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

RANI, J.

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Department of Agricultural Entomology
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM - 695 522

DECLARATION

I hereby declare that this thesis entitled **"Bioecology and Management of Spiralling Whitefly, *Aleurodicus dispersus* Russell (Homoptera : Aleyrodidae)"** *is a bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani.
21 -10-2004

RANI. J
(2002-11-39)

CERTIFICATE

Certified that this thesis entitled **"Bioecology and Management of Spiralling Whitefly, *Aleurodicus dispersus* Russell (Homoptera : Aleyrodidae)"** is a record of research work done independently by Ms. Rani.J (2002-11-39) under my guidance and supervision and that it has not previsouly formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani,
21-10-2004

Dr. N. Anitha
(Chairperson, Advisory Committee)
Assistant Professor
Department of Agricultural Entomology
College of Agriculture, Vellayani
Thiruvananthapuram

Approved by

Chairperson :

Dr. N. ANITHA
Assistant Professor,
Department of Agricultural Entomology,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

4.1.05

Members :

Dr. T. NALINAKUMARI
Associate Professor and Head,
Department of Agricultural Entomology,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

4.1.2005

Dr. K.D. PRATHAPAN
Assistant Professor,
Department of Agricultural Entomology,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

4.1.2005

Dr. V.A. CELINE
Associate Professor,
Department of Olericulture,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

4/1/05

External Examiner :

Dr G. MADHAVAN NAIR
Professor and Head (Rtd)

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Rani. S.

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LIST OF ABBREVIATIONS

a.i	active ingredient
%	Percentage
CD	Critical Difference
°C	Degree Celsius
cm	centimeter
mm	millimeter
et al	And others
Fig.	Figure
g	gram
DAT	Days after treatment
ml	millilitre
l	litre
Viz	namely
sp	species
No.	Number

Introduction

1. INTRODUCTION

Whiteflies are minute plant bugs mostly infesting the foliage of plants. They are so called because the adults are small, fly like, often dull white in colour. The powdery wax on their membranous wings gave the alternate name mealy wing. Whiteflies have received great attention throughout the world owing to their sudden appearance in large numbers on economically important crops. Both the nymphs and adults inflict damage to plants by sucking the plant sap. Adults are vectors of many plant viral diseases.

The spiralling whitefly native to Caribbean islands and Central America (Russell, 1965) has spread to North America, South America, Asia, Africa and Australia (Waterhouse and Norris, 1989; Martin, 1990; Lambkin, 1999; Ramani *et al.*, 2002). This insect is described as the spiralling whitefly due to its egg laying habits, the eggs being deposited on a loose spiral, with waxy outgrowths resembling fingerprints. The spiralling whitefly *Aleurodicus dispersus* Russell (Homoptera: Aleyrodidae) is one among the invasive pests in India. This pest might have been introduced into India from neighbouring countries through plant materials. Its presence in the country was first reported in 1994 from Kerala (Palaniswami *et al.*, 1995).

A. dispersus is a polyphagous pest known to attack about 500 plant species including many vegetables, fruits, ornamentals as well as numerous trees and shrubs. The population in the weeds and avenue trees serves as perennial source of infestation that can switch on to cultivated plants (Srinivasa, 2000; Mani *et al.*, 2004) Both nymphs and adults feed through stylet mouthparts with which they pierce plant tissue and suck phloem sap. They produce a large amount of sugar rich excreta termed 'honey dew' which support the growth of sooty mould on affected plants. Heavy infestations thus adversely affect their hosts both by excessive sap loss and through sooty mould interfering with photosynthesis. Copious amount of white flocculence secreted by the nymphs creates not only an

intolerable nuisance when dispersed by the wind but also gives an unsightly appearance to the plant.

Tomato is one of the preferred hosts of spiralling whitefly (Mani and Krishnamoorthy, 1999). The crop has tremendous potential in India. It is grown in an area of 0.32 million hectares with an annual production of five million tones (Reddy and Rao, 1999).

Management of this pest with chemical and cultural measures is difficult because of its broad host range and presence of heavy waxy flocculent material in the later nymphal instars (Mani and Krishnamoorthy, 2002). However the natural enemies have proved to be useful in suppressing the spiralling whitefly in its native places. In India several indigenous predators are found associated with this pest (Ramani *et al.*, 2002). These natural enemies do not control the pest completely and a low population continues to exist. This residual pest population should be lowered by some alternate methods. One important aspect in this regard is the use of botanicals that are ecofriendly, biodegradable and readily available.

