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

Thesis submitted in part fulfillment of the requirements for the degree of

Master of Science (Agriculture) in Agricultural Entomology

to the Tamil Nadu Agricultural University,

Coimbatore.

By

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1999

CERTIFICATE

This is to certify that the thesis entitled "**BIOLOGY AND MANAGEMENT OF SPIRALLING WHITEFLY *Aleurodicus dispersus* (Russell) (Homoptera : Aleyrodidae) ON MULBERRY** submitted in part fulfillment of the requirements for the award of the **DEGREE OF MASTER OF SCIENCE (AGRICULTURE) IN AGRICULTURAL ENTOMOLOGY** to the Tamil Nadu Agricultural University, Coimbatore - 3 is a record of bonafide research work carried out by **Miss.M.ASIA MARIAM** under my supervision and guidance and that no part of this thesis has been submitted for award of any other degree, diploma, fellowship or any other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

With immense and heartfelt love I would like to keep on record the matchless efforts and insight taught of my Chairman **Dr.N.Chandramohan,** Professor and Head, Department of Sericulture, TNAU, Coimbatore for his tireless efforts, surpassing guidance, immense patience cordial treatment, constructive criticisms and timely help bestowed throughout the course of this investigation.

I owe a great deal to **Dr.P.C.Sundara Babu**, Registrar, TNAU, Coimbatore for his valuable suggestions and guidance during the initial period of my research work.

With deep respect and esteem regards I owe my indebtedness to the members of the Advisory Committee **Dr.M.Swamiappan**, Deputy Registrar, TNAU, Coimbatore and **Dr.K.Parvathy,** Associate professor, Department of Biochemistry, TNAU for their thoughtful suggestions.

I express my sincere thanks to **Mr.S.Douressamy,** Assistant professor and **Dr.N.Sivaprakasam,** Associate Professor, Department. of Sericulture, TNAU for their meticulous help extended during the research work.

I cannot forget the help rendered by **Dr.S.Mohan,** PG-Coordinator, and **Dr.S.Kuttalam,** Associate Professor who were helping me at times.

I am here to express my indebtedness to **Dr.A.Subramaniam, Dr.M.Muthusamy, Mr.R.Krishnan, Mrs.Manimegalai** and **Dr.S.Sridhar**, for their timely help.

I remember with gratitude, the staff members of Department of Agricultural Entomology for their kind co-operation during the period of my research.

I annex my gratitude to my everlasting friends **E.Sumathi, S.Anitha, S.Bhuvana, P.Malathi** and my colleagues **Chelladurai, Deena, Devaraj, Ramesh, Sarala, Sathyaseelan** and **Subramanian** who directly and indirectly helped me in finishing this thesis by offering me a great deal of material and moral support.

I would like to pour out my heart for my beloved parents **Mr.Mohd. Shahabudeen** and **Mrs. Shajahan Beevi** for carrying me on their shoulders through out the phases of my life till now.

On a more personal note I wish to place on record my loving thanks to my dear brothers **Sheikh, Yusuf** and sister **Yasmin** for their love and encouragement without whom the study would not have blossomed.

I extend my thanks to Department of Sericulture for offering me a scheme.

I would also like to thank **Mr.Chokkalingam** for his help during my analysis of results.

My sincere thanks to M/s **Sowmiya Computer Communications,** TNAU Campus, CBE for the neat typing of this thesis.

Above all, my heartfelt thanks to 'Allah' for the wisdom, energy and enthusiasm infused in me to carry out the research works successfully and His abiding presence in past, present and future parts of my life.

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7/5/99
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ABSTRACT

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BY

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Spiralling whitefly (SWF), *Aleurodicus dispersus* (Russell) is a new exotic pest in India causing damage to mulberry crop. Comparative biology of SWF on tree type mulberry and potted mulberry plants under screen house indicated the suitability of the tree mulberry for higher pest multiplication than in laboratory condition. Life cycle was extended for 10.5 days under captive condition. Pedicelled eggs of SWF were elongate, oval, smooth and light yellow colour. Pest underwent four instars in mulberry crop.

The third and fourth instars produced waxy flocculences which was impermeable to toxic insecticides and protected the pest against adverse climatic condition. Fourth instar was distinct with red colour eyes.

Fifty three plant species were identified as alternate hosts of SWF around mulberry ecosystem. Plant species under the families of Euphorbiaceae, Solanaceae and Fabaceae were more susceptible to SWF. Eleven plant species were recorded as new alternate hosts for SWF.

Whitefly population in mulberry ecosystem was more in top and middle leaves than in bottom canopy of the plant.

Biochemical analysis in SWF affected mulberry leaves revealed, significant reduction in the levels of moisture content, chlorophyll, nitrogen, phosphorous, total sugar and total protein content.

Feeding SWF affected leaves to silkworms, caused significant reduction in effective rate of rearing. Prolongation of larval period and higher mortality due to grasserie incidence were attributed to low effective rate of rearing.

Preliminary studies on the field reaction of different genotypes against SWF, indicated 12 genotypes with low level of adult and egg population, 17 accessions with moderate level of pest population and five genotypes as susceptible.

Trap studies on the attractancy of SWF population indicated that light trap was more appropriate tool for SWF monitoring and control than yellow sticky trap.

Various studies on insecticidal evaluation against different stages of SWF resulted that dichlorvos 0.08 per cent was more toxic against SWF adults. LC_{50} and LT_{50} values of 10.06 ppm and 12.18 minutes at 96 ppm were recorded for dichlorvos. Ovicidal action was also higher (89.38 per cent) in dichlorvos followed by Neemoil (B) formulation. Dichlorvos also inflicted higher percentage of nymphal mortality (90.42) followed by 4 per cent fish oil rosin soap spray.

Feeding the silkworm with insecticides treated leaves up to tenth day after spraying, significantly reduced the larval and cocoon characters. Phosalone 0.07 per cent spray was highly toxic and residues persisted even on 10th day after application.

Survey on the occurrence of natural enemies in mulberry ecosystem revealed that the occurrence of Coccinellid predators than other species of entomophagous insects.

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CHAPTER - I

INTRODUCTION

Silk remains an exquisite fabric of inimitable excellence as queen of textiles. India has the unique distinction of being the only country in the world bestowed by nature with all four varieties of silk viz., mulberry, tasar, eri and muga. Mulberry the best known of all silks is the product of *Bombyx mori* Linnaeus.

A major factor determining the productivity and profitability in sericulture is the yield of mulberry. The quality and quantity of mulberry leaves have direct relationship with effective silkworm rearing. The larval and cocoon economic characters are directly influenced by the quality of crop.

Mulberry crop is affected by 300 insect and non insect species of pests (Kotikal, 1982). Among the different groups of insect pests, sucking pests inflict more damage during different growth phases and affect the quality and yield of mulberry crop.

Of late, mulberry is severely affected by an exotic homopteran pest viz., spiralling whitefly (SWF), *Aleurodicus dispersus* Russell. Invasion of the pest was noticed in the mulberry crop during September - October 1996 in Coimbatore district of Tamil Nadu (Douressamy *et al.,* 1997). The spiralling whitefly *A. dispersus* is native to Caribbean islands and Central America and was able to spread very fast to different continents (Mani and Krishnamoorthy, 1997a).

It is a major pest posing serious problem in many African and Asian countries besides several Pacific islands. This pest is hard to kill because, its body is covered with heavy waxy flocculent materials.

Though several workers attempted to develop Integrated pest management (IPM) strategies for SWF in horticultural crops (Palanisamy *et al.*, 1995; Mani and Krishnamoorthy, 1997a), the work on mulberry is very limited.

Developing an IPM component in mulberry with emphasis on integrating soft pesticides, natural enemies and resistant genotypes is essential, because the synthetic chemicals are highly toxic to silkworm.

Hence the present investigation was undertaken with the following objectives :

i. To study the biology of spiralling whitefly on mulberry and enlisting the alternate hosts,

ii. To investigate the effect of whitefly damage on mulberry leaf quality and its effect on economic characters of cocoon,

iii. To identify the reaction of different mulberry genotypes against SWF and

iv. To study the efficacy of different IPM components against SWF.

REVIEW OF LITERATURE

CHAPTER - II

REVIEW OF LITERATURE

Spiralling whitefly is a key pest on many horticultural crops in different parts of the world. Biology, host plants, natural enemies, symptoms of damage, management practices, effect of affected leaves on economic characters of cocoon, toxicity and persistence of insecticides against silkworm are reviewed in this chapter.

2.1 Biology

The wings of newly emerged SWF adults (body length 2.28 mm in male and 1.74 mm in female) are clear on emergence, but develop a covering of white powder over the next few hours (Plate 1). The eyes are dark reddish brown and the fore wings, each have two characteristic dark spots. Adults are particularly active during the morning hours (Waterhouse and Norris, 1989).

According to Henderson (1982) mating occurs during the afternoon. Stationary males attract females by partially spreading their wings and beating them up and down rapidly on the leaf surface. Males then copulate with females that approach. Generally whitefly eggs are pyriform or ovoid and possess a pedicel, that is a peg like extension of the chorion (Poinar, 1965).

Plate 1. SWF adult (10x)

39^oC (Waterhouse and Norris, 1989). Douressamy *et al.* (1997) observed that the egg period of 4 to 6 days in Tamil Nadu.

Spiralling whitefly undergoes four nymphal stages. Nymphs are greenish white and oval.On hatching, the tiny first instar nymphs, viz., crawlers settle in a spiral pattern near eggs from which they were emerged, although some move within the confines of their leaf. The first instar nymphs have distinct antennae and functional legs and crawl actively. First instar lasts for six to seven days (Waterhouse and Norris, 1989).

Waterhouse and Norris (1989) observed that the second (0.5mm long) instar nymph and subsequent instars remain feeding on the same place.

Mani and Krishnamoorthy (1997c) observed that the legs and antennae of the remaining instars are atrophied since nymphs are sedentary.

Parallel observation was also recorded by Douressamy *et al.* (1997).

The duration of second instar varies from four to five days (Waterhouse and Norris, 1989).

Wijesekera and Kudagamage (1990) reported that the first and second instar lasts for six to nine days.

Paulson and Beardsley (1985) and Henderson (1982) reported that the SWF eggs are laid at right angles to the leaf veins in association with irregularly spiralling deposits of waxy white flocculences from which the whitefly derives its common name. The eggs are smooth surfaced, elliptical and yellow to tan in colour. Eggs have a characteristic short subterminal stalk or pedicel which is inserted into the stomata of lower leaf surface.

Similar observation of yellow elliptical eggs (0.33 mm long) on the leaf vein in association with irregularly spiralling deposits of waxy white flocculences was reported by Mani and Krishnamoorthy (1997a).

Waxy flocculences of SWF eggs are protective in nature, however the spiralling pattern of waxy material on non-host plants and inanimate surfaces even in the absence of eggs was reported by Henderson (1982). Parallel observation of SWF oviposition behaviour on both hosts and non-hosts was reported (Anon, 1981).

Fecundity of the SWF varies with the biotic and abiotic factors. The fecundity was maximum (28 ± 14.5 eggs) at 25^oC (Wen-hung chich *et al.,* 1994a).

Incubation period of SWF reported to vary from four to six days in India (Palanisamy *et al.,* 1995) and seven to ten days in Sri Lanka (Wijesekera and Kudagamage, 1990). Egg hatches in 9 to 11 days at 20 to

Whiteflies are distinctive in that all life stages except, the egg, can produce extra curricular waxes that cover the body. Some of the waxes are similar in form to those found on coccids (Mckenzie, 1967).

The third instar larvae of SWF (0.65 mm long) can be distinguished by the numerous evenly spaced, short, glass like rods of wax along the sides of the body. The third instar lasts for five to seven days (Waterhouse and Norris, 1989).

Extended third instar nymphal duration (more than 10 days) was reported by Wijesekera and Kudagamage (1990).

Mani and Krishnamoorthy (1997c) observed that the whitefly develop a characteristic row of anterior and mid dorsal waxy tufts from third instar.

Aleyrodids exhibit a degree of holometabolism and fourth instar nymph is commonly referred as pupa (Bemis, 1904) and it is of taxonomic importance.

In SWF, the fourth instar nymphs are 1.06 mm long and covered with copius amount of white materials and glass like rods. These protective layers are produced from a single pair of cephalic and three pairs of abdominal pores. Rods may be upto 8mm long, although most of them are shorter due to fragmentation. The fourth instar is at first a feeding stage like earlier instars, but later ceases feeding and undergoes moulting to the adult. Fourth instar lasts from 10 to 11 days (Waterhouse and Norris, 1989).

Gill (1990) observed in *Bemisia tabaci* Genn., that the last stage, when the pharate adult form is present, has the red eyes and the yellow body pigment of the adult, the same was observed in SWF also.

Wijesekera and Kudagamage (1990) observed that the SWF fourth instar lasts from 5-16 days.

Douressamy *et al.* (1997) reported that the entire nymphal period of SWF lasts from 14 to 21 days and pupal period from two to three days.

Total life cycle of SWF ranges from 21 to 38 days in different parts of the world.

Douressamy *et al.* (1997) reported that in Tamil Nadu the total life cycle of SWF ranged from 21 to 32 days.

Waterhouse and Norris (1989) reported that the total development from egg to adult occupies 34 to 38 days.

The total life cycle of SWF lasts from 18 to 23 days in Kerala (Palanisamy *et al.*, 1995), 30 days (Esquerra, 1987) and 26-36 days in Sri Lanka (Wijesekera and Kudagamage, 1990).

In Karnataka, the nymphs develop into adults in 20-25 days. Total life cycle is about 35 days (Mani and Krishnamoorthy 1997a).

Under laboratory condition, the maximum longevity of adult SWF was 39 days. Females oviposit throughout their life span commencing within a day of emergence. Mated females produce offspring of both sexes, where as unmated females produce male progeny only (Waterhouse and Norris, 1989).

2.2 Host plants

A.dispersus is highly polyphagous and it is known to attack more number of plants in different countries in which the pest was introduced. It was first collected on coconut in Florida (Russell, 1965).

As many as 44 host plants in Florida, Central and South America and Caribbean islands (Russell, 1965), 100 in Hawaii (Nakahara, 1978) 60 in Sarawak (Megir-Gumbek, 1987) 27 in Kiribati (Waterhouse and Norris, 1989) 22 in Indonesia (Kajita *et al.*, 1991), 144 in Taiwan (Wen-Hungchich *et al.*, 1994b) and 30 in Sri Lanka (Chandrasekara, 1990) had been reported for the spiralling whitefly.

In India, the pest was first collected in September 1994 on wild tapioca and wild rubber by David and Regu (1995).

A. dispersus was recorded on 25 plants (David and Regu, 1995), 70 (Prathapan, 1996), 22 (Ranjith *et al.*, 1996) and 45 (Mani and Krishnamoorthy, 1997c).

David and Regu (1995) enlisted 19 plants as host plants for SWF and they indicated mulberry as one of the most preferred hosts for SWF.

The SWF was also collected from *Euphorbia fulgens, Anacardium occidentale, Manihot utilisima, Solanum sp.* and *Psidium guajava* from Marayapuram in Kanyakumari district of TamilNadu during 1995 (David and Regu, 1995).

Mani and Krishnamoorthy (1997a) observed that the spiralling white fly is polyphagous and is known to attack more than 100 plant species including fruit trees, ornamentals, vegetables, shade trees and other crops such as tapioca, cashew, mulberry and cotton in penninsular India.

Douressamy *et al.* (1997) reported extensive host range which covers 27 plant families, 38 genera and more than 100 species including anona, banana, okra, egg plant, cassia, calophyllum, citrus, chilli, coconut, fig, guava, hibiscus, jasmine, mango, ocimum, rose, sapota, papaya and cotton.

2.3 Symptoms of damage

Nymphs and adults congregate generally on the lower surface of leaves (David and Regu, 1995), but sometimes on the upper surface also. In mulberry, they were mostly found congregated on the lower surface of leaves (Douressamy *et al.,* 1997) and suck the sap. The injury caused by heavy infestations were usually insufficient to kill the plants. However, phytotoxaemia associated with SWF damage are yellowish (Plate 2) speckling on the leaves, crinkled leaves and premature dropping of leaves (Plate 3) with sooty mould infection which interferes with photosynthesis (Mani and Krishnamoorthy, 1997a). Such leaves are unfit to feed the silkworm larvae. The infestation generally spreads from bottom to top. Young leaves mostly harboured less egg masses than matured leaves.

Besides the direct damage to different crops, the pest also causes indirect ill effects to human beings by its waxy secretion. Copious white waxy flocculent material secreted by nymph is readily spread elsewhere by wind and creates a very unsightly nuisance. The sticky honeydew carried by wind on the flocculent wax adheres to windows and cars and causes considerable annoyances. In Hawaii, complaints were received for allergies and dermatitis, although it is not known whether it is due to the adult whitefly or the flocculent material or both are responsible. (Anon, 1981; Kumashiro *et al.,* 1983 and Esguerra, 1987).

Plate 2. Symptoms of damage - yellowing of leaves

a - Healthy leaf b - Yellowing of leaf c - SWF affected leaf

Plate 3. SWF damage - premature leaf fall

David and Regu (1995) considering the widespread and severe incidence of SWF on wide variety of plants in Kerala and Tamilnadu cautioned that it is likely that soon this species may pose a threat to cultivation of economically important field and plantation crops in India.

A.dispersus was once suspected as being vector of the mycoplasma, causing coconut lethal yellow disease in Florida (Weems, 1971) but later it was proved to be a plant hopper related disease (Anon, 1981).

2.4 Natural enemies

A.dispersus is native of Caribbean Islands and majority of natural enemies reported on *A.dispersus* are from West Indies.

Though several species of parasites and predators were recorded on SWF, the aphelinid parasite *Encarsia haitiensis* (?) was found promising in all the islands. Successful control of SWF within three months after the release of adults of *Encarsia* was reported in Lanai Islands (Anon, 1981).

Fortutious biological control of SWF by accidental introduction of *Encarsia* along with host was also reported in African Countries. (M'Boob and Vanoers, 1994).

Next to aphelinid parasite, three Coccinellid predators were found to be important against *A.dispersus* (Waterhouse and Norris, 1989).

