus* sp.	*Axinosymnus* sp.	*Scymnus* sp.	Chilocorus sp.	*Chilomenes* sp.	*Micraspis* sp.	*Anegleis cardoni*
1.	*Manihot esculenta*	1408	89	49	24	19	218	39	11
2.	*Psidium guajava*	352	241	46	14	176	25	10	17
3.	*Gossypium hirsutum*	36	9	3	1	-	24	3	-
4.	*Capsicum annuum*	9	2	3	-	-	8	-	-
5.	*Abelmoschus esculentus*	11	-	-	2	-	11	2	-
6.	*Glycine max*	8	3	4	2	-	2	-	-
7.	*Arachis hypogea*	5	3	2	4	-	4	-	-
8.	*Cajanus cajan*	4	4	3	4	-	9	3	-
9.	*Solanum melongena*	12	2	6	-	-	14	-	-
10.	*Lycopersicon esculentum*	15	-	4	-	-	9	-	-
11.	*Musa* spp.	37	19	6	2	2	11	4	-
12.	*Punica granatum*	30	4	-	-	-	4	-	-
13.	*Carica papaya*	208	13	7	2	-	13	-	4
14.	*Manihot glaziovii*	862	109	13	4	3	17	16	2
15.	*Manihot* sp.	719	184	4	9	11	19	4	7
16.	*Thespesia populnea*	82	230	27	2	8	41	-	-
17.	*Terminalia catappa*	21	15	-	-	-	4	2	-
18.	*Acalypha indica*	44	29	3	-	-	-	-	2
19.	*Euphorbia poinsettia*	27	32	-	4	2	15	-	-
20.	*Dhombia spectabilis*	11	2	-	-	-	2	-	-
21.	*Bauhinia purpurea*	-	2	-	2	-	2	-	-

Contd ....

Sl. No.	Species	*Cyboce-phalus* sp.	*Cryptola-emus* sp.	*Axinosy-mnus* sp.	*Scym-nus* sp.	*Chiloc-orus* sp.	*Chilo-menes* sp.	*Micra-spis* sp	*Anegleis cardoni*
22.	*Plumeria alba*	21	14	2	-	-	6	-	2
23.	*Solanum trilobatum*	-	2	-	-	-	4	-	-
24.	*Amaranthus* sp.	9	-	-	-	-	2	-	-
25.	*Euphorbia heterophylla*	16	-	2	4	-	6	3	5
26.	*Corchorus capsularis*	6	-	-	-	-	4	3	-
27.	*Alternanthra triandra*	-	-	-	-	-	4	2	-
28.	*Euphorbia hirta*	-	-	-	-	-	6	-	-

Plate 16.Coleopteran predators of *A. dispersus*

Chilocorus nigritus

Chilomenes sexmaculatus

Anegleis cardoni

Axinoscymnus puttarudriahi

Female

Male

Cybocephalus sp.

Jauravia sp.

and *P. guajava* (46). A higher number of *C. nigritus* was found on *P. guajava* (176). *Chilomenes sexmaculatus* population was high on *M. esculenta* (218 numbers). Predators were also found on weeds, among them the population of *Cybocephalus* sp was high on *E. heterohylla* (16) *A. indica* (14) and *C. capsularis* (6). Host plant of SWF harbouring more number of predators in Coimbatore district are listed in Table 38. A total of 1795 coccinellids were found on *M. esculenta*, which was statistically high. This was followed by *M. glaziovii* (1026) and *Manihot sp* (957).

4.8.2.2. Chrysopids

Three chrysopid species were found preying on eggs and larvae of *A. dispersus*. Among them, *Apertochrysa* sp. and *Mallada astur* were found more abundant than *Chrysoperla carnea* Stephens. Among the host plants of *A. dispersus* surveyed at Coimbatore, Chrysopids population was high on *M. esculenta* (116) followed by *Manihot* sp. (104) and *P. guajava* (101) (Table 38).

4.8.2.3. Spiders

A high population of spider, *Oxyopus* sp. (Oxyopidae) was found preying on *A. disperus* on *M. esculenta* (413) followed by *Gossypium* spp. (64) and *P. guajava* (59) (Table 38).

4.8.2.4. Survey report on predator fauna of *A. dispersus* in other districts of Tamil Nadu

Among the other districts surveyed, predator population was found to be higher on host plants of *A. dispersus* surveyed at Erode, Namakkal, Salem, Dharmapuri and Madurai districts (Table 39). In all the places, cypocephalid, coccinellids, chrysopids and spiders were found preying on *A. dispersus*. Predators were found in higher numbers on *M. esculenta* and *P. guajava* followed by *T. populnea*.

Table 38. Distribution of SWF predators on different plant species in Coimbatore (Jan. - Dec.'99)

	Plant Species	coccinellids	chyrsopids	spiders
1.	*Manihot esculenta*	1795^{a} (3.27)	116^{a} (2.07)	413^{a} (2.62)
2.	*Gossypium hirsutum.*	76^{j} (1.88)	36^{j} (1.56)	64^{b} (1.81)
3.	*Capsicum annuum*	26^{q} (1.42)	43^{h} (1.64)	13^{j} (1.13)
4.	*Abelmoschus esculentus*	26^{q} (1.42)	32^{l} (1.51)	10^{k} (1.02)
5.	*Glycine max*	18^{r} (1.27)	32^{l} (1.51)	8^{l} (0.93)
6.	*Arachis hypogea*	18^{r} (1.27)	4^{u} (0.65)	13^{j} (1.13)
7.	*Cajanus cajan*	27^{p} (1.44)	24^{n} (1.39)	20^{h} (1.31)
8.	*Solanum melongena*	34^{n} (1.54)	29^{m} (1.47)	14^{i} (1.16)
9.	*Lycopersicon esculentum*	28^{o} (1.45)	33^{k} (1.52)	9^{l} (0.98)
10.	*Psidium guajava*	881^{d} (2.95)	101^{c} (2.01)	59^{c} (1.77)
11.	*Musa* sp.	81^{g} (1.91)	62^{g} (1.80)	8^{l} (0.93)
12.	*Punica granatum*	38^{m} (1.59)	21^{o} (1.33)	11^{k} (1.06)
13.	*Carica papaya*	231^{f} (2.36)	66^{f} (1.82)	24^{f} (1.39)
14.	*Manihot glaziovii*	1026^{b} (3.01)	93^{d} (1.97)	53^{d} (1.73)
15.	*Manihot* sp.	957^{c} (2.98)	104^{b} (2.02)	49^{e} (1.69)
16.	*Thespesia populnea*	390^{e} (2.59)	39^{i} (1.60)	15^{j} (1.19)
17.	*Terminalia catappa*	42^{l} (1.63)	16^{r} (1.22)	7^{p} (0.87)
18.	*Acalypha indica*	78^{I} (1.89)	84^{e} (1.93)	23^{g} (1.37)
19.	*Poinsettia pulcherrima*	80^{h} (1.91)	17^{q} (1.24)	2^{m} (0.40)
20.	*Plumeria alba*	45^{k} (1.66)	14^{t} (1.16)	2^{m} (0.40)

Figures in parentheses are log (x + 0.5) transformed values.
Means followed by common letters are not significantly different at 5% level (DMRT).

Table 39. Survey report on predators population of SWF in various districts of Tamil Nadu

Districts	Plant species	Coccinellids	Chrysopids	Spiders
Erode	*P. guajava*	37	17	5
	M. esculenta	39	11	20
	C. annuum	6	4	7
	Musa sp.	6	17	5
	T.populnea	18	10	2
	A. indica.	13	19	4
Namakkal	*M. esculenta*	42	31	17
	P. guajava	40	14	12
	C. papaya	14	19	5
	Musa sp.	8	12	2
	L. esculentum	11	19	2
	T.populnea	24	2	2
Salem	*M. esculenta*	39	4	4
	P. guajava	18	20	3
	Musa sp.	2	19	2
	T. catappa	3	11	4
	C. papaya	11	2	2
	S. melongena	4	21	4
Dharmapuri	*M. esculenta*	93	15	7
	P. guajava	10	19	2
	Musa sp.	4	21	-
Madurai	*M. esculenta*	47	53	11
	P. guajava	15	8	4
	R. communis	19	11	4
	G. hirsutum	10	24	9
	Musa sp.	2	4	1
	S. melongena	2	9	3
	A. indica	4	15	4

4.8.3. Feeding potential and longevity of predators of *A. dispersus*

4.8.3.1. Feeding potential of coleopteran predators and spider on *A. dispersus*

The data on the mean number of *A. dispersus* preyed by larvae and adults of *Cybocephalus* sp, *C. montrouzieri* and spider on *P. guajava* are presented in Table 40. There were significant differences in prey consumption by the different larval instars and adults of the predators tested.

4.8.3.1.1. *C. montrouzieri*

The first instar larva consumed an average of 20.50 eggs and 19.70 nymphs during its developmental period of 3.80 days. Second and third instar larva consumed comparatively more number of SWF, than early instar. Fourth instar larva had developmental period of 5.80 days, consumed 21.10 eggs and 117.00 nymphs. The results clearly indicated that early instars preyed more on eggs whereas late instar preyed more of nymphal stages of SWF. A single larva consumed a total of 138.6 eggs and 228 nymphs during its developmental period of 16.60 days. Adult consumed an average of 89.00 eggs and 173.00 nymphs of SWF during its life period of 12.40 days (Table 40) (Plate 17).

4.8.3.1.2. *Cybocephalus* sp.

The mean consumption of eggs and nymphs of SWF by a single larva during its developmental period of 10.20 days was 95.36 and 49.13 respectively. A single adult consumed on an average of 41.07 eggs and 12.69 nymphs during its life period of 5.90 days (Table 40) (Plate 18).

4.8.3.1.3. Spider (*Oxyopus* sp.)

On an average 49.00 eggs, 10.60 nymphs and 17.13 adults of SWF were consumed by a single spider during its life period of 19.80 days (Plate 18). The spider adults lived longer period than *Cybocephalus* and *C. montrouzieri* adults, with lesser predatory potential (Table 40).

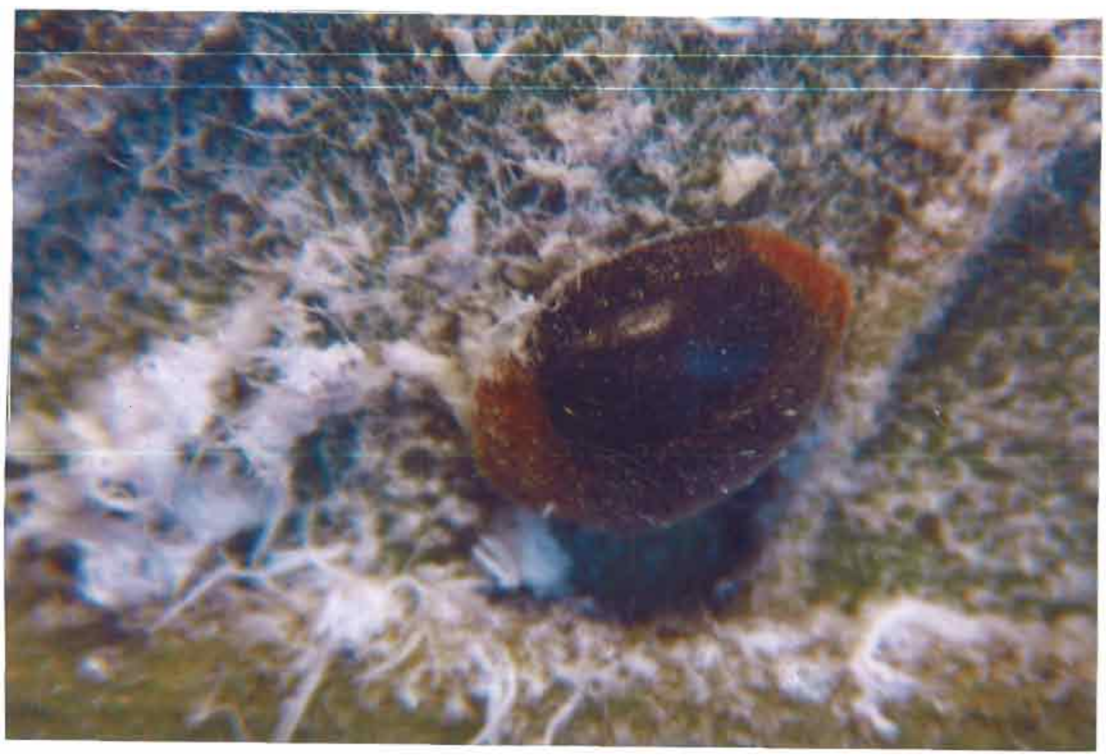
Table 40. Feeding potential and longevity of predators on *A. dispersus*

Stage of predator	Developmental period (days)	No. of whitefly consumed		
		Egg	Nymph	Adult
1. *Cryptolaemus montrouzieri*				
Larva				
I	3.80[bc]	20.50 ± 5.12[b] (4.58)	19.70 ± 4.21[d] (4.49)	-
II	3.10[c]	39.50 ± 7.20[a] (6.32)	38.50 ± 6.08[c] (6.24)	-
III	3.90[bc]	29.70 ± 11.08[b] (5.49)	53.00 ± 9.22[b] (7.31)	-
IV	5.80[a]	21.10 ± 9.54[b] (4.65)	117.00 ± 10.46[a] (10.84)	-
Total larval duration	16.60	138.6 ± 10.35	228 ± 9.33	-
Adult	12.40	89.00 ± 7.20	173.00 ± 14.20	-
2. *Cybocephalus* sp.				-
Larva	10.20	95.36 ± 9.43[a] (9.79)	49.13 ± 10.14[a] (7.05)	-
Adult	5.90	41.07 ± 11.32[b] (6.45)	12.69 ± 7.96[b] (3.63)	-
3. Spider *Oxyopus* sp.	19.80	49.00 ± 6.40	10.60 ± 9.10	17.13 ± 6.0

Figures in parentheses are Sqr.(x + 0.5) transformed values.
Means followed by common letters are not significantly different at 5% level (DMRT).

Plate 17. ***Cryptolaemus montrouzieri*** **feeding on** ***A. dispersus***

Grub



Adult

Plate 18. Predators feeding on *A. dispersus*

Cybocephalus sp. (both male and female)

Chrysopid *Mallada astur*

Spider *Oxyopus* sp.

4.8.3.2. Predatory potential and longevity of chrysopids on *A. dispersus*

4.8.3.2.1. *Mallada astur*

The mean number of *A. dispersus* consumed by the predator *M. astur* during the first and second instars were 22.70 and 59.40 respectively. Thirty per cent of the first instar larvae of predator died and the rest had 4.60 days of developmental period. Second instar lived for 4.20 days with mortality of 10 per cent. Remaining sixty per cent reached third instar, which had a developmental period of 5.40 days with the consumption of 118.30 SWF. All the third instar survived to pupation (Table 41) (Plate 18).

4.8.3.3.2. *Chrysoperla carnea*

None of the first instar larvae survived and died shortly after introducing on prey with the average life period of 3.20 days and consumption of 4.10 whiteflies. Sixty per cent of the second instar larvae died and the remaining moulted to third instar. Second instar had on average of 4.70 days developmental period and consumed 11.70 whitefly nymphs and eggs. Twenty per cent of the third instar died and the remaining 20 per cent survived to pupation. Third instar had developmental period of 5.60 days and consumed 29.40 nymphs and eggs of SWF (Table 41).

4.8.4. Mass culturing of predator

The predators *C. montrouzieri*, *C. carnea* and *Mallada astur* were successfully mass cultured on grapevine mealybug, *M. hirsutus* and eggs of rice moth *C. cephalonica* respectively. None of the *Cypocephalus* adults laid eggs during mass culturing in the laboratory and died soon with the average longevity of 4.5 days. Repeated attempts were made which yielded the same result, hence mass culturing was discontinued.

Table 41. Predatory potential and longevity of chrysopa larva on *A. dispersus*

Predator/Instars	Per cent larvae died	Developmental period (days)	No. of whiteflies consumed /instar*
Mallada astur			
I	30	4.60[b]	22.70[c] (6.57)
II	10	4.20[a]	59.40[c] (8.36)
III	-	5.40[a]	118.30[a] (12.24)
Total		**14.20**	**200.40**
Chrysoperla carnea			
I	100	3.20[b]	4.10[b] (2.76)
II	60	4.70[a]	11.70[b] (4.82)
III	20	5.60[a]	29.40[a] (7.87)
Total		**13.50**	**45.20**

Figures in parentheses are Sqr. (x + 0.5) transformed values.
Means followed by common letters are not significant different at 5% level (DMRT).

4.8.5. Parasitoids

4.8.5.1. Survey on collection of parasitoids of *A. dispersus*

Several host plants of *A. dispersus* were surveyed throughout Tamil Nadu for identifying the parasitoids associated with *A. dispersus*. The natural parasitism of late instar nymphs and pupae of *A. dispersus* was recorded in Coimbatore on *P. guajava*. It was the first report on occurrence of parasitoid of *A. dispersus* in Tamil Nadu. Based on this, intensive survey was made in and around Coimbatore. High level of parasitism was recorded in *P. guajava* at Patchapalayam Milk Society, Madampatti, Coimbatore from May '99. The emerged parasitoids were identified as *Encarsia* sp. near *meritoria* Gahan (Aphelinidae : Hymenoptera) (Hayat, 1999 Pers. Comm.).

Survey was also intensified in *M. esculenta* ecosystem. The survey report on parasitoid (Table 42) showed that parasitism was very high on *P. guajava* (51.19 per cent) at Patchapalayam, followed by *Gossypium* spp. (45.00 per cent) at Insectary, TNAU. Parasitism was also observed on *M. esculenta, A. indica, Manihot* sp., *Gossypium* spp. and *P. alba* in TNAU campus fields at Coimbatore. The results showed that the parasitism varied with the hosts. In Mettupalayam, Pollachi and Udumalpet, parasitism was also observed on *P. guajava*. In Erode, Salem and Namakkal, parasitoids could be collected from *P. guajava, M. esculenta, P. granatum* and *Musa* spp. In all the localities and crops surveyed, *P. guajava* recorded the highest parasitism of *A. dispersus*.

4.8.5.2. Parasitization level of the newly recorded parasitoid of *A. dispersus*

Periodical samplings were done at weekly intervals from May 1999 to March 2000 to find out the peak occurrence of parasitism on *P. guajava* at Patchapalayam. The data given at monthly intervals in Table 43 showed the per cent parasitism of 0.43 at the initial period of the study i.e. in the May 1999.