Considering the above, the study was undertaken to

1. Generate basic information on the biology and host range of spiralling whitefly
2. Identify the natural enemies of the pest and to
3. Find out effective botanicals for the management of the pest.

Review of Literature

2. REVIEW OF LITERATURE

Aleurodicus dispersus as the name implies disperses at an alarming rate. In India the southern states served good habitat for the multiplication and spread of the pest. Literature related to the distribution, host range, biology, natural enemies and management practices of *A. dispersus* are reviewed here.

2.1 ORIGIN AND DISTRIBUTION

The spiralling whitefly *Aleurodicus dispersus* Russell (Homoptera: Aleyrodidae) is an introduced polyphagous pest. It is a native of the Caribbean Islands and Central America. The insect was first collected from coconut plantations in Florida (USA) and was described by Russell in 1965. The occurrence of the insect was noted on a wide range of host plants in Florida but was not regarded as a pest (Russell 1965).

A. dispersus got introduced to American Samoa and Guam and attained pest status (Firman, 1982). Later, Waterhouse and Norris (1989) reported this pest from Pacific Islands. In Africa, it was first reported from Ibadan in 1992 (Neuenschwander, 1994) and from Australia it was first reported by Lambkin (1999).

In Asia *A. dispersus* was first reported from Philippines (Martin and Lucas, 1984). Chandrasekara (1990) observed its presence from Sri Lanka. From Indonesia it was reported by Kajitha *et al.* (1991). Wen *et al.* (1994) identified *A. dispersus* from Taiwan and from Bangladesh it was reported by Scanlan (1995).

In India, *A. dispersus* was first noticed in Kerala on cassava plants at the Central Tuber Crop Research Institute, Thiruvananthapuram during 1993 to 1994 (Palaniswami *et al.*, 1995). David and Regu (1995) recorded this insect from Western ghats in wild tapioca. Later, the pest spread to all the five states in Peninsular India attacking numerous plant species

(David and Regu, 1995; Prathapan, 1996; Geetha *et al.*, 1998a,b; Muralikrishna, 1999; Sathe, 1999; Razak and Jayaraj, 2002; Baskaran and Reddy, 2003).

There is no concrete evidence regarding the mode of entry of the spiralling whitefly into India or from where it was introduced. Muniappan (1993) reported that it might have come from neighbouring country Maldives, through planting materials due to unrigid plant quarantine measures. According to Ranjith *et al.* (1996) it might have come from Sri Lanka.

2.2 HOST RANGE

Russell (1965) described 44 plant species as host plants of spiralling whitefly from Florida and Central and South America. Fifty plant species from Sri Lanka (Chandrasekara, 1990), 22 plant species from Indonesia (Kajitha *et al.*, 1991), 144 host plants from Taiwan (Wen *et al.*, 1994), and 104 plant species from Australia (Lambkin, 1999) were described as hosts of spiralling whitefly.

The host plant species of spiralling white fly reported from different parts of India are presented in Table 1.

Table 1. Host plants of spiralling whitefly in India

Sl. No.	Scientific Name	Family	State	Reference
1	*Barleria cristata* L.	*Acanthaceae*	Karnataka	Mani and Krishnamoorthy (1999)
2	*Barleria* sp.	"	"	Muralikrishna (1999)
3	*Crossandra undulaefolia* Salisb	"	"	Mani and Krishnamoorthy (1999)
4	*Crossandra* sp.	"	"	Mani and Krishnamoorthy (1999)
5	*Rhinacanthus* sp.	"	"	Mani and Krishnamoorthy (1999)
6	*Sanchezia nobilis* H.K.f.	"	Kerala	Ranjith *et al.* (1996)