In India, eight predators were recorded on *A.dispersus.* Among them *Cryptolaemus montrouzieri* Muls, *Mallada astur* (Banks) and *Axinoscymnus puttarudriahi* (Kapur) appeared in more numbers at times (Mani and Krishnamoorthy, 1997b).

They also opined that indigenous predators including ladybird bettles (*Scymnus sp., Cryptolaemus montrouzieri,* Muls. *Menochilus sexmaculata* (Fab.) and green lace wing (*Chrysoperla sp.)* are unable to reduce the whitefly population. On the other hand, *Nephaspis oculatus* and *Encarsia haitiensis* may offer excellent control if they are imported from their native land. Recently an unidentified aphelinid parasite was reported in Kerala (Anon, 1997). The parasitic behaviour and extent of parasitism in regulating the population of SWF was not yet documented.

2.5 Management practices

A.dispersus is an exotic pest. With reference to management practices very little work has been carried out in India. For management of SWF, the IPM practices are necessary, moreover chemical alone is not sufficient to control the pest because of the waxy covering on the SWF may not reach the targetted site. Aleyrodid workers has started to develop different management practices for the suppression of the pest which includes mechanical, physical and chemical methods.

2.5.1. Mechanical methods

The management practices of this pest involves, collection and destruction of mulberry leaves with egg masses, nymphs and adults (Douressamy *et al.,* 1997).

Spraying water at the rate of 12.5 l/minute at 2 days interval for consecutive months resulted in 78.5 per cent control of nymphs and 86.4 per cent control of adults (Wen-Hungchich *et al.,* 1995).

2.5.1.1. Traps and Trap catches

For the application of effective control measures of any kind, knowledge of the whitefly population dynamics is essential. 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; Anon, 1995). Several workers reported a positive correlation between the trap catches and field population of Whiteflies (Melamed - Madjar *et al.,* 1982).

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.

Setting up of the yellow sticky traps @ 10/ acre was suggested to attract the adults and for monitoring (Douressamy *et al.*, 1997).

2.5.2 Physical methods

Spraying of Fish Oil Rosin Soap (FORS) 4% in the early morning would minimise incidence of SWF (Douressamy *et al.*, 1997).

A simple method for trapping large numbers of SWF by coating a transparent cover around a 2 feet emergency lighting tube with vaseline was suggested by Srinivasan and Mohanasundaram (1997).

2.5.3 Chemical methods

Various synthetic chemical and non chemical (Botanicals) insecticides were evaluated for the control of *A.dispersus*.

Use of chemicals like thiometon, dimethoate and phosphamidon can help to reduce the pest population to some extent. Use of chemicals like triazophos (0.04 per cent) + neem oil (0.05 per cent), phosalone (0.05 per cent) + neem oil (0.05 per cent) or acephate (0.05 per cent) + neem oil (No) (0.05 per cent) recommended for whiteflies can help to suppress the SWF population only to some extent. Moreover, migration habit of SWF from one field to the other, makes chemical control more difficult and expensive (Mani and Krishnamoorthy, 1997a).

Kavitha Kirubavathy *et al.* (1999) observed that the neem products as an effective chemical to control the SWF. Application of two per cent and three per cent neem oil (NO), two per cent Neem Seed Kernel Extract (NSKE) and two per cent and three per cent NO + NSKE were found to be effective in suppressing the adult whitefly population. For the control of nymphal population, two per cent and three per cent NO, three per cent NSKE and two per cent NO+NSKE were reported to be promising.

2.6 Effect of SWF infested leaves on economic characters of cocoon

Silkworm is domesticated over centuries, any deviation in terms of environmental changes in rearing room and leaf quality will ultimately affect the economic characters of cocoon.

Several workers reported the effect of feeding of homopteran pest affected leaves, on the nutritional indices of silkworm and consequent reduction in yield of cocoon. (Dhahirabeevi, 1989; Pradipkumar *et al.,* 1992).

Spiralling whitefly affected leaves were depleted with most two important nutrients viz., carbohydrate and protein content. Feeding the silkworms with affected leaves found to interfere with feeding physiology vis a vis cocoon characters and negative response of silkworm was observed in respect of growth and yield of cocoon (Narayanaswamy *et al.,* 1998).

2.7 Toxicity and persistence of insecticides against silkworm

Synthetic chemicals have problem of residue in mulberry leaves which inturn affect sensitive silkworm. Sufficient waiting period must be allowed to prevent mortality of worms (Yokoyama, 1962).

Safety period for utilization of insecticide sprayed leaves for silkworm rearing was found to vary from 10-15 days. (Ullal and Narashimhanna, 1981; Munivenkattapa *et al.*, 1989).

Feeding silkworm with dichlorvos 0.2 per cent, FORS 2.5 per cent and monocrotophos 0.2 per cent sprayed leaves required a safety period of 4, 9 and 14 days respectively (Dhahirabeevi, 1989).

Depending on the prevailing weather conditions, parathion 0.01 per cent spray dissipated within 13 days in mulberry and found safer to silkworm (Sengupta *et al.*, 1990).

Silkworms suffered insecticides poisoning when fed with leaf sprayed with 0.05 per cent monocrotophos even 40 days after spraying (Ali, 1995).

Fish oil rosin soap (Three per cent) had debilitating effect on silkworm even 20 days after spray (Palanidurai, 1996).

MATERIALS AND METHODS

CHAPTER - III

MATERIALS AND METHODS

3.1 Mass Culturing of SWF

Wooden wire mesh cage of 33.75 x 33.75 x 57. 25 cm size was used for laboratory culturing of SWF (Plate 4). This cage was provided with glass door in the front and on the upperside. Other three sides were provided with wire mesh.

Three months old K_2 mulberry variety plants which were grown on tumbler pots were placed inside the cage and the SWF adults were released over the leaves using a camel hair brush for egg laying. The cages were covered with gunny cloth during the day time to avoid dispersal of adults towards light.

The plants were kept inside the cage for one day. Next day they were transfered to mylar film cage for further development (Plate 5). Requisite number of whitefly adults were collected from mylar cages in the early morning hours using and aspiratior and used for various biological studies.

3.2 Biology of SWF on potted plant

The replaced potted mulberry plants with egg spirals present inside the mylar film cage were observed daily under 40x magnification. For each biological stage of the pest ten samples were observed and standard deviation

Plate 4. Mass culturing of spiralling whitefly.

Plate 5. Mass culturing of SWF inside the mylar cage.

(X ±) was worked out.To study the biology of the pest, the following parameters were recorded.

i. Number of eggs/spiral,

ii. Incubation period,

iii. Duration of different nymphal stages,

iv. Biometrical characters of different stages,

v. Emergence time and

vi. Adult longevity.

3.2.1 Biology of SWF on tree type

Mulberry crop is raised either as bushes or as tree types. In bush types, there were often change in the crop canopy due to pruning after every three months. On the contrary, tree type provide a permanent niche for the pest. To study the difference in life cycle of SWF between bush and tree type mulberry, a trial was laid out in Eastern block of Tamil Nadu Agricultural University (TNAU). Ten numbers of three years old K_2 tree type mulberry were selected for biological studies. On tree types, freshly laid SWF egg spirals were covered by a polythene cover. Obervations were recorded using a handlens.

Biological parameters listed in para 3.2. were also recorded in tree type mulberry.

3.3 Alternate Host

For identifying the alternate hosts of SWF, various crops present in and around the TNAU main campus were surveyed. More than 200 plant species were observed and the damage percentage were arrived. A standard evaluation system was developed based on the per cent leaf area damage. Level of incidence was categorised based on the leaf area damage.

Low	=	Less than 25% of leaf area damage by SWF with spirals and waxy materials.
Medium	=	26 to 50% of leaf area damage.
High	=	More than 50% of leaf area damage.

3.4 SWF population count in farmer's field

The SWF population level was assessed in the farmer's field at Avalpoonthurai village from 45 days after pruning of mulberry crop to till the completion of silkworm rearing (ie) 75 days after pruning. Population of different stages of SWF were counted from 10 randomly selected MR-2 bushes at weekly interval.

Number of spirals, nymphs and adults were counted from top, middle and bottom portions of the mulberry leaves and mean number of adults, spirals and nymphs per leaf were arrived at for each position.

3.5 Biochemical Analysis

Biochemical changes due to SWF feeding was studied in mulberry genotype K_2. Ten leaves were excised from the middle and bottom portions of the affected bushes. Same number of samples were collected from healthy bushes. The following biochemical analyses were taken up.

3.5.1 Estimation of moisture content

The percentage of moisture in different categories of leaves viz., top, middle and bottom leaves were estimated by taking fresh weight and dry weight of those leaves on fresh weight basis (AOAC, 1970).

3.5.2 Estimation of chlorophyll

The chlorophyll a, chlorophyll b and total chlorophyll were estimated as per Yoshida *et al.* (1971).

3.5.3 Estimation of total sugars

The total sugar content of the leaf samples was estimated as per Dubais *et al.* (1956) method.

3.5.4 Estimation of Nitrogen

The total nitrogen content in the leaf samples was estimated as per Jackson (1973) method.

3.5.5 Estimation of phosphorus

The total phosphorus content in the leaf samples was estimated by the method proposed by Pemberton (1945).

3.5.6 Estimation of potassium

The total potassium content in the leaf samples was estimated as per the method of Jackson (1973).

3.5.7 Estimation of total protein

Total protein content was calculated by multiplying with the constant factor of 6.25 to the total nitrogen content (Sadasivam and Manickam, 1991).

3.6 Effect of feeding SWF affected leaves on economic characters of silkworm

The walk-in-cages of size 6x6x6 feet were placed in the mulberry field (Plate 6). Twelve plants were maintained per cage. SWF adults were released daily for egg laying for a period of thirty days. After 20 days of egg laying, percentage of damaged leaves were worked out.

A laboratory experiment (Plate 7) was conducted to study the effect of feeding SWF affected leaves on the economic characters of silkworm larva and pupa. Silkworm cross breed PM x NB_4D_2 was used for the bioassay study.

Three replications each with 50 worms were maintained at 27 $\pm$ 1°C and 75-80 RH. The affected leaves were given to the worms from third instar to spinning. Larvae were fed fivetimes daily as per the standard procedure (Krishnaswami, 1978).

Treatments

T1 - Feeding the worms with 5% damaged leaves

T_2 - Feeding the worms with 10% damaged leaves

Plate 6. Walk-in cage with mulberry plants.

Plate 7. Experiment on economic loss

T_3 - Feeding the worms with 25% damaged leaves

T_4 - Feeding the worms with 50% damaged leaves

T_5 - Feeding the worms with 75% damaged leaves

T_6 - Feeding the worms with 100% damaged leaves

T_7 - Control (Healthy leaves)

Observations recorded on

1. Larval duration in days
2. Fifth instar larval weight (g)
3. Cocoon weight (g)
4. Shell weight (g)
5. Cocoon shell ratio (%)
6. Physiological and behavioural changes in silkworm larvae
7. Effective rate of rearing (ERR) (%)

3.7 Reaction of genotypes against SWF damage

Preliminary studies were made to know the reaction of twenty four mulberry genotypes available in the Department of Sericulture against SWF. In each genotype, 5 bushes were evaluated and in each bush all leaves were observed for 12 weeks period commencing from August 1st week to October 2nd week.

The following observations were recorded at weekly interval

1. No.of spirals/leaf (from top, middle and bottom positions)
2. Spatial distribution of spirals within the leaf

3. No.of eggs / spiral
4. No.of adults / leaf
5. No.of nymphs / leaf

Based on the observations the genotypes were categorised into four groups according to adult and egg population per leaf. They are 0.1-0.9; 1.0-1.5; 1.6-2.0 and more than 2.0 of population level.

3.8 Trap studies

3.8.1 Yellow sticky trap

The yellow cylindrical traps of size 15cm dia (Plate 8) were placed in the experimental field at different heights viz., 4 feet, 6 feet at the rate of four numbers per each height, to know the attractancy of SWF to yellow colour. The study was conducted for four months period from August to November. Castor oil was used as a sticky material over polythene sheet and replaced once in a week. Number of SWF adults trapped in the polythene sheet was recorded using a tally counter. Later the mean number of adults trapped per week and day were arrived at.

3.8.2 Light trap

To study the hourly attraction of SWF, a flourecent light trap (Plate 9) was placed in the mulberry field at a height of 120cm. In front of the light source, castor oil smeared polythene sheet was fixed over a bamboo frame. Trap catches were recorded from 6 pm to 6 am. Polythene sheet was replaced at hourly interval. Observations were recorded continuously for seven days

Plate 8. Yellow sticky trap

Plate 9. Light trap

and the mean number of adult SWF trapped per night and at bihourly interval were recorded.

3.9 Effect of insecticide against SWF

3.9.1 Laboratory Evaluation

Effect of insecticide against SWF adult was studied by dry film method using glass vials of 2cm dia (Gupta, 1984).

For this various concentrations viz., 3,6,12,24,48 and 96 ppm of five different chemicals viz., dichlorvos, fenthion, triazophos, malathion and phosalone were prepared by using acetone. In control, acetone alone was used. One milli litre of solution of various concentrations were placed inside the vials and these vials were rotated and dried to form a thin film. Inside the treated vials, 30 SWF adult were released. The experiment was replicated thrice. Their mortality were recorded at 20 minutes interval. LC_{50} and LT_{50} values were analysed and recorded (Finney, 1971).

3.9.2 Field evaluation - Ovicidal action

Ovicidal action of insecticides against SWF eggs was studied in a randomised replicated trial with three replications. Recommended dosage of various chemicals (tested in para 3.9.2.1) were sprayed over the leaves with spirals of SWF using a hand sprayer. After a week, the sprayed mulberry leaves were excised from the crop and $1cm^2$ area was marked. Total leaf area was scanned under 40 x magnification. Five samples were observed for each treatment and replication. Observations on per cent egg mortality / hatching were recorded. Brown or black eggs were considered as dead eggs.

3.9.2.1 Nymphal mortality

To study the efficacy of various synthetic and botanical insecticides against first and second instar nymphs of SWF, a randomised replicated trial was laid out in five years old mulberry garden (K_2) in field No 69 of Eastern block. The following nine chemicals were sprayed with three replications (Plate 10).

Treatment	Chemical/Botanical	Trade name	Concentration (%)
T_1	Dichlorvos	Nuvan	0.08
T_2	Malathion	Cythion	0.1
T_3	Phosalone	Zolone	0.07
T_4	Neem oil (NO) 60EC (A) TNAU formulation	-	3
T_5	Neem oil 60EC (B) TNAU formulation	-	3
T_6	NO + PO 60EC (C) TNAU formulation	-	3
T_7	Pungam oil (PO)	-	3
T_8	Neem seed Kernal extract (NSKE)	-	5
T_9	FORS	-	4
T_{10}	Control	-	-

Plate 10. Field view of insecticidal experiment.

The chemicals and botanicals were sprayed using a high volume knapsack sprayer. Wetting agent teepol @ 0.5ml/l was added for better adherence on the treated leaf surface. Control plot was sprayed with water.

The mortality of first and second instars nymphs were observed on one day, three days and five days after spraying. Five samples were observed @ 100 nymphs per treatment. Brown or black coloured nymphs was recorded as dead individual.

3.10 Residual toxicity of insecticides and botanicals against silkworm

A laboratory experiment was conducted to study the residual toxicity of insecticides in post treatment periods against third instar silkworm larvae (Plate 11).

For bioassay study multivoltine cross breed PM x NB_4D_2 was used. A set of three replications were maintained @ 50 larvae per replication.

The treated leaves excised from insecticide evaluation trial (3.9.2.1) were given once (first feeding) to the larvae on first day, thrid day, fifth day, seventh day and tenth day after spraying.

To know the antifeedant effect of the chemicals, leaf weights before and after feeding were recorded.

Plate 11. Larvae feeding on insecticide treated leaves.

The effect of treatment was assessed by recording larval mortality, weight of six days old fifth instar larva, cocoon weight, pupal weight, shell weight and shell ratio.

3.11 Natural enemies of SWF

For observing the natural enemies of SWF, two methods were followed.

i. *Insitu* sampling for predators

Randomly selected ten plants were observed at top, middle and bottom positions for the presence of grubs and adult stage of predator.

ii. Destructive sampling for parasitoids

The fourth instar nymphal stage of SWF was collected along with leaf. The waxy coats were removed using camel hair brush. Fifty nymphal stage were scanned for any colour change and for the presence of parasite emergence hole on the dorsal side of nymphs. Nymphs and pupae were later transfered to the screw cap vials for possible emergence of parasitoid. Percentage parasitism was worked out based on the emergence of SWF parasitoids.

3.12 Statistical analysis

The data collected from various experiments were statistically analysed using Completely Randomised Block Design (CRBD) as described by Panse and Sukhatme (1981). Duncans multiple Range Test (DMRT) was applied for comparing treatment means (Heinrich, *et al.,* 1981).

EXPERIMENTAL RESULTS

CHAPTER - IV

EXPERIMENTAL RESULTS

The experimental results derived from biology and management aspects of SWF are discussed in this chapter.

4.1 Biology of SWF on tree type and potted mulberry plants

The biology of SWF on two types of habitat are depicted in Table 1.

The number of eggs/spiral was more in tree type mulberry (21.0 $\pm$ 4.8) than on potted plant (11.8 $\pm$ 1.73). The incubation period of SWF on tree type was 5.1 $\pm$ 0.76 days. On the potted mulberry plant, incubation period was extended for another two days (7.3 $\pm$ 0.9 days). It was interesting to note that spiral pattern was very distinct only in respect of waxy secretion (Plate 12). Dissolving the waxy material with methyl alcohol revealed the random distribution of eggs than on circular pattern (Plate 13). First instar nymph was yellowish in colour (Plate 14) with distinct antenna, eyes and legs. It crawled over ventral side of the leaf insearch of suitable site and became sedantary.

Second instar was oval in shape and had many setae on the margins (Plate 15). Hypodermal glands were highly secretory and covered the third instar with white filaments (Plate 16). Fourth instar SWF which is referred

Table 1. Biology of SWF between tree type and potted mulberry plant

Biological character	Tree type Mean	Potted Plant Mean
No. of eggs/spiral	21.0±4.8	11.8±1.73
Incubation period (days)	5.1±0.76	7.3±0.9
I instar duration (days)	5.3±0.9	7.2±0.6
II instar duration (days)	6.3±0.43	7.6±0.71
III instar duration (days)	5.2±0.4	8.1±0.54
IV instar duration (days)	3.5±0.54	5.5±0.5
Nymphal period (days)	16.8±2.8	28.2±2.4
Total life cycle (days) (Egg to adult)	25.0±5.1	35.5±4.05
Adult longevity (days)	15.7±2.42	14.2±3.51

Plate 12. Egg spiral.