Table 42. Survey on occurrence of *Encarsia* parasitoid of *A. dispersus*

Sl. No.	Places	Crop	Period of occur-rence	Total samples observed	Parasi-tism (%)	Parasitoid emergence (%)
1.	COIMBATORE					
	Patchapalayam	*Psidium guajava*	May'99-Mar.2000	9193	51.19	80.33
	TNAU Orchard	*Manihot esculenta*	Dec.'98-Mar.2000	7397	9.71	61.72
	TNAU Campus	*Acalypha indica*	Jan.'99-Dec.99	940	5.42	33.33
	TNAU Insectary	Manihot sp.	Jan.'99-Mar.2000	4015	15.79	71.43
	TNAU Insectary	*Gossypium hirsutum*	Dec.'99-Mar.2000	831	45.00	70.59
	TNAU Insectary	*Plumeria alba*	Jan.2000-Mar.2000	360	25.83	77.78
	P.N.Pudur	*Thespesia populnea*	Jan.'99-Dec.'99	2098	3.48	33.33
	Vadavalli	*Psidium guajava*	Sep.'99	200	15.50	100.00
2.	METTUPALAYAM	*Psidium guajava*	Sep.-Nov.'99	160	20.00	33.33
3.	POLLACHI	*Psidium guajava*	Oct.'99	260	11.54	12.50
4.	UDUMALPET	*Psidium guajava*	Oct.'99	156	3.85	50.00
5.	ERODE	*Manihot esculenta*	Nov.'99	200	20.00	33.33
6.	SALEM	*Manihot. esculenta*	Oct.-Nov.'99	200	19.00	58.33
		Psidium guajava	Oct.-Nov.'99	250	39.60	66.67
7.	NAMAKKAL	*Psidium guajava*	Oct.'99-Feb.2000	670	59.45	87.50
		Punica granatum	Jan.2000	160	28.60	85.71
		Musa spp.	Jan.2000	70	30.00	53.85

Table 43. Periodical sampling for parasitism in guava (*P. guajava*) at Patchapalayam

Month	Number of pupae observed*	Puparia with parasitoid emergence hole	Parasitized pupae	Parasitism (%)	No. of Parasitoids emerged	Parasitoid emergence (%)
May'99	683.50	1.75	1.25	0.43	1.00	80.00
June	577.80	2.05	6.00	4.47	4.00	66.67
July	624.20	40.40	5.60	7.36	4.40	78.57
August	579.00	39.50	8.75	8.28	5.50	62.86
September	515.80	104.14	26.00	25.23	21.26	81.77
October	280.80	109.53	40.90	53.57	33.99	83.10
November	246.30	129.25	29.00	64.31	25.59	88.26
December'99	274.00	152.00	28.25	65.49	23.50	83.07
Jan. 2000	247.40	135.40	21.20	62.18	20.00	94.34
February	194.80	60.13	33.26	47.94	28.60	86.00
March 2000	159.30	31.08	12.50	27.36	10.18	81.44

*Average of standard weeks

A steady increase in parasitism of *A. dispersus* was found in the following months, reached a peak at December '99 (65.49 per cent). Thereafter the rate of parasitism declined and reached to 27.36 per cent in March 2000. The parasitoid emergence ranged from 62.86 to 94.34 per cent.

4.8.5.3. Morphology of the parasitoid, *Encarsia* sp near *meritoria*

Encarsia sp nr *meritoria* was a solitary, aphelinid, endoparasitoid had yellow coloured body with black eyes. Body length and width of the parasitoid were 0.57 and 0.261 mm respectively (Table 44). Forewings were 0.37 mm long and 0.161 mm broad. The apical angle of head was slightly obtused. Antennae were geniculate type, eight segmented with six flagellomeres which were equal in length. Wings were hyaline with marginal fringes of setae. Both wings were setaceous. Legs were ambulatorial with tarsal formula of 5-4-5 and had mid tibial spur (Plate 19 and 20).

4.8.5.4. Biology of the parasitoid *Encarsia* sp near *meritoria*

4.8.5.4.1. Parasitoid emergence behaviour

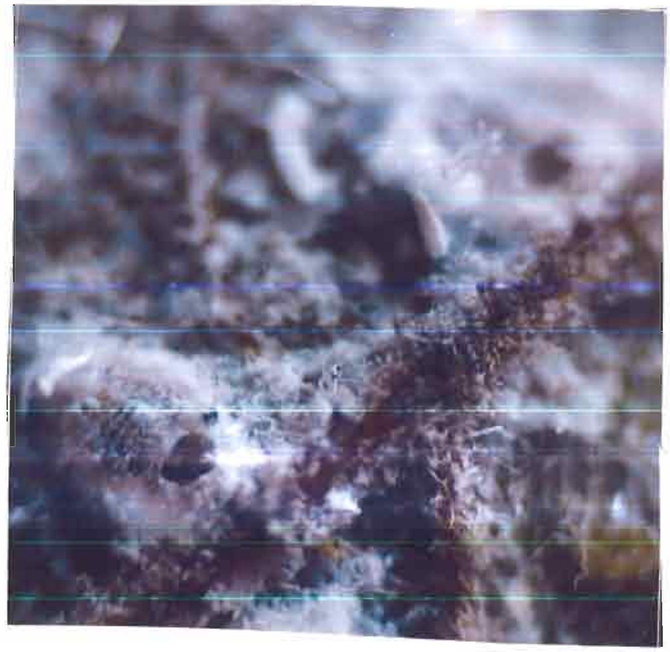
The process of parasitoid adult emergence from the pupae of *A. dispersus* and the activities on host searching and feeding of the parasitoid were studied. At the time of emergence, the parasitoid wasp made a small irregular hole in the cephalic region of the pupa. It exerted its antenna one by one through the hole and made quick spiral movements to enlarge the hole. Then the wasp tried to project its head and mouth portion through the hole and cut the irregular edges by their mandibles to enlarge the hole. Then it ejected its entire head out side the hole and moved the head sidewise and raised its body slightly. The wasp slowly pulled out its body parts one by one starting from the forelegs by making up and down movements and came out from the hole. After the emergence the shape of the hole was smooth and perfect circular (Plate 19). The parasitoid wasp took an average of 20.18 minutes duration for the emergence from the pupa, which ranged from

Table 44. Morphological features of the parasitoid *Encarsia* sp. near *meritoria*

Body parts	Description
Body length	0.570 ± 0.014 mm
Body width	0.261 ± 0.023 mm
Forewing length	0.370 ± 0.029 mm
Forewing breadth	0.161 ± 0.01 mm
Hindwing length	0.330 ± 0.18 mm
Hindwing breadth	0.143 ± 0.07 mm
Body colour	Yellow
Antennae type	Geniculate, 8 segmented and flagellomeres 6
Wing	Hyaline, Setaceous
Leg tarsal formula	5-4-5

Plate 19. Parasitoid, *Encarsia* sp. nr. *meritoria* emergence from pupae of *A. dispersus*

Parasitized pupa of *A. dispersus*



Puparia with parasitoid emergence hole

Parasitoid emerging from pupae of *A. dispersus*

14 to 35 minutes. Most of the parasitoids were found to be emerged from the pupae of *A. dispersus* during 2.30 to 4.00 p.m. (Table 45).

4.8.5.4.2. Host searching and adult feeding of the parasitoid

After emergence from the hole, the wasp which entrapped with the waxy tufts, slowly removed the waxy materials using legs. Then the female wasp moved to the leaf surface and maintained an upright position for 4 to 10 seconds and preened the wings and other body structures using legs. Again the wasp stood for few seconds and walked for 16 to 39 seconds on the leaf surface with drumming its antennae at an angle of 90° with the leaf surface to encounter a host. She mounted on the host pupae and walked to the entire length of the pupae with antennal drumming and made repeated turns on the dorsum of the pupae. After searching, the wasp stood for 4 to 19 seconds with moving its abdomen in a vertical direction and made up and down movements (drilling action). Host feeding of the wasp was also observed for 6-43 seconds, which fed the honeydew excreted on the outer surface of the whitefly pupa. While searching for a host, it discriminated the early instar nymphs and mounted on the third and fourth instar nymphs of the whiteflies during the period of 30 minutes observation (Table 45).

4.8.5.4.3. Longevity and parasitization of the parasitoid *Encarsia* sp nr *meritoria*

An average longevity of 4.0 days was observed for the parasitoid *E.* sp. nr. *meritoria* released on *P. guajava* seedlings. The parasitized pupae of *A. dispersus* turned to black colour from 16 to 18 days and the parasitoid emergence was noted at 28 to 36th days after the parasitoid released on *P. guajava* seedlings. The per cent parasitism ranged from 10.14 to 32.16 (Table 46).

Table 45. Observation on parasitoid *E.* sp nr *meritoria* emergence from the pupae of *A. dispersus*

Sample No.	Time duration for parasitoid emergence (minutes)	Time at which parasitoids emerged	Time taken by parasitoid (seconds)				No. of SWF nymphs selected by parasitoid
			Upright position	Walking	Drilling	Feeding	
1.	30	11.00 a.m.	5	20	10	14	2
2.	20	11.30 a.m.	4	30	11	21	2
3.	22	2.30 p.m.	4	39	4	6	2
4.	18	3.00 p.m.	4	20	8	30	4
5.	15	3.30 p.m.	9	18	19	28	3
6.	16	4.00 p.m.	8	16	11	17	3
7.	20	12.30 p.m.	10	18	10	28	7
8.	14	1.00 p.m.	9	16	12	43	5
9.	35	2.30 p.m.	10	20	10	13	4
10.	18	3.00 p.m.	7	29	7	27	3
Mean	20.18 ± 16.40		7.0 ± 5.90	26.2 ± 7.31	10.2 ± 6.50	32.0 ± 9.41	3.5 ± 2.17

Table 46. Longevity and parasitization of the *Encarsia sp* near *meritoria* on *P. guajava*

Sample Number	Longevity (days)	Day at which pupae turned black	Day at which parasitoid emerged	Parasitism (%)
1.	4.5	16	29	26.67
2.	3.5	-	-	-
3.	4.0	-	-	-
4.	3.5	16	36	24.40
5.	4.5	18	32	19.27
6.	5.0	17	28	10.14
7.	4.0	18	31	14.29
8.	2.5	-	-	-
9.	2.5	-	-	-
10	6.0	17	30	32.16
Mean	4.0 ± 1.17	17 ± 0.67	31 ± 8.0	21.16 ± 66.0

- Parasitism not observed

4.8.5.5. Periodical release and recovery of parasitoids of *A. dispersus*

Parasitoids could be recovered from January 2000 in *P. guajava* periodically released with *Encarsia* parasitoids at Insectary and Orchard, TNAU campus, Coimbatore (Table 47). Fortnightly observation for three months period showed the highest parasitism of 20.92 per cent from *P. guajava* at Orchard in the second fortnight of February 2000. The parasitism of *A. dispersus* pupae ranged from 4.26 to 10.79 and 7.46 to 20.92 per cent on *P. guajava* at Insectary and Orchard.

4.8.6. Parasitic mite

The natural parasitism of *A. dispersus* by a mite species was found in TNAU Orchard on various plants. These red coloured parasitic mites of *Leptus* sp. (Erythraeidae : Acari) were found feeding on third and fourth instar nymphs of *A. dispersus*. These mites were firmly attached to the host by inserting the gnathosoma and it was very difficult to remove the mite from the host body. All the mites collected were ectoparasites on *A. dispersus* by sucking the body fluid from the host. In few cases more than one mite of same species was found attached firmly to the host (Plate 20). The per cent parasitism was high (19.15) on *C. capsularis* followed by *E. heterophylla* (8.11) (Table 48). The mites were collected from five weeds and *C. annuum* around cassava field. They were found feeding perpendicularly on the dorsal surface of the nymphs. Once they pierced the host with their mouth parts, retained for 2 to5 days on the same host and sucked the body fluid. This mite was recorded for the first time on *A. dispersus* and it was a new record in India.

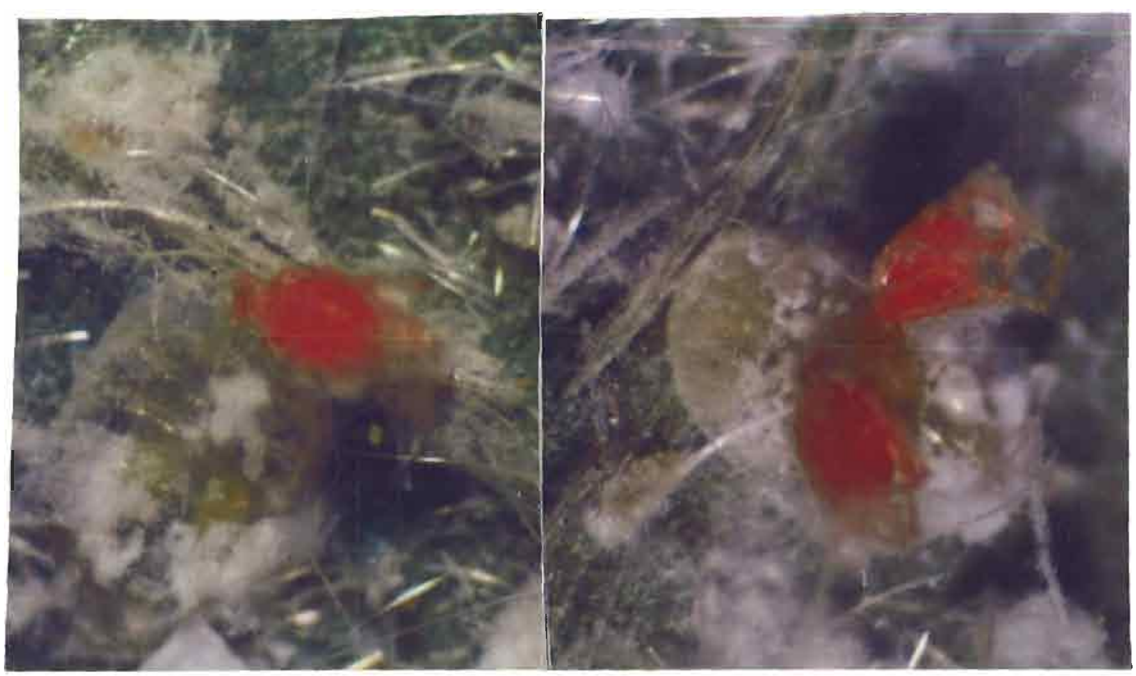
4.9. Varietal screening of crop species against *A. dispersus*

4.9.1. Evaluation of *M. esculenta* accessions against *A. dispersus*

M. esculenta accessions at TNAU orchard, were evaluated based on the level of pest population and damage intensity which is presented in Table 49. The

Plate 20.

a. Parasitoid, *Encarsia* sp. nr. *meritoria* adult (female)



b. Parasitic mite *Leptus* sp. feeding on *A. dispersus* nymph

Table 47. Periodical release and recovery of parasitoids of SWF in guava (*P. guajava*)

Month/Fortnight		Total No. of samples collected	Per cent Parasitism
INSECTARY			
December'99	I	146	-
	II	190	-
January 2000	I	137	4.26
	II	210	10.16
February 2000	I	140	-
	II	162	10.79
ORCHARD			
January 2000	I	190	18.21
	II	169	13.00
February 2000	I	180	7.46
	II	132	20.92
March 2000	I	210	13.33
	II	163	10.36

Table 48. Natural occurrence of parasitic mite, *Leptus* sp. on *A. dispersus*

Weeds	**Total no. of samples collected**	**Total no. of samples infested**	**Per cent parasitism**
Corchorus capsularis	47	9	19.15
Euphorbia heterophylla	37	3	8.11
Amaranthus viridis	35	2	5.71
Alternenthra triandra	30	1	3.33
Euphorbia hirta	32	1	3.13
Capsicum annuum	53	4	7.55

Table 49. Evaluation of *M. esculenta* accessions against *A. dispersus*

Damage & population category	Accession No.	Source / Lines	Damage intensity (%) / plant* (months)		
			3	4	5
Low	ME 4	Nilgris vella	17.21^{e} (24.51)	23.32^{b} (28.87)	36.22^{d} (37.00)
	ME 12	CTCRI Thiruvananthapuram	30.61^{g} (33.59)	62.12^{q} (52.01)	68.22^{k} (55.68)
	ME 178	CIAT 5, SM 1437-5	22.82^{e} (28.54)	39.14^{j} (38.73)	41.31^{f} (39.99)
	ME 179	CIAT 6, SM 1437-6	8.40^{a} (16.85)	26.72^{cd} (31.12)	40.12^{e} (39.30)
	ME 187	CIAT 15, SM 1444-8	21.42^{e} (27.57)	28.22^{e} (32.09)	40.02 (39.24)^{e}
	ME 224	CIAT 57, SM 1783-4	28.21^{g} (32.08)	30.02^{f} (33.22)	36.45^{d} (37.14)
	ME 246	CIAT 94, SM 1787-7	19.42^{cd} (26.15)	23.52^{b} (29.01)	26.32^{a} (30.87)
	ME 282	CIAT 143 SM 1893-2	36.41^{j} (37.11)	46.82^{l} (43.18)	47.22^{h} (43.50)
	ME 296	CIAT 160CM 8487-1	34.61^{I} (36.04)	40.21^{i} (39.36)	39.90^{e} (39.17)
	ME 324	CIAT 199 SM 1454-5	20.49^{d} (26.91)	19.41^{a} (26.140	30.82^{b} (33.72)
	ME 325	CIAT 200 SM 1454-6	20.41^{d} (26.86)	26.16^{c} (30.76)	30.50^{b} (33.52)
	ME 199	CIAT 30 SM 1670-4	38.91^{k} (38.59)	57.21^{p} (49.15)	59.42^{k} (50.43)
	ME 491	CIAT 402 SM 1667-6	30.83^{g} (33.73)	37.42^{h} (37.71)	49.11^{i} (44.49)
Medium	ME 2	Nilgris butterpoola	30.73^{g} (33.67)	31.43^{f} (34.10)	44.92^{g} (42.08)
	ME 11	CTCRI, Thiruvananthapuram, H7	19.73^{cd} (26.37)	26.34^{c} (30.88)	30.64^{b} (33.61)

Contd ...