7	*Amaranthus viridis* L.	Amaranthaceae	Karnataka	Srinivasa (2000)
8	*Gladiolus* sp.	Amaryllidaceae	Karnataka	Srinivasa (2000)
9	*Anacardium occidentale* L.	Anacardiaceae	Tamil Nadu, Kerala, Karnataka	David and Regu (1995), Prathapan (1996), Muralikrishna (1999)
10	*Mangifera indica* L.	"	Kerala	Palaniswami *et al.* (1995)
11	*Artabotrys odoratissimus* R.Br.	Annonaceae	Karnataka	Srinivasa (2000)
12	*Annona reticulata* L.	"	Tamil Nadu	David and Regu (1995)
13	*Annona squamosa* L.	"	Kerala Karnataka	Ranjith *et al.* (1996) Mani and Krishnamoorthy(1999)
14	*Polyalthia longifolia* (Sonner) Thw.	"	Kerala, Karnataka, Lakshadweep	Prathapan(1996) Mani and Krishnamoorthy (1999), Muralikrishna (1999), Ramani (2000)
15	*Centella asiatica* (L.) Urb.	Apiaceae	Karnataka	Muralikrishna (1999)
16	*Nerium indicum* Mill	Apocyanaceae	Karnataka	Srinivasa (2000)
17	*Ochrosia* sp.	"	Lakshadweep	Ramani (2000)
18	*Plumeria acuminata* Ait,	"	Kerala Karnataka	Prathapan (1996) Muralikrishna(1999)
19	*Plumeria rubra* L.	"	Lakshadweep	Ramani (2000)
20	*Thevetia peruviana (pers.)Merr.* (=*Thevetia neriifolia* Juss.)	" "	Lakshadweep Karnataka	Ramani (2000) Muralikrishna (1999)
21	*Areca catechu* L.	Aracaceae	Karnataka	Srinivasa (2000)
22	*Cocos nucifera* L.	"	Kerala Tamil Nadu Karnataka Lakshadweep	Prathapan (1996) David and Regu (1995) Mani and Krishnamoorhty (1999), Muralikrishna (1999) Ramani (2000)
23	*Colocasia* sp.	Araceae	Karnataka	Srinivasa (2000)
24	*Sundapsis* sp.	"	"	Srinivasa (2000)
25	*Asclepias curassavica* L.	Asclepiadaceae	"	Muralikrishna (1999)

26	*Calotropis gigantea* (L.) R.Br.	"	Kerala Karnataka Lakshadweep	Prathapan (1996) Mani and Krishnamoorthy (1999) Ramani (2000)
27	*Ageratum conyzoides* L.	Asteraceae	Karnataka	Muralikrishna (1999)
28	*Bidens pilosa* L.	"	Lakshadweep	Ramani (2000)
29	*Centratherum anthelminticum* O. Kze	"	Karnataka	Srinivasa (2000)
	(=*Vernonia anthelmintica* Willd.)	"	Karnataka	Muralikrishna (1999)
30	*Chromolaena* (*Eupatorium*) *adenophorum* Spreng	"	Kerala Tamil Nadu	David and Regu (1995)
33	*Conyza* sp.	"	Karnataka	Srinivasa (2000)
34	*Dahlia* sp.	"	Kerala Karnataka	Ranjith *et al.* (1996), Prathapan (1996) Muralikrishna (1999)
35	*Emilia sonchifolia* DC	"	Karnataka	Muralikrishna (1999)
36	*Solidago canadensis* L.	"	Karnataka	Srinivasa (2000)
37	*Tithonia divaricata* Gray	"	Karnataka	Srinivasa (2000)
38	*Tridax procumbens* L.	"	Kerala, Tamil Nadu	David and Regu (1995)
39	*Impatiens balsamina* L.	Balsaminaceae	Kerala, Karnataka	Ranjith *et al.*, (1996), Srinivasa (2000)
40	*Impatiens* sp.	"	Karnataka	Srinivasa (2000)
41	*Bignonia venusta* Ker	Bignoniaceae	Karnataka	Srinivasa (2000)
42	*Spathodea campanulata* Beauv.	"	Karnataka	Muralikrishna (1999)
43	*Tabebuia avellanedae* Lorentz	"	Karnataka	Srinivasa (2000)
44	*Tabebuia rosea* D.C.	"	Karnataka	Mani and Krishnamoorthy(1999)
45	*Tabebuia* sp.	"	Karnataka	Srinivasa (2000)
46	*Tecomaria capensis* (Spach.)	"	Kerala	Prathapan(1996)