Plate 13. SWF eggs (10x)

Plate 14. First instar nymphs (10x)

Plate 15. Second instar nymphs (40x)

Plate 16. Dewaxed leaf with third instar nymphs (10x)

as pupa was covered with tuft of ribbon and hair like waxy filaments and protected the pest against adverse weather condition and natural enemies (Plate 17).

The duration of each instar on tree type mulberry was 5.3 $\pm$ 0.9, 6.3 $\pm$ 0.43, 5.2 $\pm$ 0.4, 3.5 $\pm$ 0.54 days compared to the duration of (7.2 $\pm$ 0.6, 7.6 $\pm$ 0.71, 8.1 $\pm$ 0.54 and 5.5 $\pm$ 0.5 days) for I, II, III and IV instars respectively under potted condition. The total nymphal period of SWF on tree type mulberry was completed in 16.8 $\pm$ 2.8 days than that of 28.2 $\pm$ 2.4 days on the potted plants. The total life cycle and adult longevity of SWF developed from tree type mulberry plant was 25.0 $\pm$ 5.1, 15.7 $\pm$ 2.42 days respectively. Whitefly reared in potted mulberry plant registered 35.5 $\pm$ 4.05 and 14.2 $\pm$ 3.51 days respectively.

In tree type, the pest completed its life cycle 10.5 days earlier than in potted plant type. A collective analysis of different biological parameters indicated that in tree type SWF adult longevity and fecundity were higher with shorter incubation and nymphal periods.

The biometrical characters (length and breadth) of each stage of SWF on two types of mulberry canopy are given in Table 2.

The length and breadth of the egg in tree type was 0.25 and 0.10 mm respectively. The eggs deposited by adult in tree was 0.039 mm taller than

Plate 17. Fourth instar nymph covered with waxy flocculences (10x).

Table 2. **Biometrical characters of SWF stages reared on tree and potted mulberry plants**

Stage		Tree type	Potted plant
Egg	L	0.252 ± 0.03	0.291 ± 0.04
	B	0.103 ± 0.07	0.102 ± 0.08
I instar	L	0.388 ± 0.06	0.342 ± 0.06
	B	0.182 ± 0.04	0.172 ± 0.06
II instar	L	0.638 ± 0.07	0.563 ± 0.08
	B	0.391 ± 0.08	0.321 ± 0.03
III instar	L	0.130 ± 0.02	1.04 ± 0.03
	B	0.781 ± 0.43	1.153 ± 0.05
IV instar	L	1.252 ± 0.43	1.153 ± 0.05
	B	0.814±0.43	0.781 ± 0.09

L= Length; B= breadth

that of the potted condition. There was no apparent difference in the breadth between the two types. The nymphs developed in tree types recorded 0.388 mm to 1.252 length and 0.182 to 0.814 in breadth for different stages.

There were 69.00 percent increase in length and 57.87 per cent increase in breadth from first to fourth instar in the tree type.

Biometric observations on different nymphal stages in potted condition also showed similar trend of progressive increase in length and breadth. A comparison between the nymphal stages reared on tree type and potted plants showed lower values for potted plants (excepting thrid instar nymph). The nymphal body size increased by 70.33 and 77.97 per cent in length and breadth respectively from first to fourth instar. Fourth instar which usually represent the pupal stage of whitefly can be distinguished by colour of the eye, shape and thickness. In the present observation also pupa can be differentiated with the rest of the nymphal stages by its red coloured eye (Plate 18).

4.2 Alternate hosts of SWF

Out of 200 species scanned for SWF incidence, 53 plant species were damaged by SWF. Among the 53 plant species, 28 recorded low level; 14 species under medium level and 11 recorded high level of damage (Appendix I).

Plate 18. Dewaxed leaf with fourth instar (pupa) (40x)

Enlisted 53 species belonged to twenty four families. Among them, plant species belonging to Euphorbiaceae, Solanaceae and Fabaceae were mostly preferred by SWF. Among the preferred families, Euphorbiaceae exhibited high level of susceptibility to SWF followed by Solanaceae, Fabaceae, Malvaceae, Asteraceae and Labiatae.

The observed plant species were categorised into field crops, horticultural crops, trees and weed species to study the preference pattern by SWF. Among the groups, SWF prefers to breed on horticultural crops which recorded 50.94 per cent of the total observed species, followed by weeds, trees and field crops which accounts for 22.64, 15.09, 11.32 percent respectively.

4.3 SWF Population level in farmer's field

The mean number of egg spirals present on the mulberry leaves over weeks at top, middle and bottom positions were 7.24, 5.72 and 2.74. Similarly number of nymphs present on top, middle and bottom positions recorded were 20.3, 26.62 and 10.3 respectively. The number of adults present on top, middle and bottom positions were 5.42, 4.8 and 2.12 respectively.

Spatial distribution of spirals showed higher population on the top leaves (7.24) followed by middle (5.72) and bottom (2.74) (Fig.1). Similar trend was noticed in respect of adult also (Fig.2). Contrary to the above two stages, the distribution of nymphal population was more in middle portion (26.2) followed by top (23.0) and bottom (13.3) (Fig.3).

Fig.1. SWF spirals at weekly interval in Avalpoonthurai village

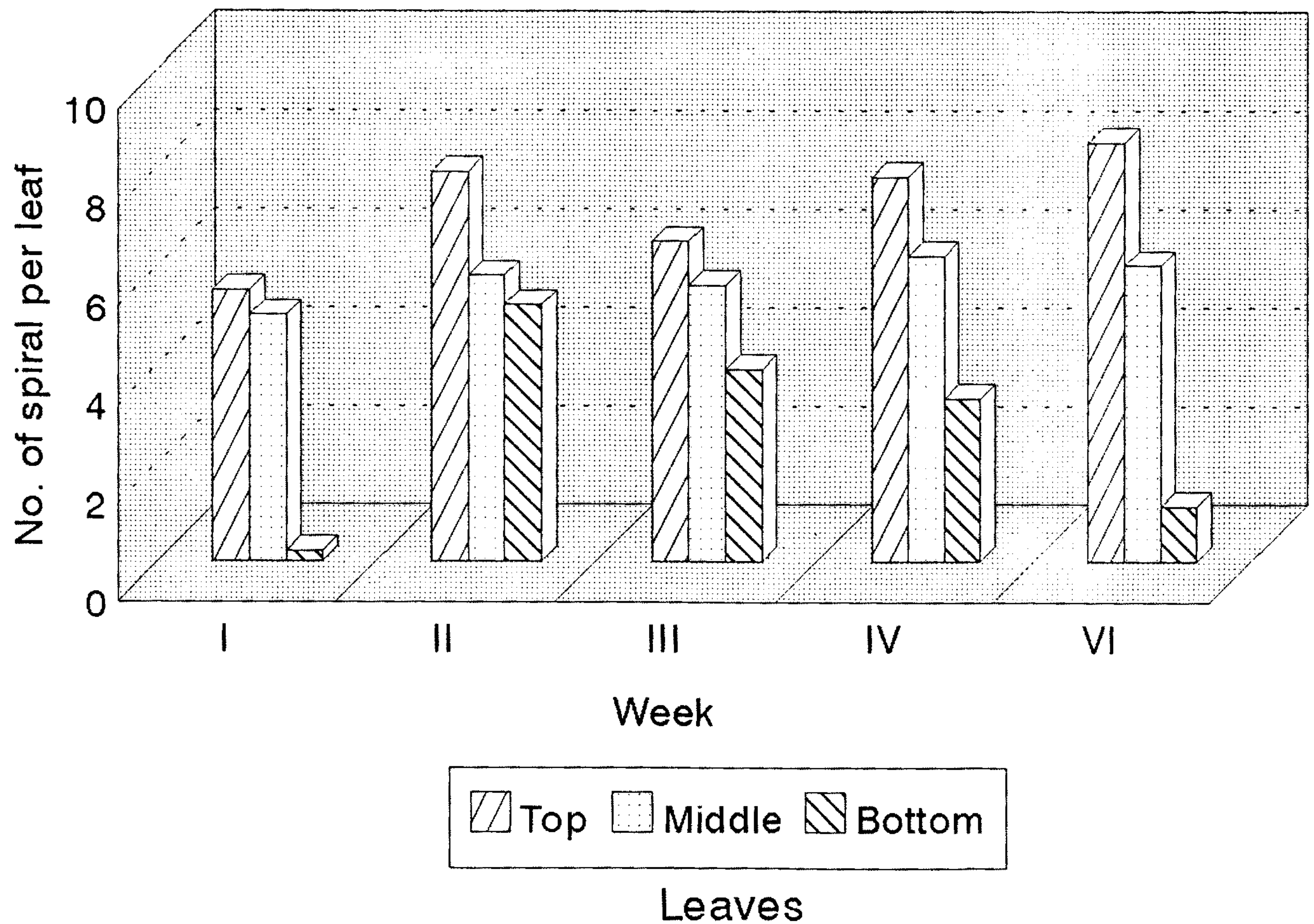


Fig.2. SWF adult population at weekly interval in Avalpoonthurai village

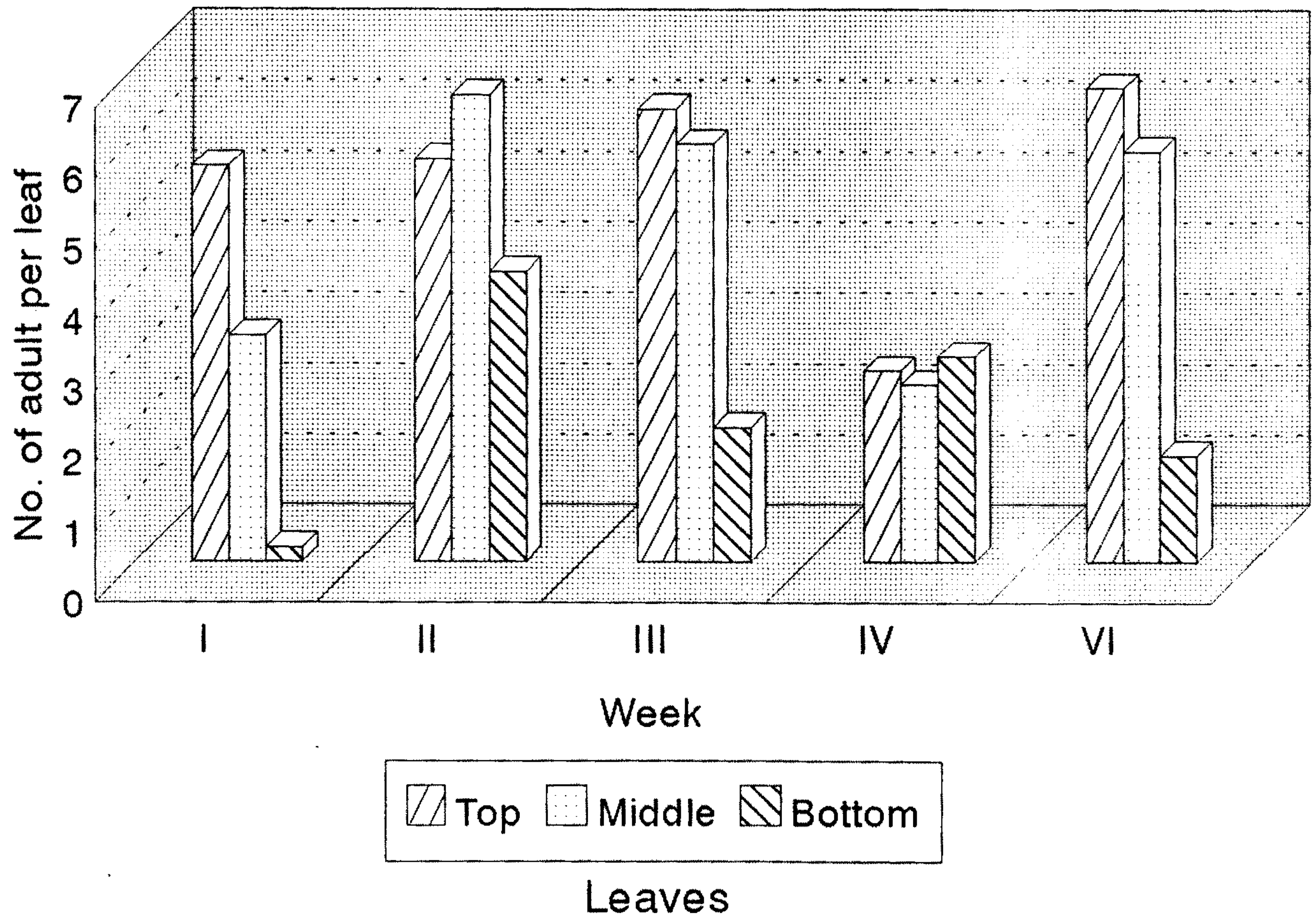
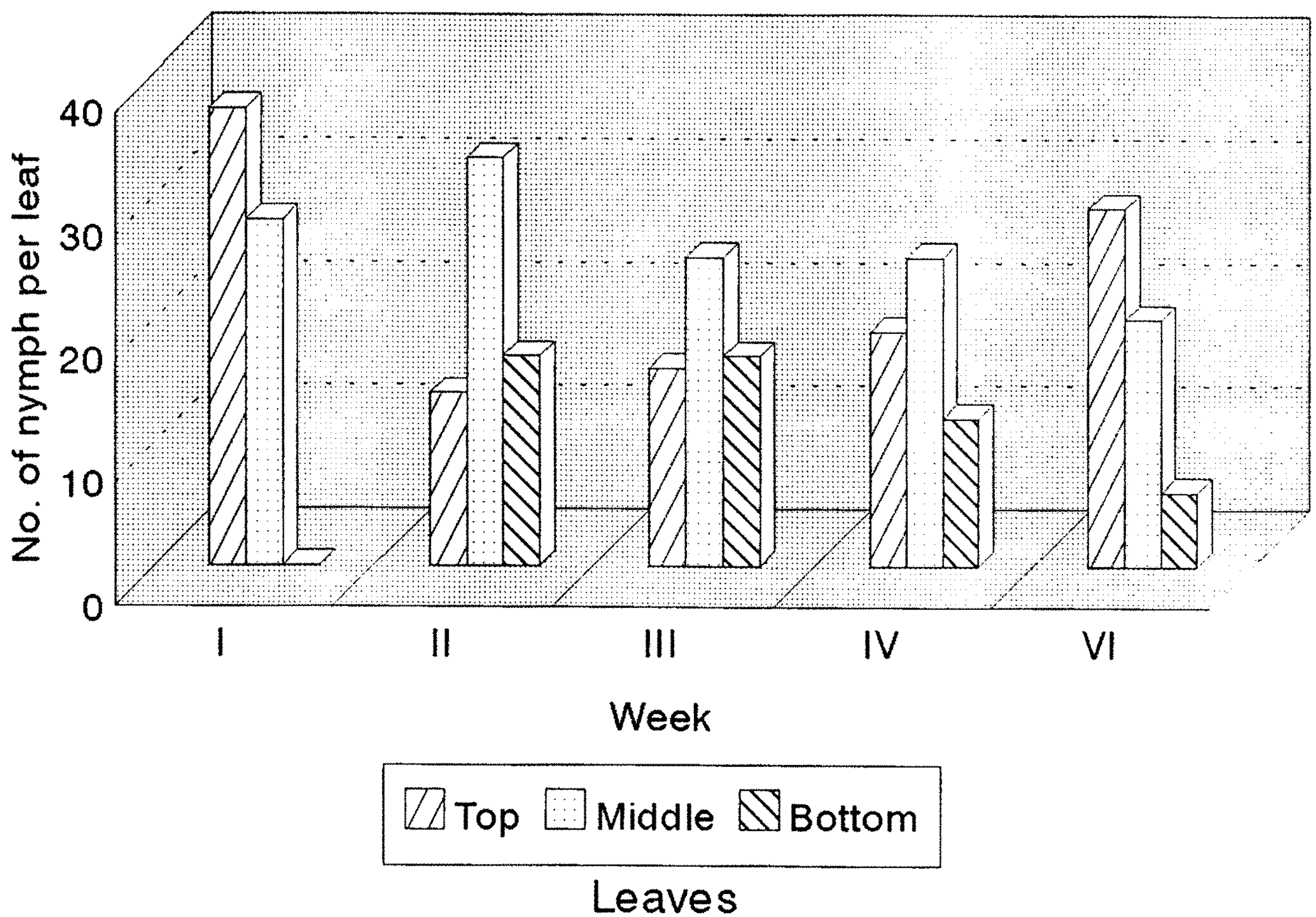


Fig.3. SWF nymphal population at weekly interval in Avalpoonthurai village



In situ population monitoring of different stages of SWF indicated that increase in number of spirals and adult stages were noticed from first week to second followed by a decline in subsequent weeks. Nymphal stages were higher in the first period (32.5) followed by reduction in subsequent periods (Fig.4).

4.4 Biochemical analysis

Biochemical results of SWF affected leaves and healthy leaves are presented in the Table 3.

4.4.1 Moisture Content

The moisture content of the SWF affected leaves registered 61.7, 64.33. 68.73 per cent for top middle and bottom leaves respectively. On the contrary, healthy leaves recorded higher moisture content. Moisture level of 70.0, 72.6 and 69.8 percent were recorded in top, middle and bottom portion of leaves. In both the treatments, leaves at the middle portion of the bushes recorded higher moisture content followed by top leaves.

4.4.2 Chlorophyll

The chlorophyll a, chlorophyll b and total chlorophyll content were found lower in affected leaves, which recorded 0.14, 1.26, 1.01 mg/g respectively compared to healthy leaves 0.43, 4.30, 3.39 mg/g of leaf samples respectively.