Damage & population category	Accessions	Description	Damage intensity (%) / plant* (months) 3	4	5
	ME 7	Musiri (Trichy) Co 1	8.82^{a} (17.27)	20.92^{a} (27.22)	36.42^{d} (37.12)
	ME 16	Nilgris, Malavella	20.68^{d} (27.05)	39.42^{i} (38.89)	49.75^{I} (44.86)
	ME 143	CTCRI, Thiruvananthapurm, Chenguvallai Red	13.77^{b} (21.78)	23.83^{b} (29.22)	32.73^{c} (34.80)
	ME 152	CTCRI Thiruvananthapuram, Kalikallan	14.38^{b} (22.28)	20.42^{a} (26.86)	40.79^{e} (39.69)
	ME 182	CIAT 10, SM 1444-3	24.32^{f} (29.55)	41.73^{j} (40.24)	49.45^{I} (44.68)
	ME 263	CIAT 120, SM 1791-2	39.46^{k} (38.92)	41.32^{j} (40.00)	56.32^{j} (48.63)
	ME 299	CIAT 164, SM 1430-1	31.83^{h} (34.35)	42.42^{k} (40.64)	46.41^{h} (42.94)
High	ME 77	Melangode,Kanyakumari Vellaikalan	20.43^{d} (26.88)	39.37^{i} (38.87)	57.24^{j} (49.16)
	ME 153	Kerala	21.43^{e} (27.58)	34.01^{g} (35.67)	57.64^{j} (49.39)
	ME 156	CTCRI Thiruvananthapuram ,H 165	40.12^{kl} (39.31)	49.70^{m} (44.83)	59.63^{k} (50.55)
	ME 374	CIAT 259 SM 1519-1	31.73^{h} (34.29)	51.50^{m} (45.86)	68.32^{n} (55.75)
	ME 578	CIAT 499 SM 1858-2	41.74^{lm} (40.25)	51.96^{mn} (46.12)	66.42^{m} (54.58)
Very high	ME 50	CTCRI, Thiruvananthapuram H 3	42.34^{lm} (40.59)	53.16^{o} (46.81)	72.82^{o} (58.58)
	ME 80	CTCRI, Thiruvananthapuram H 312	50.38^{h} (45.22)	66.76^{r} (54.79)	79.41^{p} (63.02)
	ME 81	CTCRI, Thiruvananthapuram H 38	38.09^{k} (38.11)	51.43^{m} (45.82)	63.72^{l} (52.96)
	ME 154	CTCRI, Thiruvananthapuram S 856 Sriprakash	39.73^{k} (39.07)	54.48^{o} (47.57)	80.13^{p} (63.53)

Contd ….

Damage & population category	Accessions	Description	Damage intensity (%) / plant* (months)		
			3	4	5
	ME 259	CIAT 113 SM1 790-2	69.43^{o}	71.34^{s}	90.64^{q}
			(56.43)	(57.63)	(72.18)
	ME 25	Kanyakumari, Kappivellai	40.68^{kl}	72.18st	90.86^{q}
			(39.63)	(58.17)	(72.40)
	ME 41	Kanyakumari, Ariyanvellai	40.84^{kl}	71.32^{s}	99.42^{s}
			(39.72)	(57.62)	(85.63)
	ME 155	CTCRI, Thiruvananthapuram H226 Vellai	71.43^{p}	80.08^{u}	92.71^{r}
			(57.69)	(63.49)	(74.34)

Grade

2	Low	25% leaf area damage by egg spirals with 11-25 nymphs and adults.
3	Medum	50% leaf are damaged by egg spirale, nymphs and adults with yellow speckling
4	High	75% leaf area damaged by egg spirals, nymphs and adults with slight leaf crinkling
5	Very high	100% leaf area damaged with leaf crinkling
6	Extreme	100% leaf area damaged with leaf crinkling and sooty mould

*Figures in parentheses are Arc sine transform values.

Means followed by small letters in common within columns are not significantly different at 5% level DMRT.

damage intensity at third month was low on accessions CIAT 6 (8.40 per cent) followed by CTCRI, Thiruvanathapuram Chenguvallai Red (13.77 per cent) and CTCRI Kalikallan (14.38 per cent) which were statistically on par. Slight increase in population level and damage intensity was found on accessions *viz.*, Nilgiris vella, CIAT 94, CIAT 200, CTCRI H7, CIAT 199 and Melangode Vellaikalan. Damage intensity at fourth month was low on accessions CIAT 199 (19.41 per cent), CTCRI, Kallikallan (20.42 per cent) and Musiri (Trichy) CO 1 (20.92 per cent). At 5 month old crop, per cent damage intensity was lower on CIAT 94 (26.32) followed by CIAT 200 (30.50), CTCRI H7 (30.64) and CIAT 199 (30.82) which were equally damaged. Accessions *viz.*, CTCRI Chenguvalli Red, CIAT 57 and CIAT 160 showed damage intensity of 32.73 to 39.90 per cent.

Damage intensity was high on other accessions tested which ranged from 40.02 to 99.42 per cent, with more number of nymphs and adults and caused 100 per cent leaf damage with sooty mould symptom. Over all, the per cent damage intensity was increasing from third to fifth month. The accessions *viz.*, CIAT 94, Nilgiris vella, CIAT 199, CIAT 200 CTCRI Chenguvallai Red, CTCRI Kalikallan and CTCRI H7 with low pest population and damage intensity at fifth month, showed their resistance to SWF infestation which can be used for further screening studies. The accessions CTCRI H226, Kanyakumari Ariyanvellai, Kanyakumari Kappivellai and CIAT 113 which had high per cent damage intensity even at third month exhibited their susceptibility to SWF infestation can be used as susceptible check for further resistance studies.

4.9.2. Varietal reaction of *P. guajava* genotypes against *A. dispersus*

Results on reaction of *P. guajava* varieties against *A. dispersus* population at TNAU Orchard revealed that all the varieties were infested with *A. dispersus* but with varying population levels (Table 50). Among the varieties, Chittidar,

Table 50. Reaction of guava varieties against *A. dispersus* population

Varieties	Leaf area damage (%)*	Number of nymph/leaf **	Number of adult/ leaf**
Anakkapalli	53.67^{bc} (47.03)	22.00^{cd} (4.62)	45.20^{bc} (6.72)
Alagabad seedless	68.33^{ab} (55.77)	28.40^{bc} (5.17)	51.70^{bc} (7.15)
Chittidar	80.67^{a} (63.95)	37.20^{ab} (6.09)	64.30^{ab} (8.01)
Hafshi	72.67^{ab} (58.76)	41.80^{a} (6.38)	72.40^{a} (8.50)
Lucknow 46	52.67^{bc} (46.59)	17.30^{cde} (4.04)	32.30^{cd} (5.66)
Lucknow 49	40.00^{cd} (38.87)	12.00^{de} (3.40)	24.70^{de} (4.81)
Bapatla	38.33^{cd} (38.25)	16.87^{cde} (4.0)	18.20^{e} (4.25)
Redflesh	29.00^{d} (32.46)	9.40^{e} (3.06)	18.90^{e} (4.33)
AC 10	54.50^{bc} (47.61)	28.88^{bc} (5.69)	67.30^{a} (8.20)
Seedless South	40.67^{cd} (39.36)	19.70^{cde} (4.44)	29.70^{cd} (5.40)

*Figures in parenthese are Arc sine transformed values
**Figures in parentheses are Sqr. (x + 0.05) transformed values
Means followed by small letters in common within columns are not significantly different by 5% level (DMRT)

Hafshi and Alagabad seedless were highly preferred for egg laying and the per cent spiral area was significantly high which ranged from 68.33 to 80.67. Redflesh was less preferred for egg laying. Mean number of nymphs and adults were significantly high on Hafshi (41.80 and 72.04 respectively) followed by Chittidar (37.20 and 64.30 respectively). Redflesh harboured fewer nymphs (9.40) and adults (18.90) which showed its relative resistance to SWF infestation. Based on the spiral area and nymphal population, the varieties were categorised. Population of SWF was found to be very high on Hafshi and Chittidar, high on Alagabad seedless and AC 10, moderate on Anakapalli, seedless South, Lucknow 46, Lucknow 49 and Bapatla and low on Redflesh.

4.9.3. Varietal reaction studies against *A. dispersus* on *Gossypium* spp.

The results on varietal screening of *Gossypium* spp. to the population of *A. dispersus* at Cotton Breeding Station, Coimbatore revealed that all the species of *Gossypium* were infested with *A. dispersus* (Table 51). The spiral area was found to be very low (1 to 10%) on *G. triphyllam, G. thurberi, G. barbosanum*, Surabhi and Anjali. Spiral area on MCU 11, MCU 10 and MCU 9 ranged from 73.33 to 82.83 per cent showing their susceptibility to *A. dispersus* infestation. Nymphal population was very low in most of the species tested, ranging from 0.73 to 4.97. Nymphal population was very high to high on MCU 10, MCU 11 and MCU 9 which ranged from 16.53 to 28.07. Adult population was found to be significantly high on MCU 11 and MCU 10 which were on par with MCU 9. Adult population was low on hybrid Anjali (1.00), *G. arboreum* and *G.thurberi* (1.07). Lower spiral area, nymphal and adult population on hybrids Surabhi and Anjali revealed that they were highly resistant to *A. dispersus* infestation.

Table 51. Reaction of cotton (*Gossypium* spp.) against *A. dispersus*

Sl. No.	Genotypes	Spiral area (%)*	No. of nymph/leaf**	No. of adult/leaf**
1.	*Gossypium aridum*	45.00 [b]	4.87 [fg]	5.20[fg]
		(42.11)	(2.19)	(2.27)
2.	*G. raimondii*	34.50 [bcd]	4.97 [fg]	6.63[ef]
		(35.93)	(2.18)	(2.54)
3.	*G. triphyllam*	9.67 [gh]	2.33 [ghi]	3.63 [gh]
		(18.08)	(1.52)	(1.87)
4.	*G. thurberi*	6.00 [hijk]	3.93 [gh]	1.53[ij]
		(13.97)	(1.97)	(1.22)
5.	*G. barbosanum*	2.00 [k]	2.00 [hij]	2.37[hij]
		(8.14)	(1.39)	(1.52)
6.	*G. arboreum*	2.67 [jk]	0.73 [ijk]	1.07[j]
		(9.27)	(0.85)	(1.01)
7.	MCU-5	43.67 [bc]	15.00 [bc]	24.00[c]
		(41.35)	(3.85)	(4.88)
8.	MCU-7	41.33 [bc]	7.13 [ef]	13.07[d]
		(39.99)	(2.67)	(3.59)
9.	MCU-9	73.33 [a]	20.33 [b]	35.47[a]
		(59.51)	(4.50)	(5.95)
10.	MCU-10	74.17 [a]	28.07 [a]	46.43[a]
		(59.66)	(5.29)	(6.81)
11.	MCU-11	82.83 [a]	16.53 [bc]	44.23[a]
		(65.62)	(4.06)	(6.59)
12.	MUC-12	38.33 [cd]	13.27 [cd]	29.70[bc]
		(38.13)	(3.60)	(5.44)
13.	LRA 5166	43.67 [bc]	10.00 [de]	30.60[bc]
		(41.32)	(3.13)	(5.53)
14.	Savitha	12.00 [fg]	3.87 [gh]	7.07[ef]
		(20.12)	(1.92)	(2.62)

Contd….

Sl. No.	Varieties	Spiral area * (%)	No. of ** nymph/leaf	No. of ** adult/leaf
15.	Suvin	31.33 cd	2.20 hij	4.87 fghi
		(33.72)	(1.47)	(2.18)
16.	Surabhi	8.67 ghi	3.00 gh	9.33 def
		(16.96)	(1.73)	(3.03)
17.	Anjali	4.67 ijk	0.67 k	1.00 j
		(12.42)	(0.76)	(0.93)
18.	SVPR-2	19.67 ef	2.90 ghi	6.60 ef
		(26.18)	(1.69)	(2.53)

* Figures in parentheses are Arc sine transformed values

** Figures in parentheses are Sqr. (x + 0.5) transformed values

Means followed by small letters in common within columns are not significantly different at 5% level (DMRT)

4.10. Population dynamics of *A. dispersus*

4.10.1. Population dynamics of *A. dispersus* in *P. guajava* influenced by natural enemies and weather parameters

The population density of *A. dispersus* was at a peak with 77.53 nymphs, 118.00 adults and 98.5 per cent egg spiral area per leaf during the second week of May 1999 on guava at Patchapalayam Milk Society, Coimbatore with the natural parasitism of 0.42 per cent by *Encarsia* sp. nr *meritoria* (Table 52). The parasitism rate steadily increased and reached a sudden peak of 66.67 per cent in the first week of October with a slight reduction in pest population. From the second week of October the pest population declined drastically with fluctuation of parasitization rate till the first week of January 2000. The per cent parasitism reached a peak of 81.11 with the nymph (5.55/leaf) and adult (6.25/leaf) population of *A. dispersus*. Thereafter the parasitism declined steadily with decrease in whitefly population till the end of the study period. Predator population was very less during the entire period of study (Table 52) (Fig. 8).

Simple correlations worked out between population of *A. dispersus*, natural enemies and weather factors showed the existence of a significant negative correlation between parasitism and egg spiral area (r = -0.898), nymph (-0.937) and adult (-0.809) population per leaf. This clearly indicated that increase in parasitism reduced the population of *A. dispersus*. Though the predator population had negative association with whitefly population, the variation was not significant.

Both egg spiral area and nymphal populations were negatively associated to maximum temperature with significant variations (r = -0.294 and -0.345 respectively). Increase in minimum temperature significantly increased the population of both nymphs (r = 0.705) and adults (r = 0.649) which inturn increased the egg laying on *P. guajava*. Increase in maximum relative humidity

Table 52. Population dynamics of *A. dispersus* as influenced by natural enemies on guava (*P. guajava*) (March '99 - March 2000)

Month / Standard week	Spiral area (%)	No. of nymph / leaf	No. of adult / leaf	Parasitism (%)	No. of predator/leaf
May '99					
19	80.0	67.28	97.10	0.0	0.45
20	98.5	77.53	118.00	0.42	0.35
21	98.0	60.11	92.14	0.28	0.20
22	98.0	57.92	80.69	1.02	0.55
June '99					
23	91.3	53.92	79.14	1.89	0.90
23	87.5	41.07	72.17	3.23	1.25
25	92.5	40.99	80.14	6.46	0.35
26	85.0	37.11	71.00	6.30	0.55
July '99					
27	92.5	34.08	69.17	7.86	1.00
28	90.0	25.70	60.43	8.54	0.55
29	72.5	26.15	49.15	6.75	0.90
30	69.0	29.90	42.25	5.08	0.65
31	75.5	30.35	39.70	8.58	0.50
Aug '99					
32	81.3	25.50	32.15	7.61	0.50
33	86.0	27.60	29.0	6.76	0.45
34	70.5	24.80	26.95	7.98	0.45
35	79.0	28.25	21.60	10.75	0.25
Sep '99					
36	65.0	24.95	20.55	16.84	2.30
37	72.5	17.15	18.60	20.23	1.15
38	63.5	24.60	24.50	27.62	1.05
39	53.5	16.95	20.25	36.11	1.80
Oct '99					
40	62.8	16.45	24.55	66.67	0.80
41	54.0	11.50	13.10	40.31	0.65
42	39.0	3.50	10.05	50.11	0.40
43	25.0	3.20	8.50	59.14	0.30
44	24.5	6.05	10.70	51.01	0.45

Contd ....

Month / Standard week	Spiral area (%)	No. of nymph / leaf	No. of adult / leaf	Parasitism (%)	No. of predator/leaf
Nov '99					
45	30.5	4.45	8.45	62.92	0.45
46	36.5	6.35	10.50	51.53	0.20
47	31.0	3.95	12.0	64.89	0.55
48	28.0	2.85	9.10	77.90	0.35
Dec '99					
49	32.0	4.4	7.00	69.02	0.80
50	38.5	4.8	6.20	60.00	0.85
51	31.5	3.95	5.45	72.95	0.35
52	39.0	5.60	5.90	60.00	0.65
Jan '00					
1	41.0	5.55	6.25	81.11	2.1
2	38.0	4.10	5.80	62.57	1.05
3	32.5	4.60	3.10	54.91	0.90
4	25.0	5.10	2.40	49.0	1.65
5	30.0	4.35	3.70	63.29	0.85
Feb '00					
6	28.5	4.85	4.60	55.91	0.90
7	31.0	4.20	1.05	50.21	1.15
8	27.0	3.85	3.15	41.00	0.55
9	24.0	4.00	4.45	44.05	0.85
March '00					
10	26.5	4.70	4.15	32.17	0.55
11	30.5	4.10	3.95	36.64	0.45
12	25.0	4.80	3.25	27.50	0.75
13	20.5	3.95	3.00	13.11	0.95

Fig. 8. Relationship between spiralling whitefly and its associated natural enemies on guava

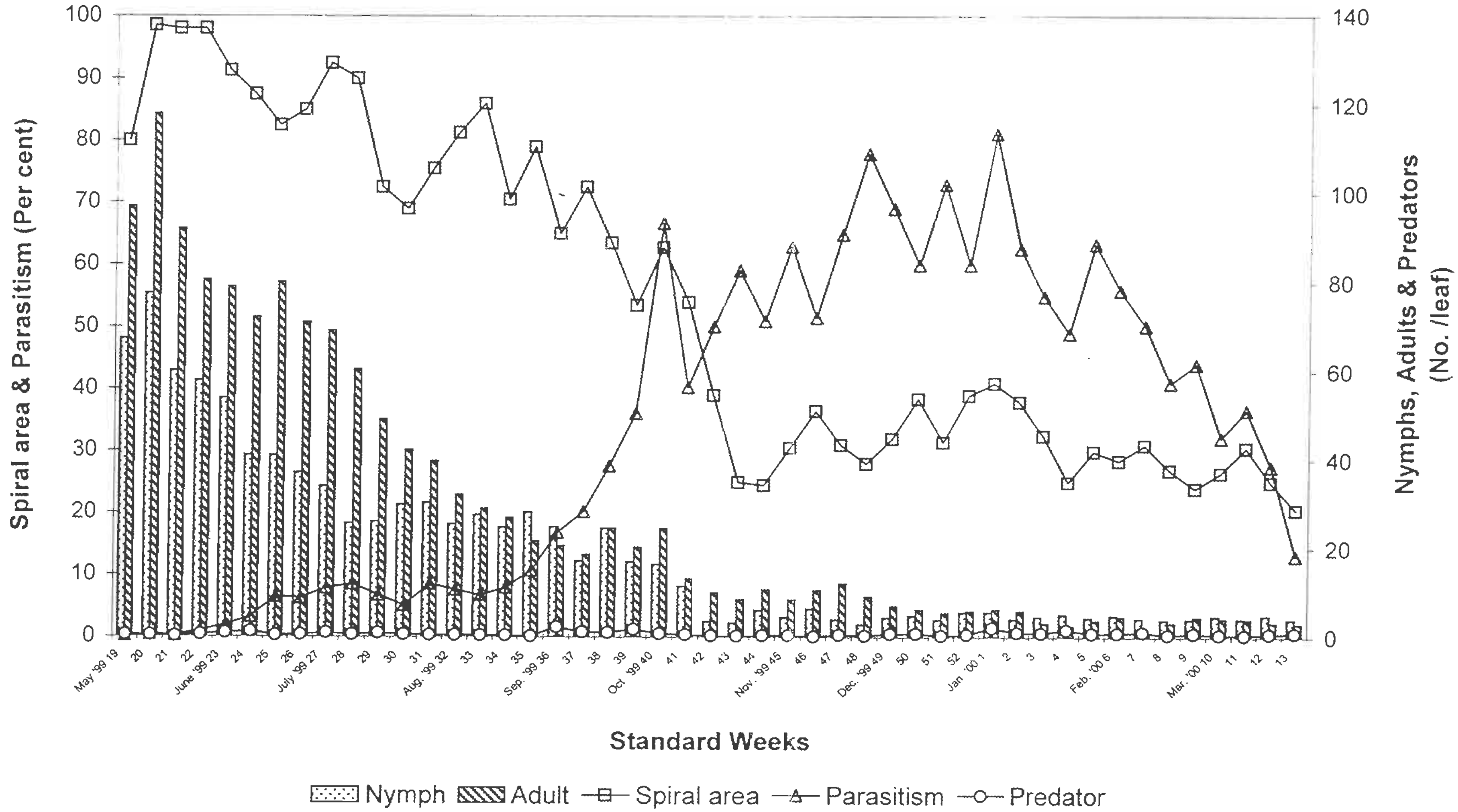


Table 53. Simple correlation coefficient of natural enemies and weather factors for population of *A. dispersus* on *P. guajava*