Fig.4. SWF count at weekly interval in Avalpoonthurai village

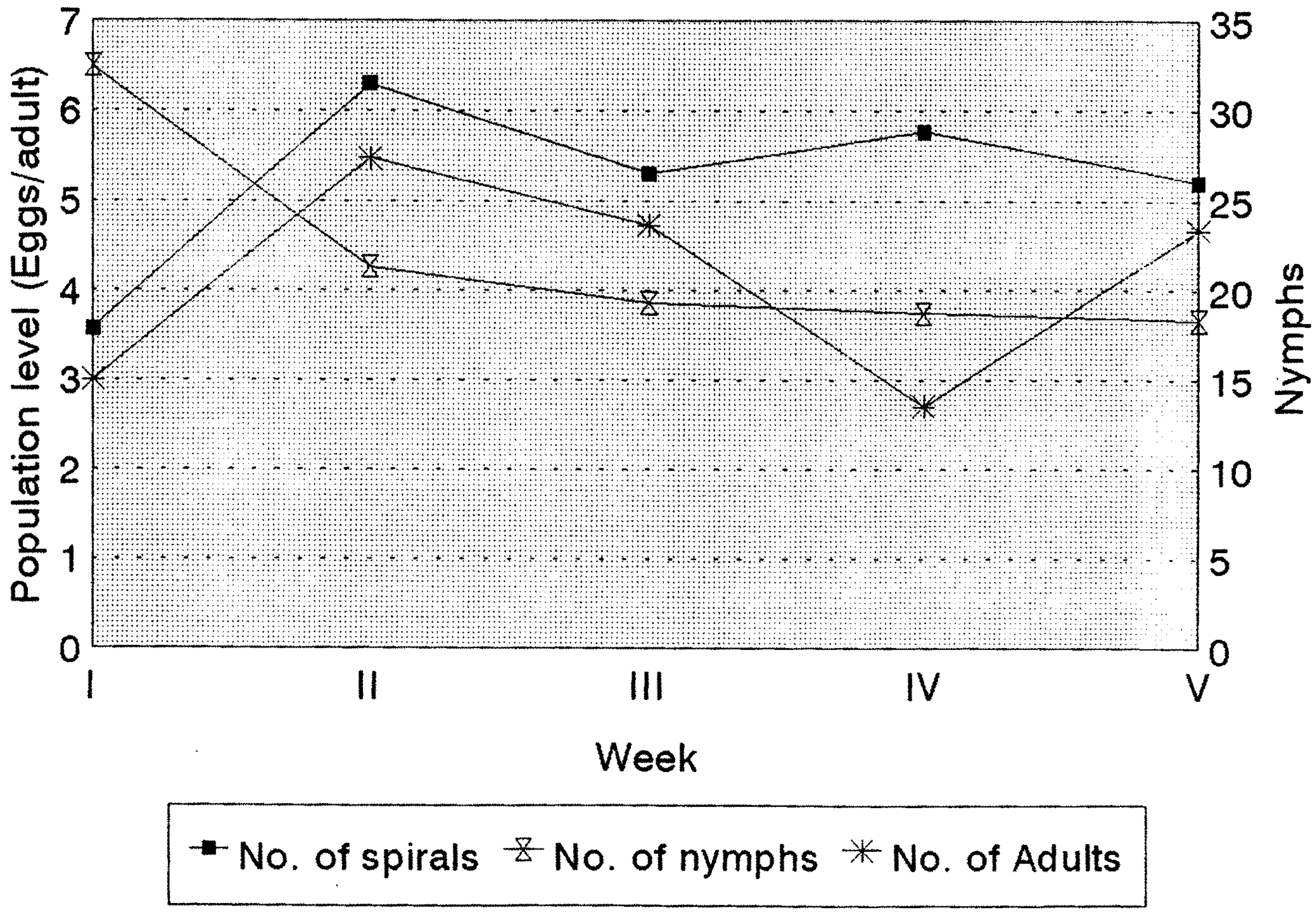


Table 3. Biochemical changes between healthy and SWF affected mulberry leaves

Biochemical parameter	Healthy	Affected
Moisture content top leaves (%)	70.0± 0.04	61.7±2.19
Moisture content middle leaves (%)	72.6 ± 0.16	64.33±0.09
Moisture content bottom leaves (%)	69.8 ± 0.28	68.73±0.09
Chlorophyll a (mg/g)	0.43 ± 0.28	0.14 ±0.032
Chlorophyll b (mg/g)	4.30 ±0.03	1.26 ±0.03
Total Chlorophyll (mg/g)	3.39±0.00	1.01±0.00
Total sugar (ug/g)	1000±0.00	562.5±0.00
Nitrogen (%)	3.32 ± 0.01	1.55±0.005
Phosphorus (%)	1.75±0.00	1.53±0.03
Potassium (%)	0.02±0.00	0.02±0.00
Protein (%)	20.78±0.44	9.68±0.20

4.4.3 Total Sugar

The total sugar content was found lower (562.5 ug) in SWF affected leaves as against 1000 ug/g in healthy leaves.

4.4.4 Total Nitrogen

The total nitrogen content of SWF affected leaves was found lower (1.55 per cent) as against 3.32 per cent in healthy leaves.

4.4.5 Total Phosphorous

The total phosphorous was found lower (1.53 per cent) in SWF affected leaves as against 1.75 per cent in healthy leaves.

4.4.6 Total Potassium

Both SWF affected leaves and the healthy leaves recorded same level of potassium content (0.02 per cent).

4.4.7 Total Protein

Drastic difference was noticed between healthy and affected leaves in respect of protein. It was found lower (9.68 per cent) in SWF affected as against 20.78 per cent in healthy leaves.

4.5 Effect of feeding SWF affected leaves on the economic characters of silkworm

Studies on the effect of feeding SWF affected leaves on the economic characters of cocoon did not derive any significant conclusion. Feeding the silkworms with mulberry leaves at different damage intensity level registered same level of biometric characters as that of healthy leaves and hence it is not set out in this chapter.

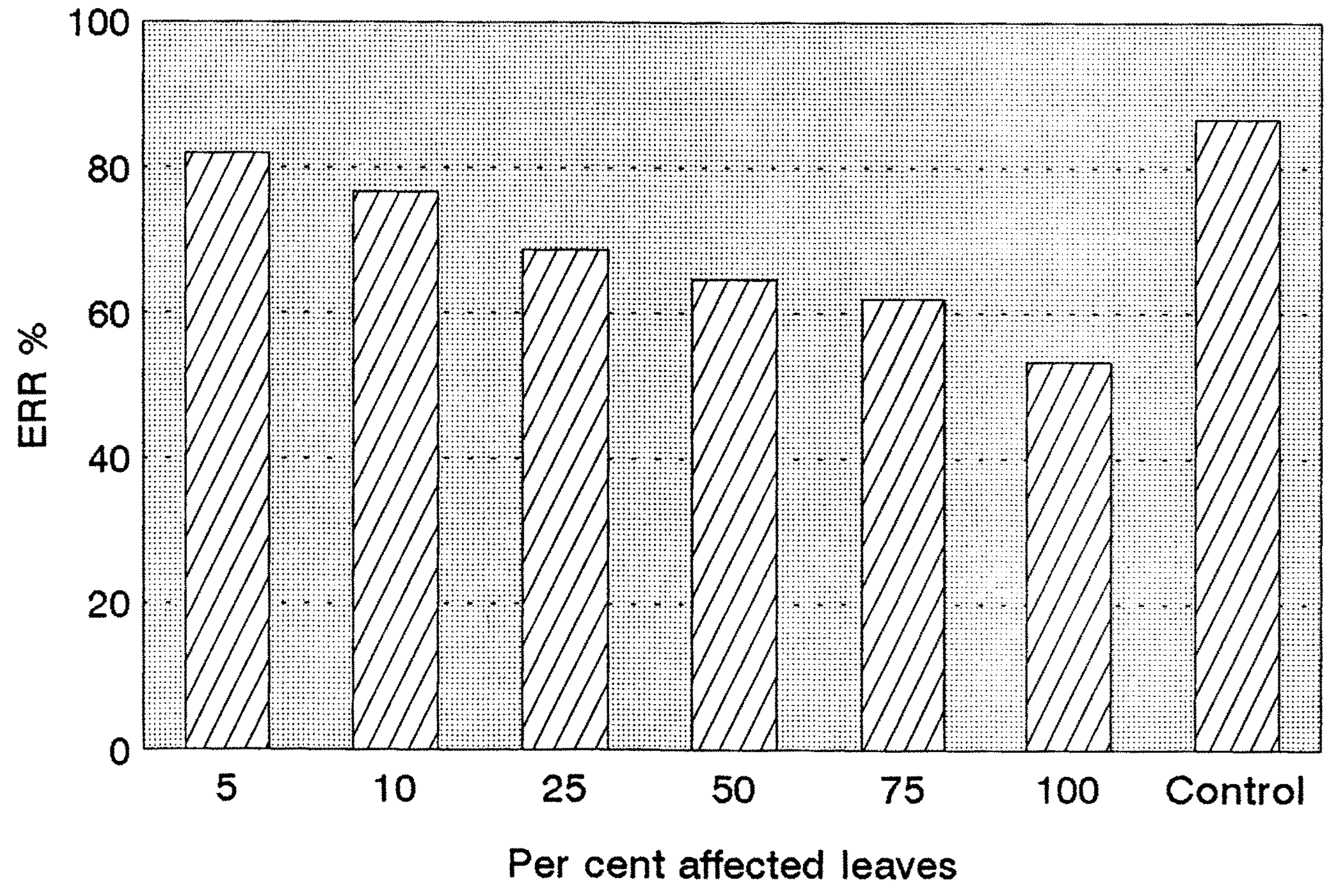
However there was significant difference among treatments in respect of effective rate of rearing (ERR). ERR was significantly lower in all the treatments fed with SWF affected leaves. Progressive decrease in ERR was noticed with increasing damage level. Leaves with 5,10,25,50 and 75 per cent damage registered 82.00, 76.66, 68.66, 64.66 and 62.0 per cent ERR respectively. Feeding the worms with 100 per cent affected leaves resulted in 53.33 per cent ERR. Feeding with healthy leaves recorded 86.66 per cent ERR (Fig.5).

4.6 Reaction of mulberry genotypes against SWF

Preliminary studies were made to know the reaction of various genotypes of mulberry against SWF. Based on the adult population, genotypes were categorised into four types.

The results of population level of SWF recorded over a period of 12 weeks showed that adult population per leaf was less than one in genotypes

Fig.5. Effect of feeding SWF affected leaves on the effective rate of rearing



S708, Berhampur, BC 259, S46, China white, DD, S39, S635 and C776, whereas genotypes S_{30}, S_{40}, S_{54}, V_1, C_{763} and C_{20} recorded moderate level of adult population (1.0-1.5). Genotypes M_5, E.Triploid, Palladam local, Kosen and S13 harboured more whiteflies (Table 4).

Susceptibility/reaction of a cultivable variety to a pest, depends on the morphological and chemical constituents, which influences the host selection and development of a pest species. The oviposition behaviour of SWF on different genotypes was studied under field condition and they were categorised into four groups. Number of spirals were minimum in S_{36}, C_{763}, China white, palladam local, S39, C776 and S_1 with lessthan one spiral per leaf. Genotypes S30, S_{708}, Berhampur, BC 259, S46, China white, DD, S635 harboured 1 to 1.5 spirals which are categorised into moderately resistant group. Higher spiral population were recorded in M_5, E.Triploid and S_{13}.

A collective appraisal of SWF adult population and spirals per leaf showed that genotypes S39 and China white recorded minimum adult and egg population as against higher popultion level in M_5, E.Triploid and S_{13} (Table 4 and 5). It is interesting to note that some of the genotypes like Palladam local and S36 which was attractive to adult whiteflies registered fewer eggs.

Table 4. Population level of adults per leaf in different mulberry genotypes

Sl.No	Adult per leaf (Mean)	Genotype
1.	0.1 - 0.9	S 708, Berhampur, BC 259, China White, DD, S 39, S 635, C 776.
2.	1.0 - 1.5	S 30, S 54, V1, C 763, C 20, S 40.
3.	1.6 - 2.0	S 36
4.	More than 2.0	M5, Erode Triploid, Palladam local, Kosen. S.13

Table 5. Population level of spirals per leaf in different mulberry genotypes

Sl.No	Spiral per leaf (Mean)	Genotype
1.	0.1 - 0.9	S 36, C 763, China White, Palladam local S 39, S 1, C 776.
2.	1.0 - 1.5	S 30, S 708, C 20, Berhampur, BC 259, DD, S 635.
3.	1.6 - 2.0	S 46, Kosen, S 40, RFS 135, V, S 54
4.	More than 2.0	M5, Erode Triploid, S13

4.7 Trap Studies

4.7.1 Yellow sticky trap

Yellow sticky trap catches of adult SWF at two different heights (four feet and six feet) at weekly interval was analysed statistically by paired t' test. The mean values of adults catches in four feet and six feet height yellow sticky traps were 10.65 and 31.67 respectively. The calculated t value prooved the significant difference between the height of the traps (Fig.6).

Mean number of catch per day recorded 0.35 adult to 2.32 in different weeks at four feet height. The trap at six feet height registered 1.78 to 7.07 adults and this has recorded higher catches than previous one. Though there were numerical differences in weekly catches, mean number of adults trapped per day was very minimal.

4.7.2 Light Trap

Light trap catches is presented in the Table 6. The mean number of adults trapped ranged from 0.00 to 996.50 in different periods. Number of adults trapped at bihourly interval was more in the early morning hours i.e 4-6 am and it accounts to 97.9 per cent of the total catch, followed by 2-4 am, 12-2 am and 10-12 midnight catches. They contributed 1.36, 0.60, 0.05 per cent to total catch. Adults were not trapped from 6 to 10 pm and the above periods are statistically on par with ten to midnight catch (Table 6).

Fig.6. Weekly catches of SWF adults on yellow sticky trap

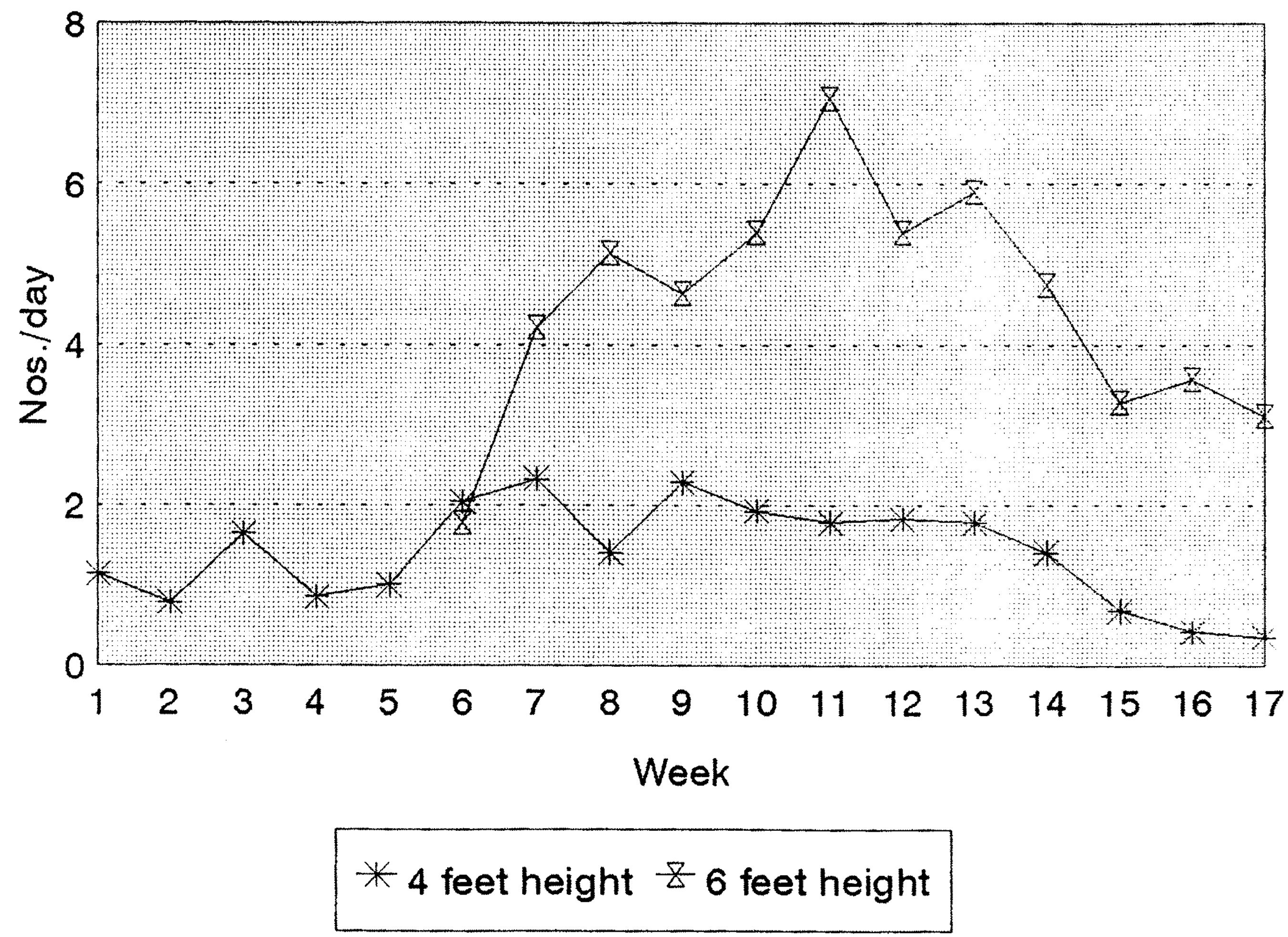


Table 6. Efficiency of light-trap against adult SWF

Time	**Mean no adults trapped**	**Percent catch**
6-8 pm	0.0 (0.7080) [a]	0.0013 (0.0716)[a]
8-10 pm	0.0 (0.7080) [a]	0.0013 (0.0716)[a]
10-12 pm	0.63 (0.0903) [a]	0.0569 (0.8320) [a]
12-2 am	6.00 (2.4910) [b]	0.6041 (4.3022) [b]
2-4 am	13.75 (3.7455) [c]	1.3604 (6.6393) [c]
4-6 am	996.50 (31.5255) [d]	97.9675 (51.8412) [d]

Figures in the parenthesis are transformed value of $\sqrt{x+0.5}$

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

4.8 Effect of insecticides against SWF

4.8.1 Laboratory study

The lab study on the effect of insecticides against adult SWF was conducted. The results of LC_{50} and LT_{50} are given below .

4.8.1.1 LC_{50}

The LC_{50} of dichlorvos, fenthion, triazophos, malathion and phosalone estimated by dry (thin) film method was 10.06, 12.88, 21.31, 32.97 and 21.26 ppm respectively (Table 7). But the slope function was more steep for fenthion (3.24) followed by dichlorvos (3.09), triazophos (2.91), malathion (2.15) and phosalone (1.85). The lower and upper fiducial limits of LC_{50} for dichlorvos were 8.42 and 12.01 while that of fenthion, triazophos, malathion and phosalone were 10.91 and 15.21, 17.87 and 25.41, 24.88 and 43.68, 16.19 and 27,92 respectively. Among the pesticides tested, the least quantity of the formulation required to cause 50 per cent mortality in the test population was dichlorvos (10.06 ppm) and highest with malathion (32.97 ppm).

4.8.1.2 LT_{50}

The LT_{50} of dichlorvos at 3,6,12,24, 48 and 96 ppm concentration ranged from 12.18 to 286.55 minutes, while that of fenthion, triazophos, malathion and phosalone were 21.91 to 307.38, 49.58 to 321.76, 44.39 to 349.52 and 52.87 to 203.63 minutes respectively (Table 8).

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Table 7. Probit analysis for dosage mortality response for adult SWF

Treatment		Regression equation y = A + B X	LC_{50} ppm	Fiducial limit	
				Lower	Upper
1.	Dichlorvos 76 WSC	1.90 + 3.09 X	10.06	8.42	12.01
2.	Fenthion 80 EC	1.39 + 3.24 X	12.88	10.91	15.21
3.	Triazophos 40 EC	1.12 + 2.91 X	21.31	17.87	25.41
4.	Malathion 50 EC	1.73 + 2.15 X	32.97	24.88	43.68
5.	Phosalone 35 EC	2.53 + 1.85 X	21.26	16.19	27.92

Table 8. LT_{50} for various insecticides against SWF

ppm	Dichlorvos				Fenthion				Triazophos				Malathion				Phosalone			
	Regression equation	LT_{50} (min)	Fiducial limit		Regression equation	LT_{50} (min)	Fiducial limit		Regression equation	LT_{50} (min)	Fiducial limit		Regression equation	LT_{50} (min)	Fiducial limit		Regression equation	LT_{50} (min)	Fiducial limit	
			LL	UL			LL	UL			LL	UL			LL	UL			LL	UL
3	-(4.45-3.84 x)	286.55	261.63	313.84	-(6.83-4.75 x)	307.38	285.09	331.42	-(12.34-6.91 x)	321.76	305.19	339.27	-(8.86-5.44 x)	349.52	326.49	374.18	-(17.19-9.61 x)	203.63	194.85	212.81
6	-(0.87-2.65 x)	161.38	140.40	185.49	-(3.63-3.58 x)	255.71	232.29	281.49	-(12.01-6.65 x)	360.17	342.04	379.26	-(20.40-10.75x)	230.03	221.58	238.80	-(7.93-5.84 x)	162.63	151.19	174.94
12	-(0.34-2.49 x)	73.55	61.67	87.71	-(5.18-5.11 x)	97.84	89.96	106.40	-(12.07-7.43 x)	197.70	187.27	208.70	-(20.75-11.22x)	197.48	190.05	205.21	-(12.24-8.08 x)	135.41	129.05	142.09
24	-(3.64-5.67 x)	33.31	29.65	37.42	-(2.09-4.18 x)	49.67	44.11	55.93	-(16.18-9.74 x)	148.91	142.68	155.42	-(11.07-7.76x)	117.69	111.58	124.12	-(6.63-6.15 x)	77.50	73.54	81.68
48	-(2.19-5.34 x)	22.16	18.81	26.11	-(6.29-7.46 x)	32.58	29.53	35.93	-(6.44-6.00 x)	80.56	74.65	86.93	-(6.48-5.97 x)	83.44	77.39	89.96	-(5.65-5.79 x)	68.95	64.88	73.27
96	-(0.11-4.50 x)	12.18	9.24	16.06	-(4.51-7.09 x)	29.91	19.27	24.91	-(9.37-8.47 x)	49.58	45.76	53.71	-(6.97-7.26 x)	44.39	40.46	48.72	-(8.60-7.89 x)	52.87	50.49	55.39

LL = Lower limit UL = Upper limit

Dichlorvos formulation required least time to kill half of the exposed SWF population at 6,12,24,48 and 96 ppm concentration whereas maximum time was taken by malathion at 3 and 48 ppm, triazophos at 6,12 and 24 ppm and phosalone at 96 ppm to produce 50 per cent mortality.

4.8.2 Field study

4.8.2.1 Ovicidal action of insecticides against SWF

Ovicidal action of different insecticides on SWF eggs is presented in the Table 9.

The ovicidal action was higher in dichlorvos (89.38 per cent). This was followed by malathion, phosalone and NO(B). All the three treatments statistically registered uniform level of toxicity. Insecticides NO(B), NO(A) NSKE and NO + PO (C) inflicted 50 to 60 per cent mortality and the order of efficacy in the increasing order was 50.99, 52.08, 53.56, 59.27 per cent for the above chemicals. Fish oil rosin soap and Pungam oil recorded less than fifty per cent mortality with a mean mortality value of 39.78 and 47.79 per cent respectively.

4.8.2.2 Nymphal mortality of SWF

The effect of insecticides on SWF nymphal mortality is set out in Table 10.

Table 9. Ovicidal action of insecticides against SWF eggs.

Treatment	Dose (%)	Percent mortality*
Dichlorvos	0.08	89.38a
Malathion	0.1	88.06a
Phosalone	0.07	82.96a
NO (A)	3	53.56bc
NO (B)	3	59.27b
NO + PO (C)	3	50.99bc
PO	3	39.78d
NSKE	5	52.08bc
FORS	4	47.79cd
Mean	62.6574	

Means followed by common letter are not significant different at 5% level by DMRT.

* Corrected mortality (Abbott's)

NO - Neem Oil
PO - Pungam Oil
NSKE - Neem Seed Kernal Extract
FORS - Fish Oil Rosin Soap

The mean nymphal mortality was higher in malathion (93.10 per cent) followed by phosalone and dichlorvos. All the three treatments are significantly on par in their efficacy. Chemicals like FORS, NO (B), NO(A), NO + PO(C), PO and NSKE recorded uniform level of toxic level and they recorded 90.63, 90.42, 42.43, 38.20, 37.92, 36.91, 24.65 and 23.97 per cent mortality of nymphs and they are statistically uniform in their effect. Pungam oil and NSKE spray registered 24.65 and 23.87 percent mortality.

Analysis of the interaction effect indicated that mean mortality level in different period did not show much variation. Synthetic chemical inflicted higher percentage of mortality than plant products and they were uniform in thier efficacy from 72 hours after spraying.

4.9 Residual toxicity of insecticides against silkworm larvae

4.9.1 Leaf Consumption

Leaf consumed by fifty siklworm larvae during post treatment periods is given in Table 11. Larvae fed with untreated leaves consumed more food material (17.82 g) followed by phosalone 16.743 g. Next to this, leaf consumption was more in FORS treated leaves with 14.988 g followed by NSKE, malathion, PO, dichlorvos, NO + PO, NO (A) and NO (B) which recorded 13.81, 12.495, 11.762, 10.614, 8.737, 7.094, 6.575 g respectively. The food consumption rate was found very lower in NO (B) (6.575 g) compared to control (17.825 g).

Table 10. Effect of insecticidal spray on SWF nymphal mortality

	Dose (%)	Percent Mortality *			Treatment Mean
		1 DAS	3 DAS	5 DAS	
Dichlorvos	0.08	89.732[b]	90.473[a]	91.064[a]	90.423[a]
Malathion	0.1	95.493[a]	94.408[a]	89.402[a]	93.101[a]
Phosalone	0.07	88.521[b]	92.952[a]	90.437[a]	90.637[a]
NO (A)	3	38.525[c]	38.890[b]	36.371[c]	37.929[b]
NO (B)	3	40.576[c]	37.439[bc]	36.597[c]	38.203[b]
NO + PO (C)	3	40.395[c]	32.713[c]	37.624[c]	36.910[b]
PO	3	24.19[d]	24.009[d]	25.769[d]	24.655[c]
NSKE	5	24.38[d]	23.136[d]	24.122[d]	23.879[c]
FORS	4	40.98[c]	40.987[b]	45.330[b]	42.434[b]
Days mean		53.64	52.779	52.968	53.130

In a column, means followed by a common letter are not signficantly different at 5% level by DMRT.

Comparision of significant effect	S.E.D	LSD(5%)	LSD(1%)
2-T*D	2.461	4.877	6.451

* - Corrected mortality (Abbott's)

DAS - Days after spray

Table 11. Effect of feeding insecticides treated leaves on silkworm food consumption (g)

Treatment	Dose (%)	Days after spraying 1	3	5	7	10	Treatment Mean
Dichlorvos	0.08	9.037f	9.517g	9.707g	12.123g	12.687h	10.614g
Malathion	0.1	11.217d	11.507e	11.730e	13.797e	14.223f	12.495e
Phosalone	0.07	16.273b	16.810b	16.910b	16.380b	17.343	16.743b
NO (A)	3	4.420h	5.280i	6.210i	7.883j	11.677i	7.094i
NO (B)	3	2.023i	3.640j	5.433j	8.377i	13.403g	6.575j
NO+PO (C)	3	6.310g	6.540h	7.217h	9.447h	14.170f	8.737h
PO	3	9.867e	10.037f	10.837f	13.387f	14.683e	11.762f
NSKE	5	11.827c	14.880c	13.130d	14.187d	15.027d	13.810e
FORS	4	17.630a	13.333d	13.523c	14.700c	15.753c	14.988c
Control		17.573a	17.603a	17.800a	18.030a	18.120a	17.825a
Days mean		10.618[c]	10.915[d]	11.250[c]	12.331[b]	14.709[a]	

* In a column, means followed by a common letters are not significantly different at 5% level by DMRT

Comparison of significant effect	S.E.D.	LSD (5%)	LSD (1%)
2-T* D Means	0.071	0.142	0.188

Gradual increase in food consumption were noticed from first day to tenth day after treatment. It increased from 10.618 to 14.709 g and each periods were independently superior over the other period.

4.9.2 Larval weight

Larval weight was higher in control (2.712 g) than in other treatments. The order of weight gain in decreasing order was dichlorvos (2.551 g) < FORS (2.541 g) < PO (2.523 g) < NSKE (2.405 g) < NO) (A) (2.285 g) < NO + PO (C) (2.325 g) < NO (B) (2.303 g) < malathion (2.140 g). Larval weight was very much lower in malathion 2.140 g compared to control 2.712 g. Feeding silkworms with phosalone treated leaves caused complete mortality of larvae even after 10 DAS. Consequently, there were no differences in the larval weight between the pre and post treatments and therefore it recorded O level of weight gain. The same trend was noticed in all the periods (Table 12).

4.9.3 Cocoon Weight

Cocoon weight was much lower (1.1577 g) in the NO (B) compared to control (1.3451), followed by NSKE, PO, malathion, NO + PO(C), NO (A), FORS and dichlorvos which registered 1.2001, 1.2113, 1.2233, 1.2405, 1.2575, 1.2921 and 1.3155 g weight respectively. In the present study, insecticidal treatments exerted toxic effect on the silkworm larvae only for a period of five days. Seven days after treatment cocoon weight were statistically uniform in all the treatments and it was on par with control. (Table 13).

Table 12. Effect of feeding insecticides treated leaves on silkworm larval weight (g)

Treatment	Dose (%)	Days after spraying 1	3	5	7	10	Treatment Mean
Dichlorvos	0.08	2.510b	2.533b	2.563b	2.543bc	2.603b	2.551b
Malathion	0.1	2.073e	2.050e	2.133f	2.217g	2.227f	2.140e
Phosalone	0.07	0.000f	0.000f	0.000f	0.000f	0.000f	0.000f
NO (A)	3	2.283d	2.300d	2.277e	2.297f	2.267f	2.285d
NO (B)	3	2.293d	2.320d	2.270e	2.313ef	2.317e	2.303d
NO+PO (C)	3	2.290d	2.330d	2.300e	2.347e	2.357e	2.325d
PO	3	2.480b	2.503b	2.517c	2.533c	2.530c	2.513b
NSKE	5	2.377c	2.427c	2.393d	2.403d	2.427d	2.405c
FORS	4	2.477b	2.517b	2.543b	2.583b	2.587b	2.541b
Control		2.710a	2.700a	2.710a	2.723a	2.717a	2.712a
Days mean		2.149a	2.168a	2.171a	2.196a	2.203a	2.177

* In a column, means followed by a common letters are not significantly different at 5% level by DMRT

Comparison of significant effect	S.E.D.	LSD (5%)	LSD (1%)
2-T* D Means	0.020	0.040	0.053

Table 13. Effect of feeding insecticides treated leaves on cocoon weight (g)

Treatment	Dose (%)	Days after spraying 1	3	5	7	10	Treatment Mean
Dichlorvos	0.08	1.5867a	1.2400ab	1.2373ab	1.2497a	1.2637a	1.3155ab
Malathion	0.1	1.2823bc	1.1657ab	1.1800ab	1.2083a	1.20800a	1.2233cde
Phosalone	0.07	0.0000e	0.0000c	0.0000c	0.0000b	0.0000b	0.0000f
NO (A)	3	1.2143bcd	1.2667ab	1.2590ab	1.2673a	1.2800a	1.2575bcd
NO (B)	3	1.0767d	1.1333b	1.1400b	1.2083a	1.2300a	1.1577c
NO+PO (C)	3	1.2167bcd	1.2367ab	1.2167ab	1.2560a	1.2767a	1.2405cd
PO	3	1.387cd	1.1500ab	1.2497ab	1.2520a	1.2660a	1.2113dc
NSKE	5	1.1900bcd	1.1900ab	1.1980ab	1.2040a	1.2187a	1.2001de
FORS	4	1.2900bc	1.2900ab	1.2970ab	1.2883a	1.2953a	1.2921abc
Control	-	1.3233b	1.3200a	1.3467a	1.3623a	1.3733a	1.3451a
Days mean		1.1319a	1.0992a	1.1124a	1.1296a	1.1484a	1.1243

* In a column, means followed by a common letters are not significantly different at 5% level by DMRT

Comparison of significant effect	S.E.D.	LSD (5%)	LSD (1%)
2-T* D Means	0.0759	0.1507	0.1994

4.9.4 Shell Weight

Though the toxic nature of the chemicals was apparent in cocoon weight on seventh day after spraying, the shell weight showed wide variation among treatments on the seventh day. On tenth day, the chemical can be categorised into four groups. Control registered higher shell weight (0.2567) and independently significant. This was followed by NO (A) (0.2300) and FORS (0.2167). All other chemicals were statistically on par and the shell weight ranged from 0.2000 to 0.2053 g (Table 14).

Among the period mean, leaves given on tenth day after spraying registered higher shell weight (0.199 g). All other periods are statistically on par and interfered spinning of larvae.

4.9.5 Shell ratio

Shell ratio was higher in control (18.913), followed by NO(B), NO + PO(C), NO(A), PO, and malathion which registered 17.434, 16.324, 16.083, 15.997 and 15.993 per cent respectively. The treatments PO and malathion are on par for the shell ratio followed by NSKE, FORS and dichlorvos which had 15.827, 15.039 and 14.358 respectively. Lowest shell ratio was registered in dichlorvos (14.358) compared to control (Table 15).

Table 14. Effect of feeding insecticides treated leaves on shell weight (g)

Treatment	Dose (%)	Days after spraying 1	3	5	7	10	Treatment Mean
Dichlorvos	0.08	0.1690g	0.1697e	0.1750f	0.1723e	0.2067d	0.1785d
Malathion	0.1	0.1870ef	0.1890d	0.1847e	0.1863d	0.2033d	0.1901bc
Phosalone	0.07	0.0000h	0.0000f	0.0000g	0.0000g	0.0000e	0.0000e
NO (A)	3	0.1967d	0.2033c	0.2060b	0.1623f	0.2300b	0.1997bc
NO (B)	3	0.2067c	0.2167b	0.2033bc	0.1757c	0.2053d	0.2015b
NO+PO (C)	3	0.2167b	0.2033c	0.1967cd	0.1953bc	0.2033d	0.2031b
PO	3	0.1800f	0.1927d	0.1893de	0.2033b	0.2067d	0.1944bc
NSKE	5	0.1860ef	0.1863d	0.1867e	0.1900cd	0.2000d	0.1898bc
FORS	4	0.1897de	0.1933d	0.1967cd	0.1907cd	0.2167c	0.1974bc
Control		0.2533a	0.2633a	0.2633a	0.2633a	0.2567a	0.2600a
Days mean		0.1785b	0.1818b	0.1802b	0.1739b	0.1929a	0.1814

* In a column, means followed by a common letters are not significantly different at 5% level by DMRT

Comparison of significant effect	S.E.D.	LSD (5%)	LSD (1%)
2-T* D Means	0.0041	0.0082	0.0109

Table 15. Effect of feeding insecticides treated leaves on shell ratio (%)

Treatment	Dose (%)	Days after spraying 1	3	5	7	10	Treatment Mean
Dichlorvos	0.08	13.787h	13.753i	13.777i	13.790g	16.683e	14.358h
Malathion	0.1	16.263d	16.180c	15.487f	15.450d	16.587f	15.993c
Phosalone	0.07	0.000i	0.000j	0.000j	0.000i	0.000j	0.000i
NO (A)	3	16.673c	15.990f	15.990c	12.863h	18.900a	16.083d
NO (B)	3	19.900a	18.587b	17.713b	14.103f	16.867d	17.434b
NO+PO (C)	3	18.233b	16.400d	15.737e	15.477d	15.773i	16.324c
PO	3	14.953f	16.633c	14.943g	15.990b	17.467c	15.997e
NSKE	5	15.413e	15.560g	15.890d	15.800c	16.470g	15.827f
FORS	4	14.757g	14.727h	14.477h	14.980c	16.253h	15.039g
Control		18.300b	19.507a	18.643a	19.580a	18.533b	18.913a
Days mean		14.828b	14.734b	14.266c	13.803d	15.353a	14.597

* In a column, means followed by a common letters are not significantly different at 5% level by DMRT

Comparison of significant effect	S.E.D.	LSD (5%)	LSD (1%)
2-T* D Means	0.037	0.073	0.097

4.10 Natural enemies of SWF

4.10.1 Predators

Survey for the occurance of natural enemies of SWF revealed the association of predators rather than parasitoids. Four coccinellids, were recorded in field sampling. Among the coccinellids, population of *Axinoscymnus puttarudriahi* (Kapur) was higher followed by *Cryptolaemus montrouzieri* (Muls.), *Menochilus sexmaculata* (Fab.) and *Micraspis cardonii* (Weise.). At higher population density, chrysopid predator, *Mallada astur* (Banks) was recorded. All the predators were recorded between September 1998 and November 1998 during which the population level of SWF also higher (Table 16).