Factors	Correlation coefficient		
	Spiral area	Nymph	Adult
Parasitism (%)	-0.898**	-0.937***	-0.809**
Predator (No./leaf)	-0.126^{ns}	-0.104^{ns}	-0.145^{ns}
Max.Temp. (°C)	-0.294*	-0.345*	-0.179^{ns}
Min.Temp. (°C)	0.685**	0.705**	0.649**
Max.RH (%)	-0.737**	-0.724**	-0.634**
Min.RH (%)	-0.041^{ns}	-0.056^{ns}	0.124^{ns}
Rainfall (mm)	-0.315**	-0.439**	-0.731**
Wind speed (Kmph)	0.104^{ns}	0.083^{ns}	0.162^{ns}

*Significant
**Highly significant
NS - Non significant

Table 54. Multiple regression analysis of population of *A. dispersus* with natural enemies and weather factors on *P. guajava.*

Factors	Spiral area			Nymphal population			Adult population		
	Regression co-efficient	Standard Error	't' value	Regression co-efficient	Standard Error	't' value	Regression co-efficient	Standard Error	't' value
Parasitism (%)	-0.7874	0.1390	-5.67**	-0.4108	0.0514	-7.99**	-0.4618	0.1215	-3.80**
Predators (No./leaf)	-2.7703	3.6048	-0.77 NS	-0.3063	1.3332	-0.23 NS	-1.8527	3.1517	-0.59 NS
Max. Temp (°C)	-3.5409	2.0623	-1.72 NS	-1.0747	0.7627	-1.41 NS	-0.4078	1.8031	-0.23 NS
Min. Temp (°C)	2.2291	2.1874	2.92*	0.1029	0.0368	2.78*	-0.2823	1.9124	1.39 NS
Max. RH (%)	-0.2147	0.6628	-0.32 NS	-0.0412	0.2451	-0.17 NS	-0.1109	0.5795	-0.19 NS
Min. RH (%)	-0.2763	0.4463	-0.62 NS	-0.000045	0.0046	-0.01 NS	0.4479	0.3907	1.15 NS
Rainfall (mm)	0.0036	0.0758	-0.05 NS	-0.0142	0.0280	-0.51 NS	-0.0300	0.0663	-0.45 NS
Wind speed (kmph)	0.2762	1.1508	0.04 NS	-0.0648	0.7209	0.09 NS	-0.3517	1.3027	0.11 NS
R^2			0.87**			0.92**			0.77**

*Significant
**Highly significant
NS - Non significant

caused significant reduction in nymph (r = -0.724) and adult (r = -0.634) population, which inturn reduced the egg spiral area (r = -0.737). Rainfall had significant negative correlation with egg spiral area (r = -0.315), nymph (r = -0.439) and adult population (-0.731) indicating the reduction of whitefly population with increase in rainfall (Table 53).

When the multiple regression coefficients of all the variables were considered, per cent parasitism had significant negative effect on population of *A. dispersus*. For every increase in parasitism rate by one per cent, there was a corresponding decrease in egg spiral area (r = -5.67), nymph (r = -7.99) and adult (r = -3.80) population. The analyses showed the prediction of linear equation for nymphal population (Y_2) as $Y_2 = 53.60 - 0.4\ X_1 - 0.3\ X_2 - 1\ X_3 + 1\ X_4 - 0.04\ X_5 - 0.00005\ X_6 - 0.01\ X_7 + 0.1\ X_8$ with the existence of variation of 92.00 per cent ($r^2 = 0.92$) among the variables. In adult population (Y_3), multiple regression analyses showed the prediction of $Y = 38.57 - 0.5\ X_1 - 2\ X_2 - 0.4\ X_3 + 0.3\ X_4 - 0.1\ X_5 + 0.4\ X_6 - 0.03\ X_7 + 0.4\ X_8$ with the variation of 77.00 per cent ($r^2 = 0.77$) among the variables (Table 54).

4.10.2. Population dynamics of *A. dispersus* in cassava (*M. esculenta*) influenced by natural enemies and weather factors

Whitefly population density was high with 82.5 per cent egg spiral area, 59.0 nymphs and 155.7 adults per leaf in the first fortnight of August'98. The predator, *Cybocephalus* sp. was found in less numbers at the initial period of study. Whitefly population was maintained till the first fortnight of October'99, then fluctuated at low levels in the following six months. Again there was a increase in population from May'99 till second fortnight of September '99 with the egg spiral area of 95.0 per cent, 105.8 nymphs and 144.5 adults per leaf. The parasitism by *E.* sp. near *meritoria* was at low level. The predator *Cybocephalus*

Table 55. Population dynamics of *A. dispersus* as influenced by natural enemies on cassava (*M. esculenta*)

Month / Fortnight	Spiral area (%)	No. of nymph / leaf	No. of adult / leaf	Parasitism (%)	*Cyboce-phalus* sp.	Coccinellids
Aug'98						
I	82.5	59.0	155.7	-	0.7	1.95
II	95.0	48.7	130.4	-	0.95	0.90
Sep'98						
I	86.0	46.0	98.7	-	1.35	0.90
II	72.5	54.2	100.9	-	1.65	1.2
Oct' 98						
I	75.0	43.5	91.7	-	2.1	1.65
II	66.0	36.2	70.6	-	3.4	1.00
Nov' 98						
I	55.0	38.0	41.7	-	3.75	1.25
II	42.5	42.3	30.8	-	4.60	0.80
Dec' 98						
I	47.5	31.6	48.0	0.84	4.10	1.85
II	42.5	35.3	39.4	0.92	5.45	0.85
Jan' 99						
I	42.0	32.7	18.3	-	4.05	0.75
II	48.0	28.9	19.4	1.07	5.12	1.05
Feb' 99						
I	38.5	20.5	22.1	-	4.60	1.00
II	32.5	14.5	23.5	-	5.25	0.65
March 99						
I	38.5	26.1	20.4	3.19	4.55	1.85
II	32.5	20.8	24.1	2.23	4.90	1.10
April 99						
I	20.5	24.7	48.7	2.74	4.45	1.65
II	36.5	20.4	31.2	3.26	5.45	1.25
May 99						
I	48.5	28.5	24.4	4.38	5.00	2.10
II	79.0	24.4	36.1	2.03	5.20	0.90
June 99						
I	89.5	37.3	34.9	2.15	6.85	2.10
II	90.0	40.4	39.3	2.40	7.65	0.95

Contd ...

Month / Fortnight	Spiral area (%)	No. of nymph / leaf	No. of adult / leaf	Parasitism (%)	*Cybocephalus* sp.	Coccinellids
July 99						
I	86.5	52.5	66.0	3.17	4.90	2.20
II	95.0	68.3	84.7	1.12	5.30	1.20
Aug' 99						
I	90.0	102.4	160.2	1.85	4.55	1.15
II	82.5	89.4	93.7	2.60	8.65	1.05
Sep' 99						
I	92.5	110.2	127.1	3.08	9.50	1.95
II	95.0	105.8	144.5	5.62	10.60	2.00
Oct' 99						
I	80.0	79.3	90.4	6.81	7.05	1.30
II	60.0	58.3	68.3	6.54	6.30	1.75
Nov' 99						
I	45.0	42.3	33.7	5.33	7.10	3.25
II	32.5	38.0	28.2	7.20	5.40	2.25
Dec' 99						
I	60.0	49.2	54.2	6.80	5.60	2.05
II	75.0	69.4	108.2	6.32	7.30	1.90
Jan' 00						
I	82.5	77.2	117.4	3.29	8.95	1.60
II	87.5	93.3	164.2	4.81	7.80	2.05
Feb' 00						
I	80.0	109.7	194.2	4.41	10.35	1.75
II	62.5	119.4	160.2	3.37	9.60	1.35
March 00						
I	47.0	61.5	82.7	4.18	7.80	1.0
II	30.0	31.7	49.5	4.26	6.50	1.1

Fig. 9. Population dynamics of spiralling whitefly and its natural enemies on cassava

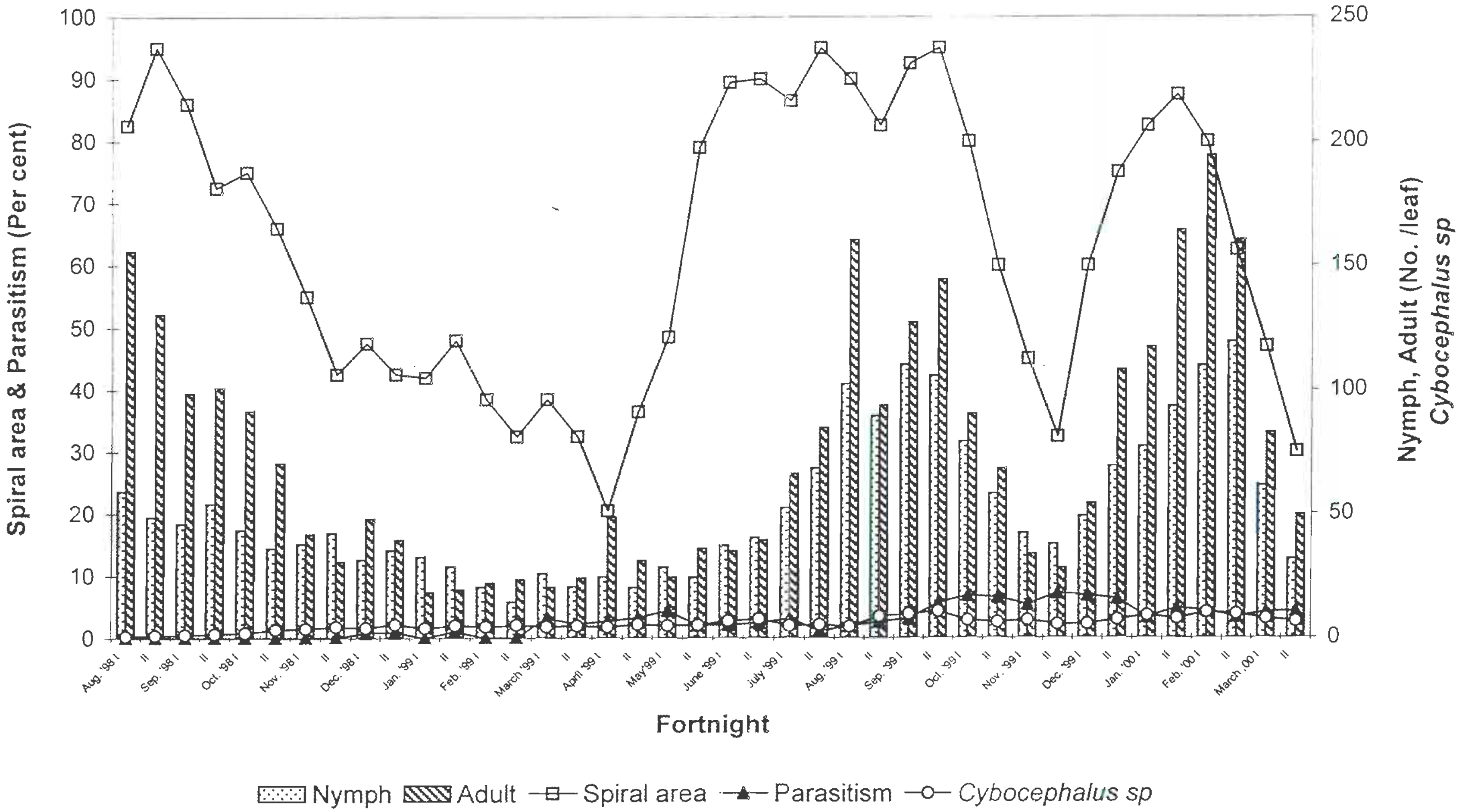
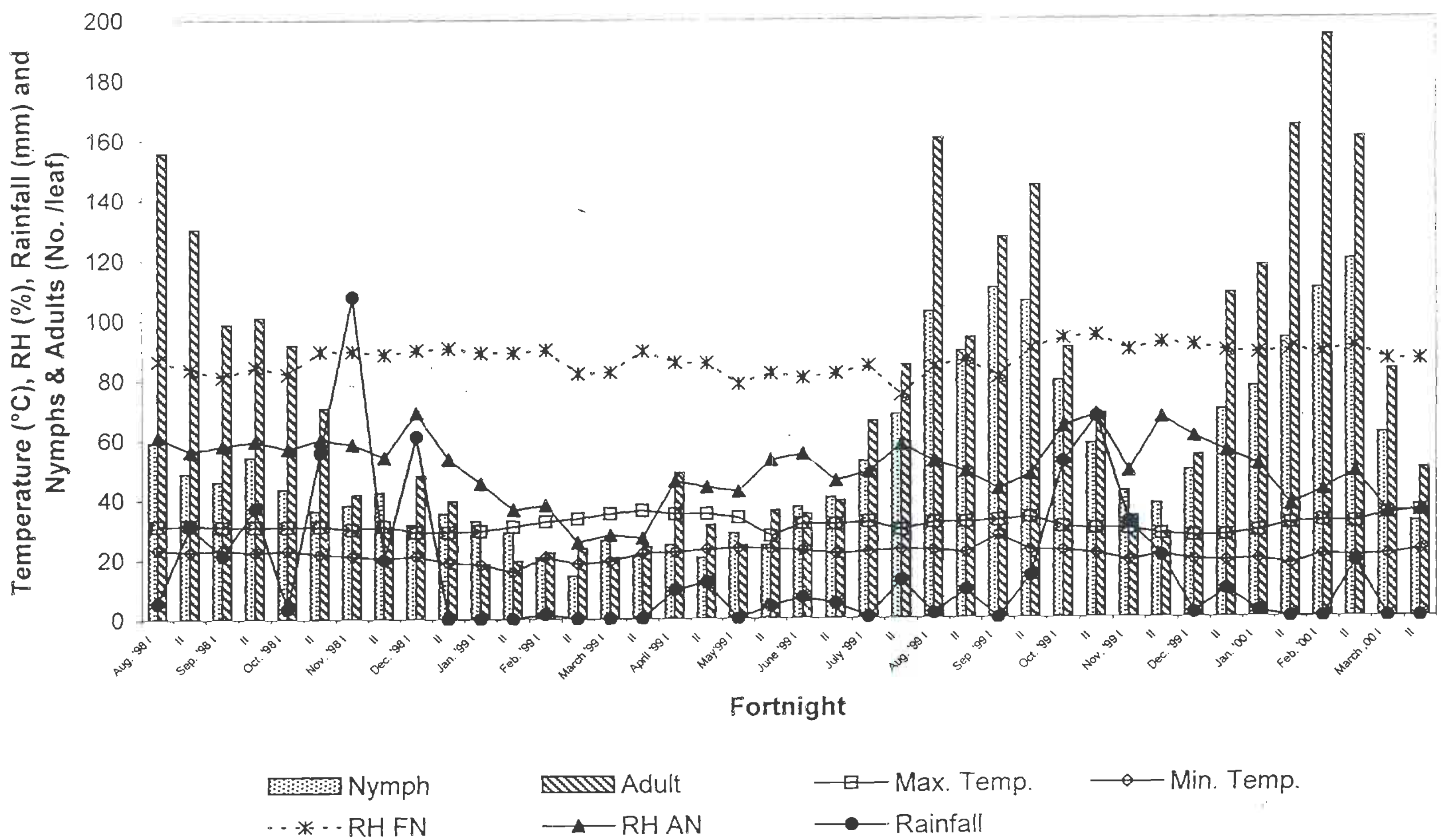


Fig. 10. Population dynamics of spiralling whitefly with weather factors on cassava



sp population steadily increased and reached a peak of 10.60 individuals per leaf in the second fortnight of September'99 (Table 55) (Fig. 9).

Correlation studies showed that *Cybocephalus* sp. had positive correlation with egg spirals and adult population without any significant but had significant negative correlation with nymphal population (r = 0.360). There was a significant negative correlation between maximum temperature and egg spiral area (-0.424), nymph (-0.713) and adult population (-0.493). Minimum relative humidity had significant positive correlation with egg spiral area (0.480), nymph (0.385) and adult (0.477) population. Increase in rainfall decreased the population of *A. dispersus* significantly (Table 56) (Fig. 10).

When multiple regression coeffcients were considered the maximum temperature had significant negative effect on egg spiral area (r= -2.60), nymph (r = -4.77) and adult (-3.86) population. Minimum temperature had significant positive effect on nymph (r = 2.89) and adult (r = 2.96) population. Rainfall had negative association with egg spiral area and nymph population without any significance but had significant effect in adult population (r = -3.590). The results clearly explained that for every increase in maximum temperature and rainfall reflected decrease in the population density, whereas one unit increase in minimum temperature yielded corresponding increase in the population of *A. dispersus* (Table 57).

The multiple regression analyses showed the prediction of linear equation for nymphal population (Y_2) as $Y_2 = -67.73 - 5\ X_1 + 3\ X_2 + 8\ X_3 - 5\ X_4 + 7\ X_5 + 1\ X_6 - 0.4\ X_7 - 5\ X_8 + 0.2\ X_9$ with the existence of variation of 66.00 per cent ($r^2 = 0.66$) among the variables. In adult population (Y_3), the analyses showed the prediction of linear equation as $Y_3 = 18.64 - 15\ X_1 + 3\ X_2 + 10\ X_3 - 8\ X_4 + 15\ X_5 + 0.1\ X_6 - 0.1\ X_7 - 8\ X_8 - 3\ X_9$ with the variation of 47.00 per cent ($r^2 = 0.47$) among the variables.

Table 56. Simple correlation coefficient of natural enemies and weather factors for population of *A. dispersus* on *M. esculenta*

Factors	Spiral area	Nymph	Adult
Parasitism (%)	0.240^{ns}	0.408**	1.124^{ns}
Cybocephalus sp (No./leaf)	-0.250^{ns}	0.360^{ns}	0.155^{ns}
Coccinellids (No./leaf)	0.329*	0.306^{ns}	0.133^{ns}
Max.Temp. (°C)	-0.424**	-0.713**	-0.493**
Min.Temp. (°C)	0.400*	0.385*	0.477**
Max.RH (%)	-0.220^{ns}	0.136^{ns}	0.042^{ns}
Min.RH (%)	0.48**	0.117^{ns}	0.158^{ns}
Rainfall (mm)	-0.229^{ns}	-0.492**	-0.638**
Wind speed (Kmph)	0.210^{ns}	0.074^{ns}	0.071^{ns}

*Significant
**Highly significant
NS - Non significant

Table 57. Multiple regression analysis of population of *A. dispersus* with natural enemies and weather factors on *M. esculenta*.