5.10.2 Parasitoid

Observations carried out for natural parasitism did not indicate the occurence of any parasitoid on SWF.

Table 16. Predator fauna associated with SWF in mulberry ecosystem

Predator	Family	Stage which feed on SWF	Period of abudance ('98 - '99)
Cryptolaemus montrouzieri **(Muls.)**	Coccinellidae	Grub and Adult	September
Axinoscymnus puttarudriahi **(Kapur)**	Coccinellidae	Adult	October, November
Menochilus sexmaculata **(Fab.)**	Coccinellidae	Grub and Adult	October, November
Micraspis cardonii **(Weise.)**	Coccinellidae	Grub and Adult	September
Mallada astur **(Banks)**	Chrysopidae	Grub	December '98, January '99

DISCUSSION

CHAPTER - V

DISCUSSION

Owing to the increasing importance of SWF as pests of many agricultural, horticultural and tree plant species, it has become an object of intensive investigations on an international scale. Spiralling whitefly has reached this climatic point by spreading into new geographic areas, attacking previously uninfested plant species, becoming acclimatised to new environments and becoming resistant to insecticides. Because of the above propositions, experiments were conducted on the ecology and management of SWF. Results of the above studies are discussed in this chapter.

5.1 Biology of SWF on tree mulberry and under screen house condition

Mean number of eggs/spiral was more in (21.0 ± 4.8) in tree mulberry than in potted mulberry plant. Spiralling whitefly is primarily a pest of perennial cropping system (Byrne *et al.*, 1990) and found to establish well in an undisturbed system than in annuals. Present investigations support the above results wherein potted plant with more succulent leaves resulted in lesser biological parameters. In the present investigation, eggs per spiral was 21.0 ± 4.8 in tree type and 11.8 ± 1.72 in potted plants. Wijesekera and Kudagamage (1990) also reported similar number of eggs of 14-26 eggs per spiral. Several whitefly workers established linear relationship between the preferred host and fecundity, adult longevity and developmental period (Boxtel *et al.*, 1978). Compared to eggs observed in potted plant, tree type harboured more eggs. This indicates that SWF prefers mostly the tree type which is rather undisturbed niche than potted plants. Present result is in agreement with the result of Lenteren and Noldus (1990) who reported that eggs per spiral of whitefly is highly variable and is influenced by species, cultivar and physiological state of the host plant, green house temperature and experimental set up like type of cage and frequency of whitefly transfer.

The colour of the SWF egg was light yellow with short pedicel. The egg shape was elongate and oval. Similar observation of elongated oval egg of whitefly was documented by Gill (1990). Whitefly eggs are sometimes sculptured and the sculptured patterns have been used to seperate species (Cohic, 1968). But in the present study SWF egg surface was smooth and glistening. This was also earlier reported by Paulson and Beardsley (1985). Whitefly eggs are broader at basal end, has a pedicel or stalk of varying length by which female attaches the egg to the host (Gill, 1990). Pedicel helps to extract water from the plant and replace the water loss from the egg surface (Wigglesworth, 1965). The SWF egg also had small pedicel to meet its water requirement. Because of the poor dispersal ability, most of the female whiteflies use the same leaf for oviposition and feeding. The spiral patterns which are often found on the leaves are the results of concurrent feeding and oviposition, whereby the female rotates around the point where these stylets are inserted into the leaf.

The waxy flocculences secreted by whiteflies over the egg and immature stages are protective in nature (Henderson, 1982). Spiralling whitefly forms mostly spiral pattern of waxy flocculences. Eggs were also laid even without waxy coating or mere secretion also deposited on leaf surface. Similar oviposition behaviour wherein deposition of waxy secretion alone on non host and inanimate surfaces without eggs was reported by Henderson (1982). In the present investigation also, mere waxy flocculence materials without eggs were observed on the mulberry leaf surface and on the wooden materials of cages.

Incubation period of SWF on tree type lasted for 5.1 $\pm$ 0.76 days and in potted mulberry plant it was protracted to 7.3 $\pm$ 0.9 days. Longer incubation period of SWF in peninsular India was also reported by Palanisamy *et al.* (1995) and Douressamy *et al.* (1997). In the present place of study, SWF underwent four instars. First instar nymph was light yellow in colour with antenna and three pairs of legs by which it crawl and select a suitable place for feeding. The first instar nymphal period was recorded as 5.3 $\pm$ 0.9 and 7.2 $\pm$ 0.6 days in tree type and in potted plant respectively. Waterhouse and Norris (1989) reported similar nymphal period of 6-7 days for first instar.

Second instar nymphal period registered 6.3 ± 0.43, 7.6 ± 0.71 days in tree type and potted mulberry plants respectively. Second instar nymph of SWF was oval in shape and has many setae. The nymphs of the Aleurodicinae have three distinct leg segments (Hargreaves, 1914), but in SWF, leg segments are not distinct.

Whitefly nymphs and pupae produce thin layer of transparent wax over the body surfaces (Gill, 1990). The shape may be spine like rays, ribbons or straight or curled cylindrical rods, aggregation of many wax rods and woolly flocculent or cottony wax composed of many very thin curled, randomly arranged threads.

Species under investigation produced two types of flocculent wax viz., thin and ribbon like. Wax plates in first two nymphal stages are not secretory in function (Russell, 1965). From third instar onwards wax glands are highly secretory and they are covered with wax secretion. In the present study, first two instars were free from waxy secretion, and only from third and subsequent stages, the waxy glass rods like secretion was observed which in line with earlier report of Waterhouse and Norris (1989). The shape of the nymph was oval with light yellow colour. Third instar nymphal duration of SWF on tree type and potted plants was 5.2 ± 0.4, 8.1 ± 0.5 days respectively. The above findings corroborates with the earlier result of Waterhouse and Norris (1989).

Fourth instar nymph or pupa can be identified by the colour of the eye and by the spines and waxy filaments on the marginal sides. The eyes of fourth instar are red coloured with oval shape body and thicker size than that of the other stages (Gill, 1990). This stage produced copious amounts of waxy filament through wax pores. The pupal instar duration under different habitat was found as 3.5 ± 0.54 and 5.5 ± 0.5 days for tree type and potted mulberry respectively. Comparatively in both types, fourth instar duration occupied lesser days than the other nymphal period.

Similar observation was recorded in the present investigation wherein entire pupae was completely covered with a mat of waxy material. At the time of adult emergence it formed 'T' shape exit rupture, from which adult emerged out. Initially the wings were not expanded and they were hyaline without powdery coat. Most of the adults emerged during the morning hours and for complete white powdery covering on wings, it took another few hours (Waterhouse and Norris, 1989). Present observations was also in agreement with the above statement and this was supported by the light trap data described elsewhere in this chapter.

The total lifecyle of SWF on tree type mulberry and potted mulberry was found as 25.0 ± 5.1, 35.5 ± 4.05 days respectively. This is in agreement with the earlier reports of Waterhouse and Norris (1989) and Mani and Krishnamoorthy (1997a). The reason for completing the lifecyle earlier potted plants by SWF is attributed to the poor nutritional quality than in tree type which forces it to complete earlier for the perpetuation of its progeny. This was further confirmed by the biometrical characters on the length and breadth of the various stages of SWF. Increased nymphal growth rate was observed in potted mulberry plant (70.33 and 77.97 per cent) for length and breadth respectively compared to tree type (69.00 and 57.87 per cent) respectively.

5.2 Alternate hosts of SWF

Distribution of whitefly in diverse biomes and their ability to reach and occupy varied habitats is the results of man's intervention. He transported the SWF to new localities through plants and altered the existing environments in ways that allow their survival in areas which normally would not support these population.

In a variable environment whiteflies may encounter several plant species that differs substantially in suitability for the phytophages. In the present investigation, SWF was recorded both in annual cropping system and in perennial cropping system. Polyphagy leads to higher incidence of migration among pest species as they move between hosts, many of which are annual hosts. This allows them to exploit the continuum of crop and weed host which is made available to them year around (Byrne *et al.,* 1990).

In support of the above ecological observations, SWF was recorded on weed hosts, perennial fruit crops, tree species and agricultural crops. The above observations was further strengthened in India by several workers (David and Regu, 1995; Prathapan, 1996; Ranjith *et al.*, 1996).

Leaf hairiness clearly influences host plant selection by whiteflies. Direct effects can be two fold; hairs can provide a physical barrier (Duffey, 1986) as well as a favourable micro climate (Willmer, 1986) for phytophages. In the alternate hosts list of SWF, twenty three plant species under Euphorbiaceae, Solanaceae and Fabaceae registered higher population than the others. This is attributed to the more pilose nature of the leaf lamina than in other families.

5.3 SWF Population count in farmer's field

Adult population assessment in farmer's field showed that they were mostly distributed on the top and middle portions of mulberry plants. The capacity of whiteflies to select specific feeding and oviposition sites leads to characteristic distribution pattern of whiteflies over plants.

Preference of a particular leaf, by whitefly in a particular plant for feeding depends on various factors. Number of trichomes (Duffey, 1986), thickness of the cuticle (Walker, 1985 and 1987), thickness of the leaf cuticle and vascular tissues (Kamp and Lenteren, 1981), stylet length (Pollard, 1955), protection against adverse conditions like temperature and nutritional factors (Noldus *et al.*, 1986) decide the oviposition behaviour and nymphal development. Most of the whitefly workers documented higher adult and nymphal population in the top canopy of the plant. Present investigation also supports the above results wherein SWF was mostly recorded on adaxial surface of the top and middle portion of mulberry bush. This was supported by Coombe (1982), who observed that the whiteflies often land on the upper leaf surface, start walking until they reach the edge of the leaf, then walk to the underside where they usually start probing immediately and lay eggs for further multiplication. The population of adult and nymphs were higher in the first observation followed by reduction in subsequent observations. This was attributed to the frequent disturbance of the plants by plucking the leaves for silkworm feeding in later periods and consequent dispersal of the whiteflies to nearby tapioca field.

5.4 Biochemical analysis

The mechanism contributing directly to crop loss has been studied in many crops, where direct loss of nutrients by feeding of insects appears to be the primary factor. The above hypothesis was proved positive in the present investigation also.

5.4.1 Moisture content

Moisture content of the SWF affected leaves showed lower values (64.92 per cent) than that of the healthy leaves. This was due to the depletion of the phloem sap by whitefly. Lloyd (1922) reported that homopteran insects damage crops, by extracting large quantities of phloem sap,which can result in more than 50 per cent yield reductions by moisture loss and subsequent leaf fall.

5.4.2 Chlorophyll

In this study, a decrease in the chlorophyll content of SWF affected leaves compared to healthy leaves was noticed. Chlorophyll content serves as an index for photosynthetic efficiency. The feeding injury caused by the sucking pest leads to reduction in chlorophyll content (Jayaraj, 1976). The decreasing chlorophyll contents in SWF infested leaves was attributed to the sap sucking nature of the pest (Douressamy *et al.*, 1997).

5.4.3 Total sugar

Total sugar content was also found to be less in SWF affected leaves compared to that of healthy one and this was supported by Suresh (1992) who recorded similar decrease in carbohydrate content due to sucking pest incidence. Palanidurai (1996) also reported the reduction of sugar content in coccid affected mulberry leaves.

5.4.4 Total Nitrogen, Phosphorous and Potassium

Total Nitrogen and Phosphorous content were less in SWF affected leaves than that of the healthy leaves. This was due to depletion of nutrition rich phloem sap by the pest.

Similar evidence exists for the mechanisms of loss in nutrients in perennial crops. Severely infested plantings by whitefly had lower level of leaf nitrogen, lower leaf dry weight and lower sucrose content than healthy plants. (Sandhu and Singh, 1963; Sandhu, 1966).

5.4.5 Total protein

Total protein content in mulberry leaf depends on the nitrogen content because protein synthesis was directly related with utilization of nitrogen. Reduction in nitrogen content leads to the decrease in protein content of mulberry leaf.

Collective analysis of biochemical studies clearly indicated the impact of SWF damage on mulberry. It can significantly affect the leaf quality directly, through the consumption of nutrients from the phloem sap.

5.5 Effect of feeding SWF affected leaves on the economic characters of silkworm

The ubiquitously severe impact on mulberry for which SWF is responsible in perennial cropping system, has contributed to a lack of studies quantifying the relationship between whitefly density and reduction in productivity in mulberry. In sericulture, quantifying the loss of mulberry leaf yield alone is not sufficient. This is to be related with silkworm rearing and subsequent cocoon yield. Mulberry silkworm, *Bombyx mori* is domesticated over centuries and good quality leaf alone contribute to 38.2 per cent in successful cocoon harvest. (Anon, 1989).

Feeding SWF affected leaves to the silkworm, did not give any significant differences in respect of economic characters of cocoon. However a significant difference was noticed in respect of effective rate of rearing. Mortality of silkworm was recorded in all the treatments due to feeding of mulberry leaves ridden with waxy material and *Capnodium* fungus. Any stress, interms of poor environmental condition either in rearing room or feeding with poor quality of leaves may lead to the outbreak of diseases in silkworm (Krishnaswami, 1978).

Besides infectious diseases, non-infectious diseases in silkworm may occur due to poor nutritional level and contamination of rearing room or food material coated with extraneous material. Dysentry associated symptom due to spinning mill dust and lint was earlier documented (Steinhaus, 1949). Feeding the silkworms with mulberry leaves, soiled with the dust formed in the room, showed a marked repulsion for such nourishment and accept it only in very small quantities (Paillot, 1930).

Poor ERR in the present investigation is attributed due to the feeding of affected leaves which are not nutritionaly superior and also contains various waxy materials secreted by nymphs and pupae of SWF. This might have caused deranged physiology (Steinhaus, 1949). Author also observed extended fifth instar larval duration due to feeding by waxy coated damaged mulberry leaves with subsequent baculovirus infection at the time of spinning. All these factors cumulatively contributed to poor ERR value.

5.6 Reaction of genotypes against SWF

Resistance is a natural phenomenon. Susceptibility is generally the result of insect specialization. Plant - insect co-evolution has resulted in a wide variation in host-plant suitability between and within plant species. Spiralling whitefly is an exotic pest and its preference to over array of host plants including the mulberry depends on the plant diversity in a given ecosystem. Periodical pruning of mulberry once in three months may be detrimental to the colonisation of pest and natural enemies and they may tend to move a stable host or in susceptible mulberry cultivar. All these hypotheses need detailed investigations with reference to mulberry ecosystem and will pave way for further studies on host plant resistance for ecological pest management.

Resistance in a given genotype is the results of antixenosis and antibiosis which often occur together. Cultivated mulberry varieties are mostly diploid. Triploid varieties are nutritionally superior to silkworm but higher trichome densities in triploids may be a favourable morphological trait for SWF oviposition. In the present investigation, 12 genotypes having low adult and egg population were identified.

Genotypes exhibiting moderate level of resistance is more durable and has the advantages for the development of stable agro-ecosystem, especially in the tropics (Budden hagen and Deponti, 1983; Kennedy *et al.*, 1987).

A total of 17 accessions with moderate level of damage was documented in the present investigation. The present study would help the future workers to make detailed research programme on host plant interaction studies on SWF.

5.7 Trap studies

5.7.1 Yellow sticky trap

Almost all whiteflies of economic importance have been sampled using yellow traps (Harlan *et al.,* 1979). The attraction towards yellow colour can be explained by the importance of laying its eggs on younger leaves, which are more yellowish than older leaves. Much work has been done to determine the best placement of traps in different systems and different crops (Ekbom and Rumei, 1990). Number of white flies attracted in traps varies with the species behaviour.

In the present study, though there was numerical difference between the height of the trap and the number of whiteflies attracted per day was very minimal, this may not be useful either for monitoring the pest population or for suppression using the trap. Behaviour of SWF in this regard seems to be an unique phenomenon than other aleyrodid members.

Adult SWF catches was more at six feet height compared to that of four feet height. This indicated the necessity of increasing the height of trap depending upon the phenology of mulberry. Present finding was further strengthened by the earlier report of Ekbom (1980), who reported that traps attracted more whiteflies when placed most appropriately at the top of the plants, as the insects fly up from their emergence leaves seeking new leaves for oviposition. Similar behaviour was observed in SWF also resulting in marginally higher catches, when trap was placed just above the canopy than at lower level.

5.7.2 Light trap

Traps are used as a tool for monitoring the population in a particular field and for the dispersal studies. Results of yellow sticky trap are not encouraging due to poor catches and therefore light trap was used to study the phototrophic behaviour of the whitefly.

Higher trap catches were recorded in flourescent light and maximum catches were noticed in the early morning. Between 4 - 6 am, the SWF adult catches were recorded more than 90 per cent of the total catch. Srinivasan and Mohanasundaram (1997) reported similar results of higher catches of SWF during early morning hours in Guava ecosystem.

Whiteflies generally emerge and migrate from the place of emergence to the young leaves in the early morning hours. Higher percentage of catches of SWF was mainly attributed to the emergence behaviour and phototrophic response of whiteflies to ultra violet rays (Lenteren and Noldus, 1990).

5.8 Effect of insecticides against SWF

5.8.1 Laboratory Study

Both LC_{50} and LT_{50} values of various insecticides with different concentrations against SWF adults revealed that dichlorvos was very effective to cause 50 per cent adult mortality quickly. This might be due to quick evaporation capacity and higher fumigant action of dichlorvos. Dichlorvos possessed triple actions viz., stomach, contact and vapour action with quick knock down effect on the targetted pest (David and Kumaraswami, 1982). Malathion, triazophos and phosalone required more time to inflict 50 per cent adult mortality and also recorded higher LC_{50}. This was supported by earlier work of Patil *et al.*. (1986). They observed higher efficacy of triazophos at lower population level of whitefly than at higher density. Under high population levels presence of adults were recorded even after spraying (Anon, 1985).

5.8.2 Field study

5.8.2.1 Ovicidal action of insecticides against SWF eggs.

Higher level of ovicidal action was recorded in synthetic chemical (93.10 per cent in malathion) when compared to plant products, which registered egg mortality ranging from 50 per cent and below. Synthetic chemicals have several auxillary compounds like solvent, emulsifier and surfactants etc, which might have influenced in dissolving the waxy covering over the eggs in the spirals. In the absence of above materials in botanicals they might have exerted little effect over synthetic compound. Efficacy of organophosphorous chemical against whitefly immature stages were earlier reported by many workers (Jayaraj *et al.*, 1986; Sellammal *et al.*, 1981; El-Bashir, 1974).

Fish oil rosin soap mainly acts as a physical barrier and has asphyxiant action against sedentary stages of homopteran species. Low level of ovicidal action in FORS treatment is attributed due to the inability of the physical poison to dissolve the waxy coating on the eggs and to form thin film of layer around chorion of SWF eggs.

Among botanicals, neem oil formulations were found more effective than others. Neem oil act as a more sensitive compound to homopterous insect (Schmutterer, 1990). Similar effect was also observed by Kavitha Kirubavathy *et al.* (1999). They reported neem products as an effective chemical against SWF.

5.8.2.2 Nymphal mortality

Synthetic chemicals viz., malathion, dichlorvos and phosalone caused higher nymphal mortality of first and second instar nymphs and they were on par in their efficacy. Sidhu and Dhawan (1986) reported the adulticide action of phosalone than on nymphal and pupal stages in *Bemesia tabaci*. On contrary, in the present investigation, phosalone was more effective against nymphal stages of SWF than the adults.

Fish oil rosin soap was moderate in its efficacy. First two nymphal stages are not clothed with waxy secretion and FORS has the ability to act on these stages in a better way than on egg stage. Several workers documented the efficacy of FORS in suppressing the population of sedentary pests (Palanidurai, 1996). Even during the rainy days Singh and Rao (1979) observed higher whitefly nymphal mortality (83.0 per cent) in FORS spray.

An analysis of interaction between botanicals and post treatment mortality indicated that low level of mortality in all the botanical formulations, which ranged from 24.12 to 45.33 per cent. This might be attributed due to the higher photo degradation nature of the plant products and often warrants repeated spraying (Schmutterer, 1990). Persistence of toxicity by botanicals for an ephemeral period of five to seven days in mulberry ecosystem was earlier reported by Dhahira beevi (1989).

5.9 Residual toxicity of insecticides against silkworm

5.9.1 Leaf Consumption

Silkworm larvae fed with insecticides treated mulberry leaves recorded lower food consumption than that of untreated leaves. Similar feeding behaviour of silkworm in insecticidal treatment was reported by Quadri (1973). Silkworm consumed fewer quantity of mulberry leaves in neem oil sprayed leaves because of the antifeedant effect. Schmutterer (1990) found that neem products found to possess deterrent, and antifeedant effects.

Gradual increase in leaf consumption from first day to 10th day after spraying, indicated the degradation nature of pesticides (Schmutterer, 1990) and 10 DAS the leaves were residue free and found safer for feeding silkworms.

Dhahirabeevi (1989) suggested a safe period of 4,9 and 14 days for chemicals dichlorvos, FORS and monocrotophos respectively.

5.9.2 Larval Weight

Bioassay studies on feeding insecticides sprayed leaves on the economic characters of silkworm larvae and cocoons, indicated the ill effects of synthetic compounds against sensitive domesticated species. Weight gain of the larva was higher in untreated followed by FORS and dichlorvos.

Fish oil rosin soap is a physical poison and will be toxic to pest species alone and hence it has not effected the organism at the next trophic level. Dichlorvos quickly dissipated within a day. Among the chemicals tested, phosalone was found highly toxic to silkworm. All the test insects died in all the periods and toxicity persisted even upto 10 days after spraying. Oral LD_{50} value for phosalone is 135 (David and Kumaraswami, 1989) and this value was found to be extremely toxic to silkworm and dissipation rate was also slow in respect of phosalone than other chemicals (Anon, 1987).

Weight gain by silkworm larvae was moderate in all the botanicals treatment. This is mainly attributed to the antifeedant action.

5.9.3 Cocoon Weight

Bombyx mori is a proovigenic insect and the amount of food ingested in larval stage is used to meet the energy requirement of pupal and adult stages. Larvae fed on the leaves from control plot registered higher cocoon weight followed by dichlorvos and FORS. Non-toxic nature of FORS, and higher degradation of dichlorvos was brought out in the above result.Cocoon weight was moderate in plant products treatment. This is attributed due to the interference in the feeding physiology of silkworm (Palanidurai, 1996).

Experiment also clearly brought out the toxic nature of different chemicals. Variation among treatments were noticed upto fifth day. From the seventh day onwards all treatments registered uniform level of cocoon weight. Studies indicated that a safer period of 10 days was ideal under mulberry ecosystem to avoid lethality in silkworms. Similar observation of toxic nature of chemicals and botanicals for ten days was reported by Ullal and Narasimhanna (1981); Munivenkattapa *et al.* (1989).

5.9.4 Shell weight

Spinning behaviour depends on the silkworm race, amount of reserve food in the larval body, multitude of factors like type of mountage and environmental condition. Nearly 60 per cent of the nitrogen in the mulberry leaves is used for silk synthesis. Any deranged feeding physiology will adversely affect the formation of foundation layer, shell and pelade layer (Hui, 1998).

Though there was not much significant difference in cocoon weight even on fifth day after spraying, shell weight recorded great deal of variation among different treatments and periods. Toxic nature of the chemicals interfered with shell formation upto seven days after spraying. Higher shell weight in control followed by lesser shell weight in chemicals and plant products was earlier reported by Palanidurai (1996) and Baskar (1997).

5.9.5 Shell ratio

Untreated control recorded higher shell ratio than other treatments. Inconsistent results were obtained in respect of shell ratio. This is attributed to wide variation between the pupal weight and shell weight.

5.10 Natural enemies of SWF

Classical biological control aims at limiting the exotic pest by its native natural enemy in the introduced land. Spiralling whitefly is native of Western hemisphere and it was introduced into several countries without its natural enemy. Initial survey in the present study indicated the occurence of native predators of polyphagous nature than parasites. Mostly Coccinellid predators and one Chrysopid were associated with SWF.

Several workers enlisted the natural enemies associated with SWF (Yoshida, 1982; Waterhouse and Norris, 1989; Nechols, 1982 and 1983) which include Encyrtid parasite and Coccinellids. Successful control of SWF by release of parasite *Encarsia haitiensis* was achieved in several islands. Next to parasite, Coccinellid *Nephaspis* was found promising (Nechols, 1982 and 1983).

Acceptance of an exotic pest as an alternate host by native parasites may prove successful in course of time. The pest was introduced into India during 1994 and native predaceous coccinellids viz., *Axinoscymnus puttarudriahi* (Kapur), *Mallada astur* (Banks), *Menochilus sexmaculata* (Fab.) and *Micraspis cardonii* (Weise.) were found to accept this species as one of the prey insects.

Though number of protelean parasites were documented against SWF in West Indies, in the present investigation no parasite was found associated with SWF in Tamil Nadu. Survey conducted at Kerala bordering Tamil Nadu reported the occurence of a native *Encarsia* Sp (Anon, 1997).

Since the pest was introduced into Tamil Nadu from Kerala, there is a chance of establishing native *Encarsia* sp in Tamil Nadu also in course of time. Intensification of survey in future may identify newer native *Aphelinid* spp or importation of exotic natural enemy *Encarsia haitiensis* and integrating with several IPM components may be helpful in suppressing the SWF population in mulberry ecosystem.

SUMMARY

CHAPTER - VI

SUMMARY

Results on the various experiments conducted on the biology and management of spiralling whitefly are summarised below.

Biology of SWF on two different habitats indicated that multiplication rate was higher in the treetype of mulberry than in bush type.

Higher number of eggs per spiral and shorter life cycle were observed in tree type of mulberry. Life cycle was completed by 10 days earlier in tree type.

Eleven newer alternate hosts were identified for SWF. Plant species belonging to Euphorbiaceae, Solanaceae and Fabaceae were more susceptible to SWF attack.

Spiralling whitefly population in farmer's field showed higher colonisation of pest on the top and middle portion of the leaves than in the bottom leaves of mulberry.

Biochemical analysis of SWF affected leaves indicated reduced level of moisture content, chlorophyll, total sugar, total nitrogen, total phosphorous, and total protein content.

Feeding of SWF affected leaves to silkworms caused prolongation of larval period and mortality with lower ERR value.

Preliminary studies on the field reaction of 24 mulberry genotypes showed that, 12 genotypes with low level of adult and spiral population, 17 genotypes with moderate level of incidence and five genotypes with high level of population.

Yellow sticky trap was found ineffective in monitoring and controlling the whitefly population.

Light trap, attracted more adult whiteflies with a peak catch between 4 and 6 am.

Laboratory studies on the LC_{50} and LT_{50} values of different insecticides against SWF adults resulted in the lower LC_{50} and LT_{50} values for dichlorvos, indicating the toxic nature of the chemical compared to other chemicals.

Dichlorvos 0.08 per cent spray exhibited maximum level of ovicidal action followed by NO(B) 3 per cent formulation.

Nymphal mortality of first and second instar was found higher in malathion 0.1 per cent spray followed by FORS.

Feeding the insecticide treated leaves to silkworms, caused reduced leaf consumption, larval weight, cocoon weight, shell weight and shell ratio. A safer waiting period of 10 days are required to prevent lethality in silkworms.

In the mulberry ecosystem Coccinellid predator were more than the other groups, in regulating the population of SWF.

REFERENCES

REFERENCES

Abbott, W.S. 1925. A method of computing the effective insecticide. **J. Econ. Ent.**, **18**: 265-267.

Ali, S.M.A. 1995. Mealy bug infestation in mulberry. **Indian Silk, 33**: 15-16.

Anonymous. 1981. **Hawaii pest Report, 1**(5): 1-10.

Anonymous. 1985. Entomology Unit. AICRIP, APAU, Guntur.

Anonymous. 1987. **The Agrochemicals Hand book**. 2nd Edn. Royal Society of Chemistry. London. 569 p.

Anonymous. 1989. **A Guide for Bivoltine Sericulture** CSR & TI. Central Silk Board. Mysore.

Anonymous. 1995. Eco behavioural studies on the whitefly *Bemisia tabaci* (Gennadius) (Aleyrodidae : Homoptera) in poly crop ecosystems. **Project completion report 91-95**, Tamil Nadu Agric. Univ., Coimbatore.

Anonymous. 1997. **Annual Report**. Project Directorate of Biological Control. Bangalore. 86 p.

Association of Agricultural Chemist. 1970. **Methods of Analysis**. 9th Edn. Washington D.C.789 p.

Baskar, P. 1997. **Bioecology and management of California red Scale** ***Aonidiella aurantii*** **(Maskell) in Mulberry**. M.Sc. Thesis. Tamil Nadu Agric. Univ., Coimbatore.

Bemis, F.C. 1904. The aleyrodids, or mealy-winged flies, of California, with references to other American species. **Proc. US. Nat. Mus., 27**: 471-53.

Berlinger, M.J. 1980. A yellow sticky trap for whiteflies. *Trialeurodes vaporariorum* and *Bemisia tabaci* (Aleyrodidae). **Entomol. Exp. Appl., 27**: 98-102.

Boxtel, W.Van, J.Woets and Lenteren, J.C. Van. 1978. Determination of host plant quality of egg plant (*Solanum melongena* L.), Cucumber (*Cucumis sativus* L.), tomato (*Lycopersicum esculentum* L.) and paprika (*Capsicum annuum* L.) for the greenhouse whitefly (*Trialeurodes vaporariorum* (Westwood) (Homoptera : Aleyrodidae) **Mededelingen van de Faculteit Land bouwwetenschapeen Rijksuniversiteit Gent, 43**: 379-408.

Buddenhagen, I.W. and O.M.B. De Ponti. 1983. Crop improvement to minimize future losses to diseases and pests in the tropics. **FAO Plant Prot. Bull., 31**: 1-30.

Byrne, N.D., T.S. Bellows, JR and M.P. Parrella. 1990. Whiteflies in Agricultural systems. In: **Whiteflies : Their Bionomics, Pest Status and Management**. Ed. Gerling, D. Intercept Ltd., London. pp 227-261.

Chandrasekara, D.K. 1990. Effect of weather and natural enemies on population variation of the spiralling whitefly, *Aleurodicus dispersus* Russell (Homopetera - Aleyrodidae) **Res. Report Submitted to the degree of BSC University of Peradeniya,** 26 p.

Cohen, S. and V.Melamad - Madjar. 1978. Prevention by soil mulching of the spread of Tomato yellow leaf curl virus transmitted by *Bemisia tabaci* (Gennadius) (Homoptera : Aleyrodidae) in Israel. **Bull. Entomol. Res., 68**: 465-70.

Cohic, F. 1968. Contribution a'l'etude des aleurodes africains (4e Note). **Cahiers ORSTOM Serie Biologie, 6**: 63-143.

Coombe, P.E. 1982. Visual behaviour of the green house whitefly, *Trialeurodes vaporariorum*, **Physiol. Ent., 7** : 243-251.

David, B.V. and K.Regu. 1995. *Aleurodicus dispersus* Russell (Aleyrodidae - Homoptera) a whitefly pest new to India. **Pestology, 19**(3): 5-7.

David, B.V. and T.Kumaraswami. 1982. **Elements of Economic Entomology**. Ist. Edn. Popular Book Depot, Madras. 536 p.

Dhahirabeevi, N. 1989. **Investigations on the mealybug** *Maconellicoccus hirsutus* **(Green) (Homoptera : Pseudococcidae) and it's phytotoxemia in mulberry.** M.Sc. (Ag.) Thesis. Tamil Nadu Agrl. Univ., Madurai.

Douressamy, S., N.Chandramohan, N.Sivaprakasam, A.Subramaniam and P.C. SundaraBabu. 1997. Management of spiralling whitefly. **Indian Silk**, 15-16.

Dubais, M., K.A. Giller, J.K. Hamilton, P.A. Rebers and F.Smith. 1956. Colorimetric method for estimation of sugars and related substances. **Anal. Chem., 28:** 350-354.

Duffey,S.S. 1986. Plant glandular trichomes : their partial role in defence against insects. In: **Insects and the Plant Surface**. Edward Arnold. London. pp 173-183.

Ekbom, B.S. 1980. Traps for the discovery of whitefly infestations and something about the colour preferences of *Encarsia formosa.* **Vaxtskyddsnotiser, 44**: 115-120 (In Swedish).

Ekbom, B.S. and Rumei Xu. 1990. Sampling and spatial patterns of whiteflies. In: **Whiteflies: their Bionomics, Pest Status and Management** Ed. Gerling, D. Intercept Ltd., London. pp 107-117.

El-Bashir,S. 1974. Effect of some insecticides on immature stages on the cotton whitefly **Cotton Grow. Rev., 51**: 62-69.

Esguerra, N.M. 1987. The spiralling whitefly *Aleurodicus dispersus* (Russell) **Entomol. Bull., 1**: 1 p.

Finney,D.J. 1971. **Probit Analysis**. A statistical treatment of the sigmoid response curve. Cambridge Univ. Press, London. 318 p.

Gill, R.J. 1990. The morphology of whiteflies. In : **Whiteflies: their Bionomics, Pest Status and Management.** Ed. Gerling, D. Intercept Ltd., London. pp 13-46.

Gupta, D.S. 1984. Bioassay techniques for residue analysis. In : **Residue Analysis of Insecticides**. Haryana Agrl. Univ., Hisar. pp 57-64.

Hargreaves, E. 1914. The life history and habits of the greenhouse whitefly. **Ann. of Appl. Biol., 1**: 303-334.

Harlan, D., W. Hart, C.Garcia and J.Caballero. 1979. A yellow coffee lid trap for the citrus blackfly, *Aleurocanthus woglumi*. **The Southwestern Entomologist, 4**: 25-26.

Heinriches, E.S., S.Chelliah, S.L.Valencia, M.B. Arces, L.T. Fabellar, G.B. Aquino and S.Pickin. 1981. **Manual for Testing Insecticide on Rice**. IRRI, Philippines. 133 p.

Henderson, D.S. 1982. **Biological Aspects of *Aleurodicus dispersus* (Russell)**. M.Sc. Thesis, December, 1982. University of Hawaii. 52 p.

Hui, H.G. 1998. **Silk Reeling (Cocoon Silk Study).** Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi. 461 p.

Jackson, M.L. 1973. **Soil Chemical Analysis**. Prentice Hall private limited, New Delhi.

Jayaraj, S. 1976. The influence of the feeding by the leaf hopper *Empoasca flavescens* (F.) on transportation and moisture content of certain varieties of *Ricinus communis*. **Phytopathol., 57**: 121-126.

Jayaraj,S. A.V. Rangarajan, Sellammal Murugesan, G.Santharam, S.Vijayaraghavan and D.Thangaraj. 1986. Studies on the outbreak of whitefly, *Bemisia tabaci* (Genn.) on cotton in Tamil Nadu. In : **Resurgence of Sucking Pests - Proc. Natl. Symp.** Ed. Jayaraj, S. Tamil Nadu Agric. Univ., Coimbatore. pp 103-115.

Kajita, H., M.Samudra and A. Watto. 1991. Discovery of the spiralling whitefly, *Aleurodicus dispersus*. Russell (Homoptera : Aleyrodidae) from Indonesia with notes on its host plants and natural enemies. **Appl. Entomol. Zool., 26**(3): 397-400.

Kamp,R.J. Van Der and Lenteren, J.C. Van. 1981. The parasite - host relationship between *Encarsia formosa* Gahan (Hymenoptera : Aphelinidae) and *Trialeurodes vaporariorum* (Westwood) (Homoptera : Aleyrodidae). XI. Do mechanical barriers of the host plant prevent successful penetration of the phloem by whitefly larvae and adults? **Zeitschrift fiir Angewandte Entomologie, 92**: 149-159.