Factors	Spiral area			Nymphal population			Adult population		
	Regression co-efficient	Standard Error	't' value	Regression co-efficient	Standard Error	't' value	Regression co-efficient	Standard Error	't' value
Parasitism (%)	0.7491	1.8272	0.41^{NS}	-5.9072	3.2635	-1.81^{NS}	-15.8892	5.9462	-2.68*
Cybocephalus sp. (No./leaf)	2.5944	1.8805	1.38^{NS}	3.3464	2.7956	1.20^{NS}	3.3078	5.7081	0.58^{NS}
Coccinellids (No./leaf)	4.6651	5.4931	0.85^{NS}	8.0123	8.1653	0.98^{NS}	10.5294	18.4710	0.57^{NS}
Max. Temp (°C)	-1.8456	0.7112	-2.60*	-5.0426	1.0574	-4.77**	-8.3219	2.1584	-3.86**
Min. Temp (°C)	0.6374	1.7284	0.37^{NS}	7.4335	2.5685	2.89**	15.5682	5.2594	2.96**
MaxRH (%)	-0.4087	0.9733	-0.42^{NS}	1.2093	1.4475	0.84^{NS}	0.1478	2.9551	0.05^{NS}
Min RH (%)	0.5762	0.3673	1.57^{NS}	-0.4117	0.5466	-0.75^{NS}	-0.1164	1.1142	-0.10^{NS}
Rainfall (mm)	-0.1051	0.1464	-1.72^{NS}	-0.5574	0.1846	-3.02^{NS}	-8.1042	2.3155	-3.50**
Wind speed (kmph)	-1.0897	0.7032	-1.55^{NS}	0.2675	1.7833	0.15^{NS}	-3.0572	2.5357	-1.20^{NS}
R^2			0.64**			0.66**			0.47**

*Significant
**Highly significant
NS - Non significant

DISCUSSION

CHAPTER V
DISCUSSION

The spiralling whitefly, *A. dispersus* which was accidentally introduced into India has established during the past five years throughout Tamil Nadu due to its rapid dispersal rate. The pest is emerging as a major pest on *M. esculenta, P.guajava* and other economic crops, necessitating measures to control the same. Keeping in view about the prosperity to know the pest habit and damage, comprehensive investigations were taken up to study the distribution, host range, biology, damage potential and management of the pest. The data generated from these studies are discussed in this chapter.

5.1.Distribution and host range of Spiralling whitefly in Tamil Nadu

5.1.1.Distribution of *A. dispersus*

The incidence of *A. dispersus* was found in all the districts of Tamil Nadu except Udhagamandalam. In India, its first occurrence was found in Kerala in 1993-1994 on cassava (Palaniswami *et al.*, 1995) and on wild cassava and wild rubber in parts of Kerala and Kanyakumari district of Tamil Nadu (David and Regu, 1995). Later the pest has spread to the other parts of Tamil Nadu. The reason for the heavy incidence of this pest particularly in Coimbatore, Salem, Namakkal, Dharmapuri, Erode, Kanyakumari and Tuticorin (ranging from 94.17 to 76.04%) might be due to spread from the adjoining districts of Kerala and Karnataka states. Survey report showed its steady spread throughout Tamil Nadu year after year. The pest being a native of tropical and sub tropical region, it might not have occurred in high altitude area like Udhagamandalam. The world wide distribution of *A. dispersus* showed its steady spread from its native islands to almost all the countries gaining economic importance. In India, though its occurrence is found in Southern states *viz.*, Kerala, Tamil Nadu, Karnataka, Andhra Pradesh and Maharastra it is likely to spread to Northern parts rapidly if left unchecked.

5.1.2. Host range

Interactions between host plants and insects are spread over a wide spectrum of intensity. Insects have often exhibited feeding preferences for particular plant organs or for foliage of certain specific age. Majority of the insects have wide host range. As many as 128 crop species belonging to 52 families and 25 weed hosts from 12 families were reported in the present investigaton as host plants of *A. dispersus* in Tamil Nadu. Host range includes perennial trees, shrubs, annuals, vegetables, fruits, ornamentals, shade trees and alternate weed hosts. Reports on wide host range of this pest are being made from several countries where the occurrence of this pest has been found. As many as 44 host plants in Florida, Central and North America (Russell, 1965 and Anonymous, 1986), 100 in Hawaii (Nakahara, 1978), 30 in Sri Lanka (Chandrasekara, 1990), 22 in Indonesia (Kajita *et al.,* 1991) and 144 in Taiwan (Wen *et al.,* 1994a) had been reported earlier as host plants for SWF. Martin (1990) reported a wide host range for *A. dispersus* and its rapid extension of range across Pacific and South East Asia. In India, *A. dispersus* was earlier recorded on 25 plants in Kerala and Tamil Nadu by David and Regu (1995), 70 in Kerala by Prathapan (1996), 22 in Kerala by Ranjith *et al.* (1996), 45 in Karnataka by Mani and Krishnamoorthy (1999c) and 53 in Tamil Nadu by Asia Mariam (1999).

Plants vary greatly in their food value for different insects, so that host plants specificity was based in large part on the insect's nutritional requirements (Dhaliwal and Arora, 1996). The plants belonging to Euphorbiaceae, Malvaceae, Myrtaceae and Solanaceae families were more susceptible, which showed incidence of 20.40 to 98.25 per cent, with leaf area damage of 10.0 to 98.25 per cent. Among the crop plants, *A. dispersus* infestation was very high on

P. guajava, *M. esculenta*, *M. glaziovii*, *A.indica*, *T. populnea*, *C. papaya* and *T. catappa* and were more susceptible in Coimbatore which showed their nutritional adequacy for the development of *A. dispersus*.

Whittaker (1970) explained that allelochemicals characteristic of various plant species exert strong influences on the developmental success of feeding insects. This might be the reason for heavy incidence of *A. dispersus* on particular crop families *viz.*, *Euphorbiaceae, Myrtaceae, Malvaceae* and *Solanaceae.*

Very high population density and leaf area damage of *A. dispersus* were observed on crops at homes, kitchen garden, road ways and institutions in city areas when compared to homes and fields at villages in Coimbatore district. The damage was 96.00 to 98.00 per cent on crop plants at city area. The fields, which were interior and far away from the city registered low level of incidence. These results are supported by the earlier report, from Hawaii, where SWF were observed in buses and cars and new infestations were frequently found near bus stops and parking areas (Anonymous, 1981). Further the result is supported by D'Almeida *et al.* (1998) who observed the occurrence of this pest initially in towns in the Southern part of Benin in West Africa in 1993, and later its spread was found in 1994 to 1995 in rural localities. These results clearly explained that the spread of *A. dispersus* is strongly linked to human activities, modern transport and fast commercial exchanges and above all these bright light sources in these locations which facilitate movement of *A. dispersus* through cuttings, twigs and other plant parts which often harbour whiteflies. Prevailing wind also aid in fast dispersal of *A. dispersus* to nearby areas, which increases the distribution of the pest all over the places. It is also suggested that high industrial and automobile pollution and high temperatures in cities would have been favourable for the pest for its development resulting in heavy incidence.

5.2. Biology of *A. dispersus*

5.2.1. Egg

A.dispersus adults laid elliptical eggs, covered in wax spirals and a mass of eggs were found in each spiral. Each egg possess a hollow extension of the chorion called as pedicel which was inserted into host plant stomata during oviposition (Paulson and Beardsley, 1985). Pedicel serves to secure the eggs to host plant leaves and a primary conduit through which moisture essential for normal egg development is absorbed from the host plant (Deshpande, 1936 and Poinar, 1965). Eggs were 0.310 mm long and 0.119 mm broad, similar to the earlier report by Henderson (1982). Incubation period varied among the host plants, longer on *M. esculenta, C. papaya, A. esculentus, Musa sp.* (6.4 to 7.9 days) and shorter on *S. melongena* and *Gossypium* sp. (5.2 to 5.6 days). But Palaniswami *et al.* (1995) reported a short incubation period on *M. esculenta* (4 to 6 days). These variations are probably due to the varied host plants and weather parameters, which influence the development of the eggs.

5.2.2. Nymphal stages

The first instar nymphal stage is mobile, possessing functional legs so called as crawlers. They are translucent yellowish green, which was observed earlier as light green to yellow (Gill, 1990), further reported that this kind of coloration is due to the transparent nature of the crawlers. They were found on the leaf surface parallel to vein or veinlet. Crawlers walk rather quickly in warmer days over the leaf surface in search of an available minor vein (Walker, 1985). Wax production was noted as spots on the dorsal median area, which was supported by Gill (1990) that small amounts of powdery white wax usually are produced after the crawlers settle and begin feeding. The crawler's developmental period completed in 2.15 to 6.60 days on various host plants studied. Waterhouse and Norris (1989) reported a period of 6 to 7 days for crawlers. Wen *et al.* (1994a) reported a slightly increased period of 6.0 days on *P. guajava* at 30^0C whereas the present study showed the crawler period of 4.1 days at 28^0C. The variations in crawler duration may be attributed by physical nature of the host plants like hairiness and cuticle thickness. The leaves with more trichomes may delay the migration of crawlers to find the feeding site and settle near the veinlet which may prolong the developmental period. The crawler with restricted movement and feeding completed its developmental period quickly. This was attributed to the more trichome density per unit area in *S. melongena* and tomato whereas in the leaves of *Musa* spp. and *C. annuum* with its pilose nature, the crawler period was 4.1 to 4.5 days.

Second instar nymph produced marginal fringes of wax along the transverse grooves on its dorsum. They also had glassy wax filaments produced from compound pores. The size of the second instar nymph was 0.517 mm long and 0.294 mm broad. Waterhouse and Norris (1989) also reported parallel observation for the second (0.5 mm) and third (0.65 mm) instar nymph and Asia Mariam (1999) found the length of 0.563 to 0.638 mm for second and third instars. Developmental period of second instar nymph on *M. esculenta*, *P. guajava*, *L. esculentum* and *Musa* spp. were 4.91, 5.0, 4.75 and 4.33 days respectively. The duration of 4 to 5 days was reported for second instar by Waterhouse and Norris (1989) and 6 to 9 days for first and second instar nymphal stages (Wijesekara and Kudagamage, 1990). Asia Mariam (1999) reported a period of 6.3 to 7.6 days on mulberry.

Third instars were 0.641 mm long and 0.431 mm broad, which was similar to the previous observation by Waterhouse and Norris (1989). Third instar lasted for 3.85 to 5.96 days on *M. esculenta, P. guajava* and *Musa* spp. and were distinguished by the numerous evenly spread short, glass like rods of wax along the sides of the body (Waterhouse and Norris, 1989).

Broader yellowish mycetomes visible internally in all the larval stages were responsible for nutrients synthesis required by the insects. The presence of mycetomes in homopteran insects was earlier reported by Buchner (1965) and Byrne and Bellows (1991). As the phloem has very little sterol content and no traces of cholesterol, the specialized organs (Mycetomes) which contain intra cellular bacteria like symbiotes in phloem feeders were responsible for synthesizing of the sterols requirement by the insects (Griffiths and Beck, 1973).

5.2.3. Pupa (Fourth instar)

Fourth instar nymphs (pupae) were soon covered with copious amount of opaque white waxy material dorsally as tufts. The dorsal wax produced from compound pores are long cylindrical often longer than the length of the pupae. The compound eyes of developing adults showed as red spots through the pupae as observed earlier by Gill (1990). Total developmental period from egg to nymphal stages varied between 22.50 to 29.66 days on various host plants tested in the present study. Douressamy *et al.* (1997) also supported the present findings where the total life cycle of *A. dispersus* ranged from 21 to 32 days.

Plant stage and nutrients, photoperiod and temperature play a key role on development of the stages of *A. dispersus.* Dhaliwal and Arora (1996) reported that high level of nutrients increases the attractancy and development of whitefly and temperature also affects the biology and behaviour of the insects and that influences the insect growth. Intensity and quality of light have been reported to influence biosynthesis of anthocyanins and phenylpropanoids which may inturn affect the development of insect growth. In the present study , the biology of *A. dispersus* was studied at 28-31°C with relative humidity of 79 to 85 per cent which might be the reason for varied development period of different bio stages of *A. dispersus.* Variation in developmental period of *A. dispersus* for each biostage found with reference to various host plants was supported by Dhaliwal and Arora (1996).

5.2.4. Adults

Among the whiteflies, the adults of *Aleurodicus* spp. are larger with complex wing venation. Males have extremely long, simple claspers (Gill, 1990). Similar observations were recorded in the present investigation. The body length of male was 2.41 mm and for female it was 1.892 mm. Gill (1990) reported the body length of 2.0 mm and wing span of 3.5 to 4.00 mm for *Aleurodicus* spp. The males were longer due to the length of claspers as observed by Gill (1990). The adults after emergence had no waxy coat, but soon covered with a snow white wax powders as noted by Gill (1990). Adult longevity of 17.36, 18.20, 15.70, 20.72 and 21.70 days was found on *M. esculenta, P. guajava, S. melongena, Musa* spp. and *C. papaya.*

Longer developmental period of 14.2 to 15.7 days was observed for *A. dispersus* on mulberry (Asia Mariam, 1999). Total life cycle on various host plants were 42.52 (*M. esculenta*), 45.21 (*P. guajava*), 38.20 (*S. melongena*), 37.21 (*Musa* spp.) and 50.55 days (*C.' papaya*) in the present study. Wen *et al.* (1994a) reported the shortened life period of 17.0 to 18.5 days with rise in temperature. A maximum longevity of 39 days was observed (Waterhouse and Norris, 1989). This variation might be due to varied nature of host plants and environmental factors.

5.2.5. Egg laying by *A. dispersus* on various host plants

A.dispersus laid eggs in various patterns on host plants. The eggs were laid singly at right angles to the leaf veins in association with regular spiralling deposits of white waxy flocculence (Henderson, 1982). Egg laying was found in regular and irregular fashions. During the initial period of infestation by *A.*

dispersus, regular circular and elliptical fashions were found more on *C. annuum* and *A. esculentus*.

Irregular pattern of egg laying was found more on almost all crops during the later period of infestation by *A. dispersus*. This pattern of egg laying might be correlated with the size of the leaves. Female whiteflies use the same leaf for oviposition and feeding. The circular egg pattern are often found on relatively smooth leaves due to the concurrent feeding and oviposition, whereby the female rotates around the point where her stylets are inserted into the leaf (Lenteren and Noldus, 1990). This might be true during the initial period of infestation in case of chillies, *Manihot* sp., *C. cajan* and *M. esculenta* where the trichomes were less on the leaves.

Leaf hairiness clearly influences the oviposition behaviour of whiteflies (Mound, 1965). *B. tabaci* does not oviposit on glabrous leaves. Leaf area also influences the oviposition behaviour of whiteflies. Smaller the leaf size, as incase of chillies, *C. cajan* and palmate leaves in *M.esculenta, Manihot* sp, egg laying was circular or elliptical regular pattern during the initial stage of infestation. The adults move irregularly while feeding which coincide with egg laying on larger leaf size and it might be the reason for irregular egg laying patterns on broader leaves like *Musa* sp., *C. papaya* and *S. melongena*. The absence of trichomes on *Musa* sp. which would not disturb the adults while egg laying might be the factor for more of irregular pattern of egg laying. Continuous egg laying on the same leaf also the primary reason for the irregular pattern of egg laying which usually resulted in the later stage of infestation by *A. dispersus*. The trichome density of the leaves and size were less correlated with egg laying, size of spirals and number of eggs per cm^2.

The weed hosts *A.triandra* and *S. melongena* which had more of trichomes *viz.*, 649.2 and 502 per cm^2 had egg density of 27 and 48 per cm^2. *C. annuum* and *Musa* spp. recorded 86.4 and 48.2 eggs with no trichomes. Spiral size was the biggest on *Musa* spp., which had no trichomes followed by *M. esculenta*. The results showed that the leaves with less trichomes recorded more eggs. Hairiness on leaves can disturb the female while oviposition (Butler *et al.*, 1986). Snyder *et al.* (1998) also supported that type IV trichome density on leaves of *L. hirsutum* resulted in reduced attractancy of adult *B. argentifolii* for feeding and oviposition. The trichomes exude a sticky substance, which disturb the insect during movements.

5.3. Spatial distribution of *A. dispersus* in crop plants

The knowledge on the distribution pattern of specific life stages of *A. dispersus* within the plant is necessary to develop sampling plans and action threshold for management of this pest. Immature life stages of *A. dispersus* were distributed vertically within plants, because adults tend to oviposit on young leaves, thus regulating later developmental life stages to progressively older leaves. This showed that the vertical distribution is distinctly stratified with respect to different developmental stages (Onnesorge *et al.*, 1980 and Noldus and Lenteren, 1986a). In young crops, there was not much difference in vertical distribution and both adults and egg laying were found more in bottom leaves than top leaves. In grown up plants, egg laying was more on the top position leaves. Nymphal population was high on middle leaves whereas adult population was high on bottom leaves of *M.esculenta*. In the present study, a similar pattern of distribution was also found in *P.guajava*, where the adults were more on bottom leaves and nymphal population concentrated on middle leaves.

Wen *et al.* (1994b) also supported the findings that most of the egg spirals were found on young leaves. In case of *B. tabaci*, newly emerged adults leave the lower older leaves on which they have emerged to reach the younger leaves for feeding and oviposition (Pollard, 1955; Melamed-Madjar *et al.*, 1979 and Ekbom and Xu, 1990). Schuster (1998) also found the intraplant distributions of eggs, sessile nymphs and pupae of *B. argentifolii* on *L. esculentum* in field plots. The distribution of specific life stages depended on the age of leaves. Eggs were most abundant and variation generally low or lowest on leaflets at nodes 4 to 6 from the terminal nymphs at nodes 6 to 8 and pupae at nodes 8 to 10 in their study on tomato plants. The density of each life stage was low on very young leaflets at the tops of plants, highest on leaflets of middle age and lowest on the older leaves (Lynch and Simmons, 1993 and Naranjo and Flint, 1994). The thickness of the cuticle during the maturity may also be a decisive factor in egg laying by the whiteflies. Noldus and Lenteren (1986b) reported the impenetrability of old leaves for inserting the eggs pedicel by *T.vaporariorum,* may be the reason for the 100 per cent mortality of eggs on the matured leaves.

They also found that the adults, nine hours after emergence showed upward movement which is accomplished primarily by flight from one lower level to a higher level, within the plant of emergence, where most feeding and oviposition occur. As the larval stages from the second instar are sessile and they need young, fresh and nutritive leaves for their development, which resulted a typical vertical distribution of developmental stages particularly the eggs on top young leaves. As like other whiteflies, *A. dispersus* also preferred young leaves for feeding and oviposition, but they returned to the bottom leaves after egg laying and feeding, which was clearly noticed on *M. esculenta* and *P. gujava.*

5.4. Damage potential of *A.dispersus* on *M. esculenta*

In the present study, the pest had showed varied damage potential at its different population levels. Population build up was poor in plots initially released with 50 adults. This showed that the population level was not sufficiently enough for the initial build up. As the crop age advanced there was no difference in damage intensity of the pest in both the plots released with 50 and 250 / plot. Yield loss was 50% in plots released with 250 adults/plot as against 30 per cent in plots released with 50 adults. This clearly showed that poor pest population during the initial period resulted low yield loss. As the tuber initiation and development of the crop is high during the initial period of crop growth, absence of pest resulted in low yield reduction. Hence this study clearly indicated that control measures should be concentrated in the young stage of the crop to avoid more damage and yield loss by the pest.

5.5. Cultural control

Removal of the heavily infested branches by pruning and subsequent burning are the age old cultural practices followed to reduce the pest population. Pruning also facilitate easy spraying of chemicals. In the present study, the young shoots after pruning in *P. guajava* attracted more whiteflies for feeding and egg laying. Pruning will produce a bushier plant with fresh leaves, containing more nutrients and hence may attract more whitefly population. SWF adults might have attracted in more numbers towards the young shoots for feeding and oviposition and to avoid overcrowding of nymphal stages leading to increased population load. The population build up was high, reaching high peaks within a period of 3 months in *P. guajava*. Wen *et al.* (1994b) also reported that high nitrogen levels or pruning attracted more number of adults for egg laying and feeding on young guava shoots.

5.6. Physical control using sticky traps

5.6.1. Coloured sticky traps

Colour plays a major role in host habitat selection by whiteflies. Almost all whiteflies of economic importance have been sampled using yellow sticky traps (Harlan *et al.*, 1979 and Yano, 1987). The results of the present investigation showed the attraction of SWF adults towards yellow traps. Mound (1962) suggested that *B. tabaci* reacts to two ranges of wavelengths *viz.*, blue, ultra-violet and yellow. More attraction towards yellowish green or yellow colour might be due to colour resemblance of young fresh leaves which mislead the whitefly for egg laying. Most species of whiteflies respond to colour as a cue to select landing sites for feedings and oviposition. They respond to wavelength of approximately 550 nm, which is equal to the colour reflected by the plants as green or yellow. The attraction towards traps vary with the height of placement (Ekbom and Xu, 1990).

In the present investigation, more number of adults were attracted towards cylindrical yellow sticky traps placed at crop canopy (150 to 170 cm from ground level) followed by those kept below crop canopy (100 to 120 cm from ground level) in cassava (*M. esculenta*). The same trend was also observed on traps placed near *A. indica* plants. Poor attraction was found on traps kept above and below crop level. Similar studies were conducted by placing traps at different heights in cotton (Gerling and Horowitz, 1984). In sunflower field, traps placed at a height of 30 cm recorded significantly more catches of *B. tabaci* than traps placed at 60, 90 and 120 cm height during both kharif and rabi seasons (Uthamasamy *et al.*, 1990 and Diraviam and Uthamasamy, 1992). Present finding is further supported by the earlier report of Ekbom (1980) where more whiteflies were attracted on traps when placed most appropriately at the top of the plants, as the insects fly up for feeding and oviposition on new leaves. Asia Mariam (1990) found more catches of SWF at six feet height compared to that at four feet height.

More number of SWF adults were attracted on traps during October third week (54.57) followed by third week of December (44.57/trap) in casava field. These findings are in agreement with earlier report of Diraviam and Uthamasamy (1992) in sunflower field, where gradual increase of catches, from the first week of December was observed and the peak catches occurred during the fourth week of December.

Trap catches at *M. glaziovii* was very high ranging from 102.00 to 325.88 when compared to traps at *M. esculenta* field. As all the traps were placed on the tree at different branches, the possible reasons for more catches of *A. dispersus* adults might be due to the accidental sticking on traps while flying or the air current which carry a mass of *A. dispersus* adult might leave the adults on the traps while crossing the traps resulting in increased catches on these traps in addition to attraction towards yellow colour.

5.6.2. Coloured sticky traps in cassava

Lloyd (1922) first reported a 'colour tropism' after studying on various colours and found that whiteflies trapped on yellow sticky traps were in greater number than on other colours. Several workers reported the attraction of whiteflies towards yellow colour. In the present study also, among the various coloured traps tested, yellow caught more number of adults (226.25) followed by green and orange. The other colours *viz.*, red, black and white performed poor attraction from 3.13 to 23.63 adults per trap. Similar kind of study was conducted earlier by Husain and Trehan (1940) and confirmed that yellowish green traps strongely attracted more of *B. tabaci* adults followed by yellow, red, orange/red, dark green and purple.

5.6.3. Sticky light trap

Whiteflies are positively phototactic and a positive correlated with light intensity. Attraction of more number of whiteflies (468.29/trap/day) was found towards a flourescent light trap in the *M. esculenta* field in the present study. The attraction at early morning hours (4-6 a.m.) accounted 82.87 per cent of total catch from 6 p.m. to 6 a.m. Among the various colours tested on the flourescent light trap, more catches were found on yellow light traps (668.9 / day/ trap) followed by white and green coloured traps. Orange coloured light trap performed poor, attracted fewer number of adults. Earlier Vaishampayan *et al.* (1975) measured the response of *T. vaporariorum* to reflected and transmitted light of various colours and found that most whiteflies were trapped on a yellow surface.

Also smaller numbers were trapped on an unsaturated than on a saturated yellow surface, even though more light was reflected from the unsaturated surface across the spectrum (400 to 700 nm). The study by Coombe (1982) further confirmed the result, that under 400 nm (violet light). *T. vaporariorum* adults took off more readily and walked faster than under 550 nm (green light). When simultaneously illuminated with equal quanta of both 550 and 400 nm light in flight they oriented towards 400 nm. Hence it confirmed that flying adults would orient towards the sky (400 nm) but would tend to land on a green plant because plants reflect maximum light at 500 nm. Again Affeldt *et al.* (1983) confirmed that, maximum capture of *T. vaporarionum* was found on traps reflecting 500 to 600 nm light and inhibition of landings under 400 to 490 nm light. In the present study, the attraction of SWF adults on yellow and green traps confirmed that, during their peak activity at early morning hours, they would have been misguided by the colour of the trap as plants and landed more on yellow and green traps. Earlier studies by Srinivasan and Mohanasundaram (1997) and Asia Mariam (1999) confirmed that peak activity of adults at early morning hours and more catches of SWF adults towards light traps.

5.7. Chemical control

Synthetic chemicals do not adequately control *A. dispersus* since the nymphs are covered with heavy waxy flocculent materials and waxy threads produced by the insect, which is the great defence by this whiteflies (Waterhouse and Norris, 1989 and Neuenschwander, 1994).

Egg mortality was high in triazophos and phosalone treatments which ranged from 92.04 to 99.73 per cent at 3 DAS. Neem oil 60 EC and TNAU neem formulation were considered as next best chemicals with more ovicidal effect. Dish wash soap solution and FORS had more effect on egg mortality by dissolving the wax spirals in the first trial conducted in *M. esculenta* field. In the second trial, all the chemical insecticides tested *viz.,* triazophos, malathion, monocrotophos and phosalone were found superior with 90.03 to 98.68 per cent egg mortality. Wen *et al.* (1995) earlier reported the ovicidal effect for deltamethrin. Egg stages suffers to the greatest level of mortality when compared to other stages. Ishaaya *et al.* (1987) found the ovicidal effect of buprofezin at 125 mg/l on *B. tabaci.* Asia Mariam (1999) reported a higher level of ovicidal action (93.10 per cent) of malathion against *A. dispersus*.

Early instar (first and second) nymphal mortality of *A. dispersus* was significantly high in tirazophos treated plants (91.48%) followed by neem products. Malathion was found to be superior in reducing the population of crawlers and second instar nymphs. Phosalone and dish wash soap solution caused mortality of early instar nymphs to more than 80 per cent.

Crawlers are most susceptible to chemical treatments. As they have covered with meagre wax spots, the chemicals could easily dissolve the wax and penetrate the body. As the crawlers are mobile and have to disperse on the leaf surface before it settles, the contact with chemical is more hence they are least protected and most vulnerable to pesticidal spray. Parallel observation was reported by Prabhakar *et al.* (1989), who observed more vulnerability of crawlers of *B. tabaci* to pesticidal spray than other stages. El-Shishiny (1984) and Rodolphe (1984) also found that insecticides are most efficient if applied early against late nymphal stages.

Synthetic chemicals performed better as they have number of auxillary compounds like solvents, emulsifier and surfactants which might have influenced in dissolving the waxy covering of the egg spirals and nymphal instars. Triazophos, malathion, phosalone and neem oil 60 EC performed equally in causing the mortality of late instar nymphs. FORS and dish wash soap solution reduced the late instar nymphs to an extent of 60-70 per cent. FORS mainly acts as a physical barrier with its sticky nature and has asphyxiant action against sedentary stages of homopteran species (Palanidurai, 1996) which caused moderate level of egg and nymphal mortality of *A. dispersus*. Singh and Singh (1979) observed the highest nymphal mortality (83.0 per cent) of whiteflies using FORS even during rainy days. Earlier, monocrotophos was the only insecticide recommended for growers use against whiteflies because of its ability to penetrate leaf tissues and ability to kill the nymphs efficiently (Clower *et al.*,1971). Cauquil (1981) used triazophos against whiteflies and an increase in yield upto 30.1% was noted. Ranjith *et al.* (1997) also reported the failure of most conventional insecticides in reducing the population of *A. dispersus*. However, nymphal survival was curtailed to the maximum extent with the application of dimethoate followed by buprofezin and acephate. They also recommended three sprays of 5 per cent soap solution for maximum egg and nymphal mortality of *A. dispersus*. The soap solution dissolves the waxy coating of the whitefly and further causes impairment of respiration, leading to death.

Triazophos was highly effective and inflicted maximum mortality of adult population (92.66 to 98.61 per cent) in both the field trials. Effectiveness of triazophos in population reduction of *A. dispersus* is in agreement with the previous reports by Peregrine and Lemon (1986), Venugopal Rao *et al.* (1990) and Natarajan *et al.*, 1991. FORS and neem oil performed equally, which might have caused initial killing with subsequent ovipositional deterrent action to the adults. Toscano *etal.* (1997) also reported the effectiveness of Azadirachtin for *B. tabaci.* During spraying operation, adults exhibited a typical behaviour of avoidance. Adults immediately moved away from the field like a smoke to the adjacent fields and settled on the weeds and other crops around the *M. esculenta* field. The adults killed during the spray, fell down to the ground and formed a white powdery mat above the soil surface. The adults that escaped during the spray would have settled on alternate hosts and later migrated to *M. esculenta* field. This might be the reason for initial reduction of population to low levels and further increase of adults in the field. Horowitz *et al.* (1997) found that abamectin mixed with mineral oil was effective for control of *B. tabaci.*

Water spray also reduced the population of *A. dispersus* to some extent in the present study which is in agreement with the earlier report by Wen *et al.* (1995), who reported that water spray at the rate of 12.5 lit/minute at 2 days interval for a consecutive month controlled 78.5 per cent nymphs and 86.4 per cent of adults.

All these observations clearly showed that *A. dispersus* can be managed effectively, when the chemical sprays are given at egg and crawler stages. Chemical sprayed against late instar nymphal stages resulted in the failure of the treatment and it was also responsible for rapid increase in *A. dispersus* population. This is attributed to the elimination of natural enemies especially the parasitoids, which prefer late instar nymphs (M'Boob and Oers, 1994).

5.8. Biological control

As all the stages of *A. dispersus* has covered with white flocculent wax material, chemical sprays are only moderately effective (Akinlosotu *et al.,* 1993; Anonymous, 1982). Application of insecticides would temporarily reduce the whitefly abundance when applied at vulnerable stage of the whitefly (Waterhouse and Norris, 1989). Hence, emphasis has been given to alternate method, such as biological control for the management of *A. dispersus.* A very rich parasitoid and predatory entomofauna is frequently present in the country of origin of whiteflies that are accidentally introduced to new which some are introduced into new areas to control their host (Huffaker and Messenger, 1964). Hence searching of natural enemy complex to the pest in its native area as well as introduced area is the basic step involved in any biocontrol programme. In the present study, extensive survey was made to find out natural enemies of this introduced pest.

5.8.1. Natural enemy complex of *A. dispersus*

Totally 15 predators belonging to cybocephalid, coccinellid, chrysopid and spider groups and a hymenopteran parasitoid and a parasitic mite were recorded as natural enemies of *A. dispersus* in Tamil Nadu. They play a vital role in population regulation of *A. dispersus*. Natural enemy complex of SWF was earlier documented by several workers in several countries (Nechols 1982; Kumashiro *et al.,* 1983; Waterhouse and Norris 1989 and Blanco-Metzler and Laprade, 1998).

5.8.2. Predators

In India, during the initial period of pest occurrence (1995-96), only few predator species were found preying on *A. dispersus*. Later, predators were found everywhere and atleast one group of the predators could be observed in a plant species infested with *A. dispersus*. This showed the suitability of the pest as prey by the predators. In the present study ten coleopteran, three chrysopid and one spider predators were observed on SWF in Tamil Nadu. Earlier reports showed the presence of a total of four coccinellids, one drosophilid and few chrysopid predators preying on nymphs of SWF in Bangalore (Mani and Krishnamoorthy, 1999c) and four coccinellids, and a chrysopid predators on SWF in Coimbatore (Asia Mariam, 1999).

5.8.2.1. Coleopteran predators

The present study showed the *Cybocephalus* sp as predominant predators of SWF in cassava field in Tamil Nadu and its occurrence on SWF is a new report in India. Previously it was reported to attack *A. dispersus* on guava in Indonesia, but failed to suppress the outbreak of *A. dispersus* (Kajita *et al.,* 1991). The predator *C. montrouzieri* was found preying on SWF infesting several plant species but mostly on guava trees. There was also reduction of whiteflies to some extent when *C.montrouzieri* was observed in large numbers. The same predator was recorded earlier on *A. dispersus* in India (Mani and Krishnamoorthy, 1997a and b and Asia Mariam, 1999) and in Hawaii (Paulson and Kumashiro, 1985). The predators *viz.*, *A. puttarudriahi, C. sexmaculatus* and *C. nigritus* were also found preying on *A. dispersus* in many plant species. Earlier Mani and Krishnamoorthy (1999a) reported the abundance of *C. nigritus* on *A. dispersus* during July to August, 1996 on guava in Bangalore, India. The presence of *A. puttarudriahi* had been recorded earlier on *A. dispersus* in Sri Lanka as a potential predator of *A.dispersus* but its impact on population regulation has not yet been studied (Wijesekera and Kudagamage, 1990). Predation of *A. dispersus* nymphs by *C. sexmaculatus* and *C. nigritus* was more on *M. esculenta* and *P. guajava* than in other plant species. Several workers made studies on the predatory efficiency of the *C. sexmaculatus* and *Scymnus* sp. on *A. dispersus* on casava (Palaniswami, 1995), on *Dombeya spectabilis* (Geetha *et al.*, 1999) and mulbery (Asia Mariam, 1999) in Tamil Nadu. It was also known to feed other whiteflies like *B. tabaci* (Venugopal Rao *et al.*, 1989).

Developmental durations of whitefly predators have been studied under varying conditions using either mixtures of whitefly instars or specific, single age populations (Gerling, 1990). In the present study on longevity and feeding potential of predators, the larva of *C. montrouzieri* consumed a total of 138.6 eggs and 228 nymphs for a period 16.60 days which was higher than adults. Doutt (1964) also reported the similar result that more number of prey individuals was required for a young predator to complete its development. However the adults are not always carnivorous, hence the prey consumption was poor. Similar study was conducted earlier by Mani and Krishnamoorthy (1999b) who found that *C. montrouzieri* had completed its larval development in 17.20 days on *A. dispersus* and the fourth instar consumed on an average of 149.80 nymphs of *A. dispersus*. *C. montrouzieri* had been reported as an efficient predator of mainly mealybugs and some of the scales in India and elsewhere.

A single larvae of *Cybocephalus* sp. consumed more number of eggs (95.36) and nymphs (49.13) for a period of 10.90 days. In India, there is no earlier report on the predatory potential of this predator. In Indonesia, Kajita *et al.,* 1991 found that the predator was preying on nymphs of *A. dispersus*, on guava, but failed to suppress the outbreak of *A. dispersus* as found in the present study. As the predators are very small, the consumption of prey is less when compared to other predators of larger sizes like *C. montrouzieri*. Also the preference of these predators to feed on eggs of SWF might be the reasons for not suppressing the population of *A. dispersus*, though the predators were found abundant. The larvae of *Cypocephalus* fed on the lateral or from underneath of the SWF nymphs. This kind of avoidance of host's dorsum due to cuticle thickness of host's age was observed earlier by Kajita (1982) and Susman (1988). Clausen and Berry (1932) reported the sluggish nature of the *Cybocephalus* sp which remain on the same leaf from hatching to pupation showed its poor prey searching ability.

5.8.2.2. Chrysopid predators

Three chrysopid predators *viz., Apertochrysa* sp., *M. astur* and *C.carnea* were found feeding on SWF in *M. esculenta, P. guajava, Musa* spp., *C. annuum, A. indica, M. glaziovii* and *T. populnea* in Tamil Nadu. Earlier Mani and Krishnamoorthy (1999c) reported four species of chrysopids *viz., Apertochrysa* sp., *M. bonninensis* (Okamoto), *M. astur* and *C. carnea* commonly associated with SWF in Bangalore. Earlier *Chrysopa commonche* (Banks) in Hawaii (Paulson and Kumashiro, 1985) and several other species of *Chrysopa* in, Guam (Nechlos, 1983), Phonpei (Esguerra, 1987), Fiji (Waterhouse and Norris, 1989), Sri Lanka (Chandrasekara, 1990) and Indonesia (Kajita *et al.,* 1991) had been recorded on *A. dispersus*. *C. carnea* was reported feeding on the other whiteflies like *B. tabaci* (Anonymous, 1985) and *S. phyllireae* (Pelov and Trenchev, 1973). In the laboratory study, third instar larva of *M. astur* was found voracious and consumed more number of nymphs of SWF. Only sixty per cent of *M. astur* larvae pupated and adults emerged. In case of *C. carnea,* none of the larva survived on SWF nymphs. The feeding potential of *C. carnea* was very less. Earlier, it was found that *M. astur* had completed its life cycle on nymphs of *A.dispersus* with an average consumption of 23490 whiteflies during its entire developmental period of 13.50 days (Anonymous, 1998).