Kavitha Kirubavathy, Saranya and Mariamma Ninan. 1999. Neem for the management of whiteflies on tapioca. National symposium on Biological control of insects in Agrl., forestry, medicine and vet. Science. 21-22, Jan. 1999. **Abstracts and Souvenir.** Dept. of Zoology. Bharathiar University. 98 p.

Kennedy, G.G., F.Gould, O.M.B. De Ponti and R.E. Stinner. 1987. Ecological, agricultural, genetic and commercial considerations in the development of insect resistant germplasm. **Environ. Entomol., 16**: 327-338.

Kotikal, Y.K. 1982. **Studies on pests of mulberry** *Morus alba L.* **with special reference to the Bihar hairy caterpillar,** *Spilosoma obliqua* **Walker (Lepidoptera : Arctiidae).** M.Sc. (Ag.) Thesis. Univ. of Agric. Sciences, Bangalore.

Krishnaswami, S. 1978. **New Technology of Silkworm Rearing. Bulletin No. 2,** Central sericultural Research and Training Institute, Mysore, India.

Kumashiro, B.R., P.Y. Lai, G.Y. Funasaki, K.K. Teramoto. 1983. Efficacy of *Nephaspis amnicola* and *Encarsia* (?) *haitiensis* in controlling *Aleurodicus dispersus* in Hawaii. **Proc. Hawaiian Entomol. Soc., 24** :261-269.

Lenteren. J.C. Van and L.P.J.J. Noldus. 1990. Whitefly - plant relationships : Behavioural and Ecological aspects. In: **Whiteflies: their Bionomics, Pest Status and Management**. Ed. Gerling, D. Intercept Ltd., London. pp 47-90.

Lloyd, L. 1922. The control of the greenhouse whitefly (*Trialeurodes vaporariorum*) with notes on its biology. **Ann. Appl. Biol., 9** : 1-32.

M'Boob. S.S., and C.C.C.M.Vanoers. 1994. Spiralling whitefly *(Aleurodicus dispersus)* : a new problem in Africa. **FAO Plant Prot. Bull., 42** : 59-62.

Mani, M. and A.Krishnamoorthy. 1997a. Spiralling whitefly in horticultural crops. **The Hindu**, dt 23rd January, 1997. 28 p.

Mani,M. and A.Krishnamoorthy. 1997b. Discovery of Australian lady bird beetle (*Cryptolaemus montrouzieri*) on the spiralling whitefly (*Aleurodicus dispersus*) in India. **Insect Environ.**, **3**: 5-6.

Mani, M. and A.Krishnamoorthy. 1997c. Bionomics and Biological control of spiralling whitefly, *Aleurodicus dispersus* Russell (Aleyrodidae : Homoptera). (**Pers. Comm.**)

Narayanaswamy, K.C., T. Ramagowda, R.Raghuraman and M.S. Manjunath. 1998. Biochemical changes in Spiralling whitefly *Aleurodicus dispersus* (Russell) infested mulberry leaf and their influence on some economic parameters of silkworm (*Bombyx mori* L.) **Entomon.** (Inpress).

McKenzie, H.L. 1967. **Mealybugs of California**. : Univ. Calif. Press, Los Angeles. 525 p.

Megir-Gumbek. 1987. Study on control of whitefly. **Annual Report Research Branch Department of Agriculture for the year 1986-87**. pp 83-84.

Melamad-Madjar, V., S.Cohen, M.chen, S. Tam and D.Rosolio. 1982. A method for monitoring *Bemisia tabaci* and timing spray applications against the pest in cotton fields in Israel, **Phytoparasitica, 10:** 85-91.

Mound, L.A. 1962. Studies on the olfaction and colour sensitivity of *Bemisia tabaci* (Genn.) (Homoptera : Aleyrodidae). **Entomol. Exp. Appl., 5**: 99-104.

Munivenkattapa, M.V., M.V. Sampson, Pradipkumar and Y.R. Madhava Rao. 1989. **Mulberry and silkworm crop protection, Instructional cum-practical Manual**. Indian Council of Educational Research and Training, New Delhi. pp 82-83.

Nakahara, L. 1978. **Hawaii co-operative Economic Pest Report.** State of Hawaii, October 20.

Nechols, J.R. 1982. Entomology biological control. **Annual Report, 1982**. Guam Agricultural Experimental Station. pp 33-49.

Nechols, J.R. 1983. Entomology biological control. **Annual Report, 1983**. Guam Agricultural Experimental Station. pp 26-27.

Noldus, L.P., J.J., R.M. Xu. and Lenteren, J.C. Van. 1986. The parasite-host relationship between *Encarsia formosa* Gahan (Hymenoptera : Aphelinidae) and *Trialeurodes vaporariorum* (West wood) (Homoptera : Aleyrodidaze). XIX feeding - site selection by the greenhouse whitefly. **J.Appl. Ent., 101:** 492 - 507.

Paillot, A. 1930. Traite des maladies du vera soic. **G. Doin et Cie,** Paris. 279 p.

Palanidurai, S. 1996. **Ecology and Management of pink mealy bug** *Maconellicocus hirsutus* **(Green) in mulberry.** M.Sc. Thesis, Tamilnadu Agri. Univ., Coimbatore.

Palanisamy,M.S., K.S.Pillai, R.R.Nair and C.Mohandas. 1995. A New cassava pest in India. **Cassava News letter, 19**: 6-7.

Panse, K.G. and P.V. Sukhatme. 1981. **Statistical Methods for Agricultural Workers**. ICAR Publn., New Delhi. pp 187-202.

Patil V.L., N.Dieterich and A.G. Pawar. 1986. Paper presented in the Seminar on problem of whitefly on cotton, Pune, March 14.

Paulson, G.S. and J.W. Beardsley. 1985. Whitefly (Homoptera : Aleyrodidae) egg pedicel insertion into host plant stomata. **Ann. Entomol. Soc. Am.**, **78**: 506-508.

Pemberton, H. 1945. Estimation of total phosphorus. **J. Amer. Chem. Soc., 30**: 563-565.

Poinar, G.O. 1965. Observations on the biology and ovipositional habits of *Aleurocybotus occidus* (Homoptera : Aleyrodidae) attacking grasses and sedges. **Ann. Entomol.Soc. Am.**, **58**: 618-20.

Pollard, D.G. 1955. Feeding habits of the cotton whitefly, *Bemisia tabaci* Genn., (Homoptera : Aleyrodidae) **Ann. Appl. Biol., 43**: 664-671.

Pradip Kumar, M.K.P, Ramkishore, Noamani and K. Sengupta. 1992. Effect of feeding tukra affected mulberry leaves on silkworm rearing performance. **Ind. J. Seric., 31** : 27-29.

Prathapan, K.D. 1996. Outbreak of the spiralling whitefly *Aleurodicus dispersus* Russell (Aleyrodidae : Homoptera) in Kerala. **Insect Environ., 2**: 36-37.

Quadri, S.S.H. 1973. Some new indigenous plant repellents for storage pests. **Pesticides**, 18-20.

Ranjith, A.M., D.Sitarama Rao and Jim Thomas. 1996. New host records of the mealy whitefly *Aleurodicus dispersus* Russell in Kerala. **Insect Environ., 2**: 35-36.

Russell, L.M. 1965. A new species of *Aleurodicus douglas* and two close relatives (Homoptera : Aleyrodidae) **Florida Entomologist, 48**: 47-55.

Sadasivam, S. and A.Manickam. 1991. **Biochemical Methods**. (2 Edn.) New Age International Pvt. Ltd., Madras. 256 p.

Sandhu, J.S. 1966. Nature and extent of damage to sugarcane caused by whitefly (*Aleurolobus barodensis* Mask.) in punjab. **J. Res. Punjab Agri. Univ., 3**: 414-416.

Sandhu,J.S. and Singh, S. 1963. Studies on the biology of sugarcane whitefly - *Aleurolobus barodensis* Maskell. **Indian J. Sugarcane Res., 7**: 83-88.

Schmutterer, H. 1990. Properties and potential of natural pesticides from the neem tree, *Azadirachta indica*. **Annu. Rev. Entomol., 33**: 271-297.

Sellammal Murugesen and S.Chelliah. 1981. Efficacy of insecticides in the control of *Bemisia tabaci* (Genn.) a vector of the yellow mosaic virus disease on greengram. **Indian J. Agric. Sci., 58:** 583-584.

Sengupta,K., Pradipkumar, Murdhuza Baig and M.Govindaiah. 1990. **Hand Book on Pest and Disease control of Mulberry and Silkworm**. Published by **U.N. Econ. Soc. Commsn. for Asia and Pacific,** Bankok, Thailand. pp 29-30.

Sidhu, A.S. and A.K.Dhawan. 1986. Paper presented in seminar on problem of whitefly on cotton, Pune, March 14, 1986.

Singh S.P. and N.S. Rao. 1979. Field evaluation of rosin soap against soft green scale, *Coccus viridis* on citrus. **Indian J.Plant Prot., 8**: 208-209.

Srinivasan, G., M.Mohanasundaram 1997. A novel method to trap the spiralling whitefly, *Aleurodicus dispersus* in home gardens. **Insect Environ., 3**: 18.

Steinhaus. E.A. 1949. Diseases of nutrition and metabolism. **Principles of Insect Pathology**. McGraw Hill book Company, Inc. London. pp 69-82.

Suresh, R. 1992. **Studies on resistance of wild rices** (*Oryza* spp.) **to leaf folder** *Cnaphalocrocis medinalis* **(Pyralidae : Lepidoptera).** M.Sc. (Ag.) Thesis, Tamil Nadu Agric. Univ., Coimbatore.

Taylor, L.R. and J.M.P. Palmer. 1972. Aerial sampling. In: **Aphid Technology with special reference to the study of Aphids in the field.** Ed. Van Emden, H.R. Academic Press, London. pp 190-234.

Ullal, S.R. and M.N.Narasimhanna. 1981. **Hand Book of Practical Sericulture** 2nd Edn. Central Silk Board, Bombay. pp 46-47.

Walker, G.P. 1985. Stylet penetration by the bayberry whitefly, as affected by leaf age in lemon, citrus lemon. **Entomoliogia. exp. appl., 39** : 115-121.

Walker, G.P. 1987. Probing and oviposition behaviour of the bay berry whitefly (Homoptera : Aleyrodidae) on young and mature lemon leaves. **Ann. Entomol. Soc. Am., 80**: 524-529.

Waterhouse, D.F. and K.R. Norris. 1989. Biological control. **Pacific prospects - Supplement 1. ACIAR Monograph, No. 12,** 125 p.

Weems, H.V. 1971. *Aleurodicus dispersus* Russell (Homoptera : Aleyrodidae), a possible vector of the lethal yellowing disease of coconut palms. **Entomology circular**, Division of Plant Industry, Florida,Department of Agriculture and Consumer services. **111**: 1-2.

Wen Hung Chich, Hsu-Tungching, Hen-Hiounan, H.C.Wen, T.C. Hsu and C.N. Chen. 1994a. Effects of temperature on the development, adult longevity activity and oviposition of the spiralling whitefly *Aleurodicus dispersus* Russell (Homoptera : Aleyrodidae). **Chinese J. Entomol.**, **14**: 163-172.

Wen-Hungchich, Hsu-Tungching, Hen-hiounan, H.C.Wen, T.C.Hsu and C.N. Chen. 1994b. Supplementary description and host plants of the spiralling whitefly, *Aleurodicus dispersus* Russell. **Chinese J. Entomol., 14**: 147-161.

Wen Hung Chich, Hsu-Tungching, Hen-Hiounan. 1995. Yield loss and control of spiralling whitefly (*Aleurodicus dispersus*). **Journal of Agricultural Research of China, 44**: 147-156.

Wigglesworth, V.B. 1965. **The Principles of Insect Physiology.** 6th revised (Edn) Methuen, London. 465 p.

Wijesekera, G.A.W. and C. Kudagamage. 1990. Life history and control of spiralling whitefly *Aleurodicus dispersus* (Homoptera : Aleyrodidae). Fast spreading pest in Srilanka. **22-25 Quarterly Newsletter - Asia and Pacific Plant Protection Commission, 33**: 22-24.

Willmer, P. 1986. Microclimatic effects on insects at the plant surface. In : **Insects and the plant and the surface**. Edward Arnold. London. pp 65-80.

Yokoyama, T. 1962. **Synthesised Science of Sericulture.** Central Silk Board, Bombay. 62 p.

Yoshida, H.A. 1982. *Nephaspis amnicola* **(Wingo) (Coleoptera: Coccinellidae) a predatory enemy of** *Aleurodicus dispersus* **Russell. (Homoptera : Aleyrodidae)** M.Sc. Thesis. University of Hawaii.

Yoshida,S., D.A.Forno, J.H. Cock and K.A. Gemez. 1971. **Laboratory Manual for Physiological Studies of Rice.** IRRI, Phillippines. 43 p.

APPENDIX

Appendix I
Alternate hosts of SWF

S.No	Common Name	Scientific Name	Family	Damage level		
				L	M	H
I	**FIELD CROPS**					
1.	Lab lab	*Dolichos lablab* L. *var typicus*	Fabaceae	✤		
2.	Castor	*Ricinus communis* L.	Euphorbiaceae			✤
3.	Sun flower	*Helianthus annuus* L.*	Asteraceae			✤
4.	Cowpea	*Vigna sinensis*	Fabaceae	✤		
5.	Cotton	*Gossypium sp*	Malvaceae		✤	
6.	West Indian Turkey berry	*Solanum torvum Swartz*	Solanaceae	✤		
II	**HORTICULTURAL CROPS**					
A.	**Vegetable Crops**					
1.	Tomato	*Lycopersicon lycopersicum* (L.) Karst.	Solanaceae		✤	
2.	Brinjal	*Solanum melongena* L.	Solanaceae		✤	
3.	Chillies	*Capsicum annuum* L.	Solanaceae		✤	
4.	Bhendi	*Abelmoschus esculentus* (L.) Moench	Malvaceae		✤	
5.	Groundnut	*Arachis hypogaea* L.	Fabaceae	✤		
B	**Fruit Crops**					
1.	Guava	*Psidium guajava* L.	Myrtaceae			✤
2.	Banana	*Musa paradisiaca* L.	Musaceae			✤
3.	Papaya	*Carica papaya* L.	Caricaceae		✤	
4.	Ber	*Ziziphus mauritiana* Lamk.	Rhamnaceae	✤		
5.	Custard Apple	*Annona squamosa*L.	Annonaceae	✤		
C.	**Tuber crops**					
1.	Sweet potato	*Ipomoea batatas* (L.) Lamx.	Convolvulaceae	✤		
2.	Tapioca	*Manihot esculenta* Crantz	Euphorbiaceae			✤
3.	Taro	*Colacasia esculentai (L.) Schott*	Araceae	✤		
D	**Plantation crops**		Arecaceae			
1.	Coconut	*Cocos nucifera* L.	Palmae		✤	
2.	Wild rubber	*Hevea brasiliensis* (Willd. ex adr. de Juss.) Muell. - Arg.	Euphorbiaceae			✤
E.	**Ornamental crops**					
1.	Rose	*Rosa chinensis* Jocq.	Rosaceae	✤		
2.	Red-hot Cat-tail	*Acalypha hispida* Burmf.	Euphorbiaceae			✤
3.	Camel's foot tree	*Bauhinia purpurea* L.	Fabaceae		✤	

				L	M	H
4.	Paradise flower	*Euphorbia pulcherrima* Willd. ex klotz.	Euphorbiaceae	✤		
5.	Oleander	*Nerium oleander* L.*	Apocyanaceae	✤		
6.	Mast tree	*Polyalthea longifolia* (Sonner. Thw.)	Anonaceae			✤
7.	Chinese chaste tree	*Vitex negundo* L.	Fabaceae	✤		
8.	Frangipani	*Plumeria rubra* L.*	Apocyanaceae		✤	
9.	White frangipani	*Plumeria alba* L.*	Apocyanaceae		✤	
10.	Shoe-flower	*Hibiscus rosa sinensis*	Malvaceae	✤		
11.	Slipper flower	*Pedilanthus sp**	Amaranthaceae	✤		
III	**FOREST TREES**					
1.	Portia tree	*Thespesia populnea* (L.) Soland. ex Cort.	Malvaceae			✤
2.	Madre tree	*Gliricidia sepium* (Jacq.)	Fabaceae		✤	
3.	White Santol wood	*Santalam album* L.	Santalaceae	✤		
4.	Manila tamarind	*Pithacellobium dulce* (Roxb.)	Fabaceae	✤		
5.	Arjun terminalia	*Terminalia arjuna* L. (Roxb.)	Combretaceae		✤	
6.	Teak	*Tectona grandis* L.	Verbenaceae		✤	
7.	Pongam	*Pongamia glabra* L.	Fabaceae		✤	
8.	Banyan tree	*Ficus bengalensis* L.	Moraceae	✤		
IV	**WEEDS**					
1.	Black nightshade	*Solanum nigrumi* L.	Solanaceae	✤		
2.	Silverleaf Nightshade	*S. elaegnifolium* Cav.*	Solanaceae	✤		
3.	Indian Acalypha	*Acalypha indica* L.	Euphorbiaceae	✤		
4.	Congress weed	*Parthenium hysterophorus* L.	Asteraceae	✤		
5.	Kuppaikeerai❦	*Amaranthus viridis*	Amaranthaceae	✤		
6.	White dead nettle	*Leucas aspera* * (Willd.) spreng	Labiatae	✤		
7.	Horse purslane	*Trianthema portulacastrum* * L.	Aizoaceae	✤		
8.	Vettukkaayathalai❦	*Tridax procumbens* * Linn.	Asteraceae	✤		
9.	Australian asthma weed	*Euphorbia hirta* L.	Euphorbiaceae	✤		
10.	Devils Trumpet or Ummattam	*Datura metol* * L.	Solanaceae	✤		
11.	Holy basil or Thulasi	*Ocimum sanctum* L.	Labiatae	✤		
12.	Climbing brinjal	*Solanum trilobatum* *L.	Solanaceae			✤

* - New records

❦ - Vernacular Names

L - Low

M - Medium

H - High