Gerling (1986) found that *C. carnea* was able to develop into adult by preying on *B. tabaci* larvae alone although its development was prolonged. Legaspi *et al.* (1994) found that although all the immature stages of *B. tabaci* were preyed on by *C. rufilabris,* none of the larvae developed to the adult stage. Further Senior and McEwen (1998) supported that *C. carnea* consumed all the stages of *T. vaporariarum* but none of them survived to pupation. When compared to debris carrying chrysopids like *M. astur* and *Apertochrysa* sp., the larvae of *C. carnea* (which is not carrying debris) performed poor in the population of SWF. The reason might be the larvae of *C. carnea* while searching for prey would have been easily trapped by the waxy flocculent, tuft and glossy hair like outgrowth of the nymphs of the SWF. As they have small marginal setae, they struggled more to relieve from the wax outgrowth and as they don't have the habit of carrying debris, when they come across the wax flocculent materials, they struggled more even to more from one side to another, these all might have reduced the efficiency of *C. carnea.* The debris carrying chrysopids like *Apertochrysa* and *M. astur* easily removed the wax materials using their strong well developed setae and mandibles and also carried those wax material on its dorsum, easily moved, showed the more efficiency on prey searching and predatory potential on *A. dispersus.*

5.8.2.3. Spiders

The spider *Oxyopus* sp. was found preying on *A. dispersus* abundantly on cassava. Dhulia and Yadav (1991) reported that spiderlings of *Oxyopus* sp.

were found to feed on soft bodied insects such as aphids and jassids, whereas their adults fed on larvae of lepidopteran insects in the field. The other spiders found to feed on whiteflies, *B. tabaci* were *Argiope pulchella* (Argiopidae) and *Castianeira* sp. (Clubionidae) (Patel, 1987).

5.8.3. Parasitoids

5.8.3.1. Natural parasitism of *Encarsia* parsitoid

The natural occurrence of an aphelinid parasitoid *Encarsia* sp. near *meritoria* Gahan was found parasitizing the nymphs of *A. dispersus* on several plant species in Tamil Nadu. It is a solitary endoparasitoid developing in SWF pupa. It's occurrence was first recorded in Coimbatore on guava with the peak parasitism of 65.49 per cent during December 1999 in Patchapalayam Milk Society gardens. The identified species of *Encarsia* is closely related to *E. meritoria* and *E. haitiensis* (Hayat, 1999, Pers. comm.). . Polaszek *et al.* (1992) reported the *E* sp. nr *haitiensis, E. hispida* and *E. meritoria* and belonging to *E. luteola* group and extremely closely related and often indistinguishable in the female sex. The per cent parasitism was high on *P. guajava* in all the places surveyed. It's occurrence was also found on *Gossypium* spp., *M. esculenta, Musa* spp, *P. granatum, P. alba, Manihot* sp and *T. populnea* in Tamil Nadu. In the new environment, the enemy must be attracted to or be able to find the local habitat of the host or prey. The host must prove acceptable to the parasite, when attacked must be suitable for the enemy's use. Hence the parasitoid establishment in a new locality involved longer period (DeBach, 1966). The parasitoids could be collected only after three years of pest introduction in India. Similar parasitoid species has also been reported recently by Beevi *et al.* (1999) in Kerala and Srinivasa *et al.* (1999) in Karnataka. It is an exotic parasitoid and has never been reported on other whiteflies in India.

In many Pacific islands aphelinid parasitoid, *E.* sp. nr *haitiensis* was reported as a more valuable potential biocontrol agent against *A. dispersus* which resulted rapid population reduction (Anonymous, 1981; Nechols, 1982 and Kumashiro *et al.*, 1983). In many countries, the parasitoid, *E. haitiensis* was introduced, which yielded successful control of high population density of *A.dispersus*. As the parasitoid found in India is closely related to *E. haitiensis*, the similar establishment and success in control of *A. dispersus* would be expected in future. In Sri Lanka another *Encarsia* parasitoid namely *E. transvena* (Timberlake) was found on *A. dispersus* (Wijesekera and Kudagamage, 1990).

5.8.3.2. Parasitoid biology

The parasitoids collected had similarity in morphological features as that of the genus *Encarsia* which had antenna with seven or eight segments, wings hyaline. *E.* sp. nr *meritoria* had a tarsal formula of 5-4-5 which was similar to the earlier report on *Encarsia* (Gerling, 1990). They are solitary endo parasitoids. The eggs of parasitoid laid into the host's body fluids where they hatch into a freely swimming first instar larva.

5.8.3.3. Parasitoid emergence behaviour

The pupae were blackened before adult emergence and adults were emerged through a circular exit hole. Similar process was already reported by Gerling (1990) who explained that the pupa of the parasitoid may face the host's venter during pupation, but turning to face its dorsum before emerging as an adult through a hole that is chewed in the dorsum of the host. As like the observation on *E.* sp nr *meritoria*, the pupal skin of *E. transvena* was dark black but the adults emerged were yellow coloured (Gerling, 1990).

The activities of the parasitoids after emergence from the host *viz.*, walking, drumming, turning, mounting on nymphs and preening during host selection, host feeding and oviposition observed were explained in detail by Lenteren *et al.* (1980), on *Encarsia* species.

The time taken by the parasitoid *E.* sp. *nr meritoria* for walking, and host feeding were 26.2 seconds (ranged from 16 to 39 seconds) and 32 seconds (ranged from 6 to 43 seconds). Lenteren *et al.* (1980 and 1996) studied the time taken for the various activities of the parasitoid and found that the parasitoid took 82.2 seconds for host feeding. The parasitoids showed the oviposition postures only on few hosts. The parasitoids selected the host in random and rejected both parasitized and unparasitized hosts for oviposition. The paraitized hosts might either be rejected through the perception of "mark" or be rejected by unknown reasons as unparasitized hosts as supported by Lenteren *et al.* (1976a and b). Searching efficiency is influenced by the leaf surface characteristics. Rough leaves or leaves that are covered with dust or honeydew make travel upon them very difficult and thus slow down or even prevent parasitoid movements. Hau *et al.* (1987) found more efficient searching of *Encarsia* parasitoids on smoother leaves with less hairy. Host examination and oviposition behaviour was studied extensively by Lenteren *et al.* (1980 and 1987), who observed time and quantified 11 different behavioural entities in *E. formosa.* Among them, the antennation and ovipositor probing were the two main procedures through which the host was discovered and its suitability ascertained.

Among the samples collected, only third and fourth instar and pre pupae of *A. dispersus* were blackened which showed the parasitization by *E.* sp. nr *meritoria.* Though the younger host stages are abundant, easier to find and sometimes also less able to defend themselves than older instar, the avoidance of oviposition in young hosts might be due to small amount of nutrients. The development of parasitoid in young hosts also require longer period resulting in longer exposure to abiotic and biotic environmental hazards. Because the early nymphal instars are the smallest and more difficult to locate by the random search, the parasitoid prefer the late instar nymphs for oviposition (Horowitz *et al.*, 1984 and Gerling, 1990). Nell *et al.* (1976) also explained earlier about the host stage selection by the parasitoid, which is similar to that of the present observation. Parasitoid feeding was seen on honeydew but the feeding on host was not clear though the parasitoid had kept its mouth parts closer to the host for a maximum of 32 seconds.

Parasitoid adult longevity in the present investigation showed very short period for *E.* sp nr *meritoria.* Vet and Lenteren (1987) reported greatest longevity of 99 days at 15-16°C for *E. formosa* and 84 days for *E. deserti.* Hoddle *et al.* (1998) reported that longevity of *Encarsia* parasitoids is not correlated with body size and it decreased with increasing temperature. All the parasitoids from the samples collected emerged out from 11.00 a.m. to 4.00 p.m. Louise *et al.* (1981) studied the relationship between the parasitoid *E.* sp nr *meritoria* and *T.vaporariarum* to search an alternative parasitoid capable to control the greenhouse whiteflies. They found that *E.* sp *nr. meritoria* was less promising species compared to *E. formosa* and *E. pergandiella.* Each female of *E.* sp nr *meritoria* produced an average of 85.4 parasitized pupae (range 40 to 115) during the period of 20 days at 17 ± 1°C. They also showed a low, fairly constant parasitization rate of about 4 parasitized pupae per female per day. In the present study, the developmental period of female parasitoid was 29 to 34 days. The parasitoid emergence was 80 per cent and the correct time of natural enemy release is a primary factor for obtaining necessary synchronization with their host establishment. The increased parasitism of the *E.* sp *nr meritoria* on *A. dispersus* showed its acclimatization and spreading in the new locality indicating its efficiency under field condition.

5.8.3.4. Periodical release and recovery of parasitoid

The ecological circumstances necessary for successful establishment of entomophagous insects in a new environment are complex. The climate must be suitable in its direct effects on development, survival and reproduction of the new natural enemy. It must also be suitable in its indirect effects on the cycle synchrony between enemy and host (Flanders, 1959). In the present study, the parasitoid *E.* sp nr *meritoria* were released on guava at two spots in TNAU campus and recovered a maximum 20.92 per cent parasitism. Attempts were made on importation of *Encarsia* parasitoids for population regulation of *A.dispersus* by several workers (Gordon, 1982; Kumashiro *et al.,* 1983; Nechols, 1983 and Lai and Funasaki, 1990). Nechols (1987) found the establishment of *E. haitiensis* within a period of 9 months of initial release and its extended host range to all the affected areas by *A. dispersus.*

The abundance of natural parasitism of SWF by *E.* sp nr *meritoria* on *P. guajava* in Coimbatore might be due to the availability of other alternate hosts for the parasitoid species during the off season of the hosts. Louise *et al.* (1981) had previously collected *E.* sp. nr *meritoria* from *T. vaporariorum* on convolvulus and fragaria species and *Nicotiana gluca* Grah in California in 1979 and from *A. spiraeoides* and *T. vaporariorum* on *N. glauca* in Riverside, California. Gerling (1990) also reported the other hosts attacked by the parasitoid *E.* sp nr *meritoria* were *Aleurolobus spiraeoides, T. floridensis* (Quaintance) and *T. vaporariorum* in California. The avoidance of chemical spray on guava at Patchapalayam and continuous availability of host might also be the reasons for the establishment of this new parasitoid in that particular location.

5.8.4. Parasitic mite

A parasitic mite, *Leptus* sp was recorded newly as natural enemy of *A.dispersus.* Earlier Ramaraju (1994) recorded four mite species of the same genus on the neck, wing and abdominal region of different grasshopper hosts. The heavy infestation of this mite physically weaken the host body, their vigour and ultimately lead to the death of the *A. dispersus,* as earlier observed by

Mohanasundaram and Parameswaran (1989) and Ramaraju (1994). After studying the ecobiological aspects, the mite species could be put into use as a biological control agent of *A. dispersus.*

5.9. Reaction of genotypes against *A. dispersus*

Plant-Insect coevolution has resulted in a wide variation in host-plant suitability between and within plant species. Cultivated plant species also show this variation. Partial resistance to pest is sufficiently recognized and appreciated for screening and evaluation programmes (Kennedy *et al.*, 1987 and Ponti *et al.*, 1990). Large scale screening of a wide collection of varieties and related species is one of the first steps to a deliberate exploitation of genetic variation in host plant suitablity (Ponti *et al.*, 1990). Field screening is a prerequisite for any breeding programme to transfer the resistance.

5.9.1. *M. esculenta*

Several cassava accessions were evaluated based on the whitefly population and damage intensity. Seven accessions showed resistance to *A. dispersus* damage intensity and 4 accessions showed susceptibility with very high damage intensity even at third month stages. Totally 9 accessions showed their moderate resistance to *A. dispersus* damage. Palaniswami *et al.* (1995) also studied the host reaction to *A.dispersus* and found that the varieties H 226 (high cynogen content) Sree sahaya and Sree visakam (low cynogen content) were the most preferred hosts and the cynogen content had no influence on host preferrence by *A. dispersus*. Hence both the morphological traits like hariness, shape, thickness of cuticle and biochemical constituent might be responsible for the moderate resistance of the *M.esculenta* genotypes to the population of *A. dispersus.*

5.9.2. *P. guajava*

Among the ten accessions tested, the accession Redflesh showed its resistance to *A. dispers* *us* population. The morphological and physiological traits might be responsible for this non preference which needs further investigation.

5.9.3. *Gossypium* spp.

All the wild species and hybrids *viz.*, Surabhi and Anjali showed high level of resistance to population of *A. dispersus* and most of the cultivated species are susceptible to SWF attack. Preference to whiteflies may be attributed by the morphological traits of the plants. Pollard and Saunders (1956) demonstrated that a glabrous variety of cotton carried only few *B. tabaci* than a hairy leafed one. Leaf shape and plant architecture also cause differences in population levels of *B.tabaci* on cotton (Butler *et al.*, 1988).

These screening works are basic studies and the data derived would help the future workers for further intensive screening of resistant varieties against the population of *A.dispersus* which may throw more light on the management of the pests..

5.10. Population dynamics of *A. dispersus* influenced by natural enemies and weather factors

Biotic and abiotic factors regulate the population of *A. dispersus* in a given ecosystem.

5.10.1. Population dynamics of *A. dispersus* in *P. guajava*

Very high population of *A. dispersus* was found during May '99, which had 98.5 per cent eggs spiral area, 77.53 nymphs and 118.00 adults per leaf with a natural parasitism of 0.42 per cent by *E.* sp nr *meritoria.* The population of *A. dispersus* steadily declined and reached a minimum population during November '99. The parasitism was found increasing and reached a peak of 81.11 per cent during

January 2000 and then declined steadily till the end of study period. As the high level of parasitism significantly influenced population reduction of *A. dispersus*, the predator had no effect on population dynamics of SWF as they were in very low numbers.

Similar correlation between *A.dispersus* and *parasitism* by *E.haitiensis* was observed in Guam (Nechols, 1982). Nechols (1983) reported that in 1982, in Guam the density of SWF declined from a mean of 6.8 late instar nymphs per leaf in July-August samples to less than 1 nymph per leaf in November. Mean whitefly densities declined to less than 2 emergence per leaf at all localities by October-November with parasitism ranged from 58 to 100 per cent. *Encarsia* population increased 8 fold between July and September. Kumashiro *et al.* (1983) also found that the peak density of SWF (461.3 pupae) in May 1980 with subsequent declining in population in succeeding months with increasing parasitoid density of 16.3 pupae in October 1980. They also reported that the increase in parasite density during November and December 1981 was 61.3 pupae with a corresponding decline in the SWF population. Similar result was obtained in the present study where the increased parasitism was found in December to January 2000 and reached a peak of 81.11 per cent. This clearly indicated the parasitoid activity increased during winter and cooler months with minimum temperature of 16-20°C and maximum of 28°C. Burnett (1949) observed the more efficiency of *E.formosa* at greenhouse temperatures above 24°C and decreasing temperature causes the inefficiency of the parasitoids in controlling whiteflies. D'Almeida *et al.* (1998) also reported a decline in population of *A. dispersus* with increasing time of parasitoid presence. The annual peaks of *A. dispersus* population declined by 80% between 1993 and 1996 with increased parasitism rates on *P. guajava*.

5.10.2. Population dynamics of *A. dispersus* on cassava (*M. esculenta*)

Whitefly population density was high with 82.5 per cent eggs spiral area, 59.0 nymphs and 155.7 adults per leaf in August'98. The population of *Cybocephalus* sp was found in less numbers during August 1998 and increased steadily with SWF population was noted from May'99 till September'99. The predator population increased with the population of *A.dispersus* and reached a peak of 10.60 individuals per leaf in September'99. The positive correlation between SWF and predator was already recorded by several workers. Yoshida (1982) and Kumashiro *et al.* (1983) reported the peak density of the predator, *Nephaspis amnicola* in June 1980 and declined the density and remained at a very low level though there was a slight increase in the SWF population.

D'Almeida *et al.* (1998) found abundance of predator density on high population density of *A. dispersus.* These results showed that density dependent nature of predators. The parasitism by *E.* sp *nr meritoria* and coccinellid predator population were found at low level throughout the study period. Though the population of *Cybocephalus* sp was high when compared to SWF population its density was low. Hence in cassava, the population dynamics of SWF mainly influenced by the weather factors. Significant negative correlation was found between maximum temperature and SWF population. Cherry (1979) reported the increased mortality of immature stages and adults between the maximum temperatures of 35 to 40°C.

In Hawaii, significant positive correlation was obtained between temperature and whitefly abundance (Kumashiro *et al.,* 1983). In the present investigation though the maximum temperature had negative effect, the minimum temperature had significant positive effect on SWF population. Rainfall had negative association with egg spiral area and nymphal population, without significant differences but had significant effect in adult population. Kumashiro *et al.* (1983) reported the importance of both temperature and rainfall in regulation of spiralling whitefly population besides the natural enemies. Nechols (1983) observed declining the population following the onset of the rainy season. This was attributed to a washing off effect by rain as well as indirect influence mediated through the physiological condition of the host plants (D'Almeida *et al.*, 1998).

In the present study, drastic reduction in SWF population was found during rainy season from October 1998 and declined steadily till April 1999. Again the population increased slowly in summer months.

Ranjith *et al.* (1996) also reported that whitefly had increased drastically in summer and decreased after the premonsoon showers in Kerala, which further supported the result obtained in the present investigation. Relative humidity had not significant effect on population dynamics of whiteflies, but Chandrasekara (1990) reported the significant correlations between the relative humidity and SWF population in Sri Lanka.

Since the pest was introduced into Tamil Nadu and established on most of the crops, integrated management techniques are needed to regulate the population of *A. dispersus*. Chemical spray at early stages of the pest results only moderate effect. The establishment of exotic parasitoid species, *E.* sp nr. *meritoria* was found first time recently in Tamil Nadu. There is a great scope for the use of the parasitoids and other indigenous predators and parasitic mites in regulation of the population level of *A. dispersus*. As the pest has protective waxy coverage over its body, emphasis should be given for biological control. Further studies are needed on the parasitization efficiency of this parasitoid on SWF on various hosts and increasing its efficiency by conservation and augmentation techniques that will lead a better control of *A. dispersus*.

SUMMARY

CHAPTER VI

SUMMARY

The salient findings of the investigations on the distributions, host range, biology, damage potential, management and population dynamics of the Spiralling whitefly, *A. dispersus* are summarised in this chapter.

* Distribution of *A. dispersus* was found in all districts of Tamil Nadu except Udhagamandalam and the incidence was very high in Coimbatore, Salem, Namakkal, Dharmapuri, Erode, Kanyakumari and Tuticorin which ranged from 76.04 to 94.17 per cent.

* At cities and road sides the whitefly incidence was very high on various crop plants ranged from 31.41 to 99.83 per cent while it ranged between 6.5 to 48.0 per cent in crops at villages.

* Surveys carried out during 1997-99 throughout Tamil Nadu indicated the occurrence of *A. dispersus* on 128 crops species belonging to 52 families with the highest incidence of 99.83 per cent in Euphorbiaceae family.

* Among the wide host range, the plants highly preferred by *A. dispersus* in Tamil Nadu were tuber crops *viz., M. esculenta* and *A. companulatus*, vegetables *viz., C. annuum, S. melongena, L. esculentum* and *A. esculentus*, oil seeds *viz., C. cajan* and *R. communis*, fibre crop *Gossypium* sp, fruit trees *viz., P. guajava, C. papaya, Musa* spp., *A. squamosa, P. granatum* and *T. catappa,* ornamentals *viz., A. indica*, *P. alba* and *P. pulcherrima* and shade trees *viz., T. populnea*, *M. glaziovii* and *Manihot* sp.

* Twenty five weeds belonging to twelve families were identified as alternate hosts for *A. dispersus* around cassava and guava fields in Coimbatore. Weeds belonging to Euphorbiaceae, Teliaceae and Asteraceae were more preferred hosts.

* Eggs were stalked, elliptical, translucent and were laid in wax spirals. There were four distinct nymphal instars. All the stages were differentiated based on their shape, size and pattern of wax production. Third and fourth instar nymph secreted numerous glassy wax rods from their compound pores and covered with copious amounts of white waxy flocculent materials.

* The developmental periods of eggs, I, II, III, IV instar nymphs varied between 5.2 to 7.9, 2.15 to 6.50, 2.7 to 5.00, 2.9 to 5.96 and 6.5 to 8.1 days respectively. Total developmental period from egg to nymphal stages varied between 22.50 to 29.66 days on various host plants.

* Adult longevity varied between 13.30 to 21.70 days on various host plants tested. Whiteflies successfully completed their life cycle on papaya fruit with the total developmental period of 25.61 days from egg to nymphal stages and adult longevity was 14.21 days.

* The per cent adult emergence was highest on *Gossypium* spp. (97.31) and fecundity was highest on *M. esculenta* (27.25) with no much differences on hatchability of eggs on various hosts tested.

* Regular pattern of egg wax spirals were comparatively more on all the host plants except banana during the initial period of infestation, whereas irregular pattern of egg laying was more during the later period of infestation by *A.dispersus*.

* Variations in trichome density did not alter the egg density of *A. dispersus*.

* At three month old cassava crops, the egg spirals, nymphs and adult population were more on bottom leaves followed by middle leaves and least population was found on top leaves. In grown up plants of *M. esculenta* and *P. guajava*, egg spirals were more on top leaves, nymphs and adults were more on middle and bottom leaves respectively.

* Initial releases of whiteflies on *M. esculenta* at the rate of 50 and 250 per plot showed significant differences on plant growth only in later months.

* Damage potential of *A.dispersus* was high in plots released with 250 adults. Average tuber yield was high (2.960 kg/plant) from uninfested plants. The per cent reduction in yield was 53.10 and 30.07 in plots released with 250 and 50 adults per plot.

* In *P. guajava*, the young shoots after pruning attracted more whitfly adults for feeding and egg laying, which inturn increased the population load.

* Setting up of yellow sticky traps recorded more adult catches on traps placed at crop canopy than those above and below crop canopy in *M. esculenta* and *A. indica*.

* Among the various colour traps tested, the maximum number of adults were caught in yellow coloured traps followed by green and orange traps. Attraction by red, black and white coloured traps were poor.

* Bihourly, light trap catches were significantly higher at early mornings hours (4 to 6 a.m.) than other intervals tested.

* Attractancy of yellow coloured light trap was higher than white, green and orange coloured light traps.

* Triazophos (0.08%) and phosalone (0.072%) had more ovicidal effect in both the field trials conducted, which recorded 98.68 to 99.73 and 97.13 to 92.04 per cent respectively at three days after spraying. Neem products had also ovicidal effect ranged from 82.14 to 89.14 per cent.

* Triazophos was most effective in mortality of early instar nymphs which recorded 91.48 to 98.74 (field trial I) and 94.87 to 95.65 (field trial II) per cent at 1 to 5 days after spraying. Malathion, TNAU neem (0.03%), neem oil

60 EC (1.8%) were next best chemicals causing more early instar nymphal mortality. Dish wash soap solution and Fish Oil Rosin Soap (FORS) also were better chemicals which caused early instar nymphal mortality of 76.14 to 84.11 per cent.

* Triazophos, phosalone and neem oil 60EC were equally effective in late instar nymphal mortality. TNAU neem oil and dish wash soap solution performed next.

* Triazophos was a highly effective adulticide which recorded 97.28 (trial I) and 98.61 (trial II) per cent mortality followed by TNAU neem and phosalone.

* Chemical insecticides, neem products and soap solutions were highly effective when applied at egg and early instar nymphal stages which were more vulnerable to chemicals than late instar nymphs and adults

* Fifteen predators were found preying on *A. dispersus* during extensive surveys in Tamil Nadu. Among them the *Cybocephalus* sp were predominant in cassava field followed by the coccinellids *viz., C. montrouzieri, A. puttarudriahi, C. sexmaculatus* and *C. nigritus,* chrysopids *viz., Apertochrysa* sp and *M. astur* and predatory spider *Oxyopus* sp.

* Predatory potential of larva and adult of *C. montrouzieri* was high when compared to *Cybocephalus* sp and spiders. Larva of *C. montrouzieri* consumed on an average of 138.6 eggs and 228 nymphs during its developmental period of 16.60 days.

* Predatory potential of *M. astur* was high which consumed a total of 200.40 eggs and nymphs of *A.dispersus* during a period of 14.20 days.

* Solitary, endo, aphelinid parasitoid, *Encarsia* sp near *meritoria* of *A. dispersus* was identified, which is a first record on parasitoids of *A.dispersus* in Tamil Nadu.

* Percentage parasitism by *E.* sp. nr. *meritoria* was high on guava in Coimbatore. Parasitoid abundance was observed during December '99 to January 2000. The same parasitoid could be collected on various host plants of SWF in seven districts of Tamil Nadu.

* The parasitoid, *E.* sp. nr *meritoria* was yellow coloured and had a body length of 0.57 mm and a body width of 0.26 mm. Antennae eight segmented, both wings were setaceous and legs had a tarsal formula of 5-4-5.

* Parasitoid emergence through a circular hole on pupa of *A. dispersus* occurred between 12.30 pm to 4.00 pm with the duration of 14 to 35 minutes. Total developmental period of the parasitoid was 3.1 ± 8.0 days.

* A maximum of 20.92 per cent parasitism was recovered after the periodical releases of the parasitoid on guava.

* New record of parasitic mite, *Leptus* sp (Erythraeidae) on nymphs of *A. dispersus* was made on several weeds around cassava field.

* In the field screening of cassava accessions against *A. dispersus*, 13 accessions had low population and damage intensity and 9 had medium population of *A. dispersus* and damage intensity. The accessions *viz.*, CIAT 94, Nilgiris vella, CIAT 199, CIAT 200, CTCRI chenguvallai Red, CTCRI Kalikallan and CTCRI H7 showed their resistance to the attack of *A. dispersus*.

* Among the guava varieties, Redflesh was less preferred showing its relative resistance to *A. dispersus*.

* In cotton, wild species *viz.*, *Gossypium arboreaum* and *G. thurberi* and hybrids surabhi and Anjali had low population of *A. dispersus* whereas all the cultivated varieties harboured more population and highly susceptible to *A.dispersus* infestation.

* Population density of *A. dispersus* was high during May '99 to August '99 on guava. The parasitism by *E.* sp nr *meritoria* was high during November '99 to January 2000 with a peak of 81.11 per cent at the first week of January 2000. Parasitism had significant negative association with SWF population density.

* Whitefly population was high during August '98 to first fortnight of October '98 and again in May '99 to September '99 on cassava. The predator, *Cybocephalus* sp population was high (10.60 individuals/leaf) during September '99. Predator population increased with increasing population density of *A. dispersus*.

* Maximum temperature significantly reduced and the minimum temperature significantly increased the population of *A. dispersus*. Rainfull had significant negative association, which declined the population of *A.dispersus* to a very low level.

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* Originals not seen.

APPENDICES

APPENDIX I

HOST RANGE OF *A. dispersus*

Sl. No.	Family	Common name	Botanical name	Damage category
1.	Euphorbiaceae	Cassava	*Manihot esculenta* crantz	VH
		Wild Manihot	*Manihot* sp.	VH
		Cera Rubber	*Manihot glaziovii* M. Arg.	VH
		Castor	*Ricinus communis* L.	H
		Paradise flowers	*Poinsettia pulcherimma* Willd ex koltz	VH
		Indian Acalypha	*Acalypha indica* L.	VH
		Red hot cat tail	*Acalypha hispida* Burm. F.	VH
		Chekurmanis	*Sauropus androgynus* Meeril	M
		Croton	*Croton sparasiftorus* Morong	L
		Indian gooseberry	*Phyllanthu semblica* L.	L
		Star gooseberry	*Embilica officinalis* Gaerth	L
2.	Myrtaceae	Guava	*Psidium guajava* L.	VH
		Clove	*Eugenia caryophyllata* L.	L
		Jamun	*Eugenia jambolana* Skeels	M
		Nut meg	*Myristica fragrans* Houtt.	L
3.	Malavaceae	Cotton	*Gossypium* spp.	H
		Bhendi	*Abelmoschus esculentus* Moench	VH
		Shoe flower	*Hibiscus rosa* sinensis L.	L
		Portia tree	*Thespesia populnea* Soland ex Cort L.	VH
		Dombeya	*Dombeya spectabilis* Boj	H
4.	Solanaceae	Brinjal	*Solanum melongena* L.	VH
		Tomato	*Lycopersicon esculentum* Mill.	VH
		Chillies	*Capsicum annuum* L.	VH
		West Indian turkey berry	*Solanum torvum* Swartz.	M

Sl. No.	Family	Common name	Botanical name	Damage category
		Thoothuvilai	*Solanum trilobatum* L.	H
		Medicinal solanum	*Solanum khasianum* Clarke.	M
5.	Moraceae	Jack	*Artocatus heterophyllus* Lamk	L
		Bread fruit	*Artocarpus altilis* Lamk	L
		Indian Fig	*Ficus carica* L.	L
		Yercard fig	*Ficus racemosa* L.	L
		Bayan tree	*Ficus bengalensis* L.	H
6.	Punicaceae	Pomegranate	*Punica granatum* L.	H
7.	Annonaceae	Custard apple	*Annona squamosa* L.	VH
		Bullock's heart	*Annona reticulata* L.	VH
		Nettulingam	*Polyalthia longifolia* (Sonnerat) Th.	L
8.	Combretaceae	Badam	*Terminalia catappa* L.	VH
9.	Musaceae	Banana	*Musa paradisiaca* L.	VH
10.	Araeceae	Elephant foot yam	*Amorphophallus campanulatus* Blume.	H
11.	Apocynaceae	Frangipani	*Plumeria alba* L.	M
		Nandhya vattam	*Tabernae montana* Hutch	L
		Oleander	*Nerium oleander* L.	L
		Karonda	*Carrissa carandas* L.	L
12.	Fabaceae	Redgram	*Cajanus cajan* L.	VH
		Blackgram	*Vigna mungo* L.	L
		Greengram	*Vigna radiata* L.	L
		Soybean	*Glycine max* L.	M
		Ground nut	*Arachis hypogea* L.	M
		Lab lab	*Dolichos lablab* L var. typica	M
		Cowpea	*Vigna sinensis* Walp.	M
		French bean	*Phaseolus vulgaris* L.	M
		Cluster bean	*Cyamopsis tetragonaloba* L. Taub.	M
		Lima bean (or) Butter bean	*Phaseolus lunatus* L.	L
		Pea	*Pisum sativum* L.	L

Sl. No.	Family	Common name	Botanical name	Damaged category
13.	Caesalpinaceae	Golden shower	*Cassia fistula* L.	L
		Gulmohar	*Delonix regia* Boj ex.Hook	L
		Peacock flower	*Caesalpinia pulcherrima* L.	L
		Vada Narayanam	*Delonix elata* L.	L
		Camel's foot tree	*Bauhinia purpurea* L.	M
			Bauhinia tomentosa L.	M
			Bauhinia varigata L.	M
		Tamarind	*Tamarindus indica* L.	L
		Golden shower	*Cassia fistula* L.	M
		Red konnai	*Cassia marginata* L.	L
		Dividi	*Caesalpinia coriarea* Jacq	L
14.	Papilionaceae	Glyricidia	*Glyricidia maculata* H. B and K.	L
		Agathi	*Sesbania grandiflora* L.	L
		Jewel on a string	*Milletia ovalifolia* L.	L
		Vagai	*Albizzia lebbeck* L.	L
		Sisoo	*Dalbergia sissoo* Roxb.	L
		Pungam	*Pongamia glabra* Vent.	M
		Flame of the forest	*Butea monosperma* Lam.	L
15.	Rutaceae	Curry leaf	*Murraya koenigii* (L.) sprengal	L
		Wood apple	*Feronia limonia* L.	L
16.	Sapotaceae	Sapota	*Manilkara achras* Mill.	L
17.	Guttiferaceae	Mangosteen	*Garcinia mangostana* L.	L
18.	Malpighiaceae	West Indian cherry	*Malpighia punicifolia* L.	L
19.	Caricaceae	Papaya	*Carica papaya* L.	VH
20.	Anacardiaceae	Mango	*Mangifera indica* L.	L
		Cashewnut	*Anacardium occidentale* L.	L
21.	Rhamnaceae	Indian ber	*Zizyphus jujuba* L.	M
		Country ber	*Zizyphus mauritiana* Lamk.	M
22.	Cruciferae	Mustard	*Brassica nigra* L.	L

Sl. No.	Family	Common name	Botanical name	Damage category
23.	Vitaceae	Grapes	*Vitis vinifera* L.	M
24.	Mimosaceae	Mesquite	*Prosopis juliflora* Roxb.	L
		Rain tree	*Samanea saman* Jacq	L
25.	Rosaceae	Rose	*Rosa chinensis* Jocq.	L
		Sweet cherries	*Prunus avilum* L.	L
26.	Santalaceae	White sandal wood	*Santalum album* L.	M
27.	Amaranthaceae	Amaranthus	*Amaranthus viridis* L.	H
		Amaranthus	*A. tricolor* L.	M
28.	Labiatae	Mint	*Mentha arvensis* L.	L
		Holy basil	*Ocimum sanctum* L.	L
29.	Bignoniaceae	Indian tulip tree	*Spathodea campanulata* Beavu. Fl. Owar.	L
		Money plant	*Potha arvensis* L.	L
30.	Simarubaceae	Match wood tree	*Ailanthus excelsa* Roxb.	L
31.	Verbenaceae	Teak	*Tectona grandis* L.	H
		Lantana	*Lantana camara* L.	L
32.	Rubiaceae	Thechi	*Ixora coccinea* L.	L
		Thechi	*Ixora arboria* L.	L
		Mussaendra	*Mussaenda erythrophylla* L.	L
		Coffee	*Coffea arabica* L.	L
33.	Palmae	Coconut	*Cocos nucifera* L.	M
34.	Oleaceae	Jasmine	*Jasminum auriculatum* L.	L
			Jasminum grandiflorum L.	L
35.	Acanthaceae	Crossandra	*Crossandrum undulaefolia* Salisb.	H
36.	Piperaceae	Pepper	*Piper nigrum* L.	M
		Betelvine	*Piper betel* L.	L
37.	Moringae	Drumstick	*Moringa oleifera* Lam.	M
38.	Convolvulaceae	Sweet potato	*Ipomoea batatus* L.	L
39.	Dioscoreaceae	Greater yam	*Dioscorea alata* L.	M
40.	Magnoliaceae	Shenbagapoo	*Michelia chambac* L.	L
41.	Cochlospermaceae	Silk cotton	*Cochlospermum religiosum* L.	M

Sl. No.	Family	Common name	Botanical name	Damage category
42.	Zingiberaceae	Turmeric	*Curcuma longa* L.	L
43.	Cucurbitaceae	Cucumber	*Cucumis sativas* L.	M
		Ribbed gourd	*Laffa acutangula* Roxb.	M
		Pumpkin	*Cucurbita moschata* Poir.	L
		Irg gourd / little gourd	*Coccinia grandis* Voigt.	M
		Bittergourd	*Momordia charantia* L.	H
44.	Pedaliaceae	Gingelly	*Sesamum indicum* L.	L
45.	Teliaceae	Sunnhemp	*Corchorus capsularis* L.	L
46.	Asteraceae	Sunflower	*Helianthus annuus* L.	M
47.	Lauraceae	Avacado	*Persea americana* L.	L
48.	Zingiberaceae	Turmeric	*Curcuma longa* L.	L
49.	Cannaceae	Canna	*Canna indica* L.	L
50.	Storculiaceae	Cocoa	*Theobroma caca* L.	L
51.	Camelliaceae	Tea	*Camellia* sp.	L
52.	Nyctaginaceae	Latcha kotta keerai	*Pisonia alba* L.	L
		Bougainvillea	*Bougainvillea spectabilis* L.	L

Damage intensity	-	Category
1 - 25 %	-	Low (L)
26 - 50%	-	Moderate (M)
51 - 75%	-	High (H)
76 - 100%	-	Very high (VH)

APPENDIX II

ALTERNATE WEED HOSTS OF *A. dispersus*

Sl. No.	Family	Common name	Botanical name
1.	Euphorbiaceae	Amman patcharisi	*Euphorbia hirta* L.
		Amman patcharisi	*Euphorbia heterphylla* L.
2.	Teliaceae	Punnakku poondu	*Corchorus olitorius* L. Jew's Mallow
		Punnakku poondu	*Corchorus capsularis* L.
3.	Asteraceae	Karisalankanni	*Eclipta alba* L. (Hassk)
		Mookkuthi poondu	*Vernonia cineraria* Bioss & Bal
		Corn sow thistle	*Sonchus arvensis* L.
		Mookkuthi poondu	*Vicoa indica* Willd. DC
		Congress weed	*Parthenium hysterophorus* L.
		Vettukkaaya thalai	*Tridax procumbens* Linn.
4.	Amaranthaceae	Ponnankanni	*Alternanthra triandra* L. Smith
		Kuppaimeni	*Acalypha indica* L.
		Kuppai keerai	*Amranthus viridis* Lima.
5.	Acanthaceae	Kodagusal	*Rungia repens* Nees.
		Pattasukai	*Ruellia tuberosa* Jacq.
6.	Malavaceae	The country mallow (Tuthi)	*Abutilan indicum* G. Don.,
7.	Solanaceae	Silver leaf nightshade	*Solanum elaegnifolium* Cav.
		Black nightshade	*Datura metal* L.
		Climbing brinjal	*Solanum nigrumi* L.
		Devils Trumpet (or) Ummattam	*Solanum trilobatum* L.
8.	Commelinaceae	Kannan keerai	*Commelina bengalensis* L.
9.	Convolvulaceae	Poomichakra poondu	*Convolvulus arvensis* L.
10.	Labiatae	Whitedead nettle	*Leucas aspera* (Willd) spreng.
11.	Arizoaceae	Horse purslane	*Trianthema portulacastrum* L.
12.	Aristolochiaceae	Pelican flower	*Aristolochia grandiflora* L.