47	*Tecoma smithi* X. Hor.	"	Karnataka	Srinivasa (2000)
48	*Tecoma stans* Juss.	"	Karnataka	Srinivasa (2000)
49	*Tecoma stanes* (L.) H.B&k.	"	Karnataka	Mani and Krishnamoorthy (1999)
50	*Bixa orellana* L.	Bixaceae	Kerala, Karnataka	Prathapan (1996) Muralikrishna (1999)
51	*Bombax ceiba* L.	Bombacaceae	Karnataka	Muralikrishna (1999)
52	*Bombax ellipticum* B.Brk	"	Karnataka	Srinivasa (2000)
53	*Pachira insigne* Bourd.	"	Karnataka	Srinivasa (2000)
54	*Cordia myxa* Roxb	Boraginaceae	Karnataka	Muralikrishna (1999)
55	*Cordia obliqua* auct.non.Willd	"	Karnataka	Muralikrishna (1999)
56	*Cordia* sp.	"	Karnataka	Srinivasa (2000)
57	*Garuga pinnata* Roxb.	Burseraceae	Karnataka	Muralikrishna (1999)
58	*Canna indica* L.	Canaceae	Kerala, Tamil Nadu Karnataka	David and Regu (1995), Mani and Krishnamoorthy (1999), Muralikrishna (1999)
59	*Cleome gynandra* L.	Capparaceae	Lakshadweep	Ramani (2000)
60	*Carica papaya* L.	Caricaceae	Kerala Karnataka Lakshadweep	Prathapan (1996) Mani and Krishnamoorthy (1999) Muralikrishna (1999) Ramani (2000)
61	*Calophyllum* sp.	Clusiaceae	Kerala	Palaniswami *et al.* (1995)
62	*Garcinia indica* Choisy	"	Kerala	Ranjith *et al.* (1996)
63	*Calycopteris floribunda* Lam.	Combretaceae	Kerala	Prathapan (1996)
64	*Terminalia catappa* L.	"	Tamil Nadu Kerala Karnataka Lakshadweep Andhra Pradesh	David and Regu (1995) Prathapan (1996) Mani and Krishnamoorthy (1999) Muralikrishna (1999) Ramani (2000) Baskaran and Reddy (1999)

65	*Thottea siliquosa* (Lam.) Ding Hou.	"	Karnataka	Muralikrishna (1999)
66	*Quisqualis indica* L.	"	Tamil Nadu Kerala Karnataka	David and Regu (1995) Prathapan (1996) Ranjith *et al.* (1996) Muralikrishna (1999)
67	*Argyreia cuneata* Ker Gawler	Convolvulaceae	Karnataka	Srinivasa (2000)
68	*Ipomoea batatas* (L.) Lam.	"	Karnataka	Muralikrishna (1999)
69	*Ipomoea cairica* (L.) SW.	"	Karnataka	Srinivasa (2000)
70	*Ipomoea muricata* (L.) Jacq.	"	Kerala Karnataka	Prathapan (1996) Muralikrishna (1999)
71	*Ipomoea palmate* Forsk	"	Karnataka	Mani and Krishnamoorthy (1999)
72	*Rivea* sp.	"	Karnataka	Srinivasa (2000)
73	*Benincasa hispida* (Thumb.) Cogn.	Cucurbitaceae	Karnataka	Muralikrishna (1999)
74	*Coccinia grandis* (L.) Voigt.	"	Karnataka	Muralikrishna (1999)
75	*Coccinia indica* W. & A.	"	Kerala	Prathapan (1996)
76	*Cucumis anguria* Rodsch	"	Karnataka	Srinivasa (2000)
77	*Cucumis* sp.	"	Karnataka	Srinivasa (2000)
78	*Cucurbita maxima* Duch.	"	Karnataka	Muralikrishna (1999)
79	*Lagenaria siceraria* (Molina) Stand.	"	Karnataka	Muralikrishna (1999)
80	*Momordica charantia* L.	"	Karnataka	Srinivasa (2000)
81	*Cycas* sp.	Cycadaceae	Karnataka	Srinivasa (2000)
82	*Dillenia indica* L.	Dilleniaceae	Karnataka	Muralikrishna (1999)
83	*Dillenia pentagyna* Roxb.	"	Kerala	Prathapan (1996)
84	*Acalypha godseffiana* Masters	Euphorbiaceae	Kerala	Ranjith *et al.* (1996)
85	*Acalypha hispida* Burm.f.	"	Karnataka	Mani and Krishnamoorthy (1999) Muralikrishna (1999)

86	*Acalypha indica* L.	"	Kerala Karnataka Lakshadweep	Prathapan (1996) Muralikrishna (1999) Ramani (2000)
87	*Acalypha wilkesiana* M.Arg.	"	Karnataka	Muralikrishna(1999)
88	*Acalypha* sp.	"	Kerala, Tamil Nadu	David and Regu (1995)
89	*Aleurites trisperma* Blanco	"	Karnataka	Srinivasa (2000)
90	*Bridelia retusa* Spreng	"	Kerala Karnataka	Prathapan (1996) Muralikrishna (1999)
91	*Breynia patens* Rolfe	"	Karnataka	Srinivasa (2000)
92	*Codiaeum variegatum* Blume Bijd.	"	Lakshadweep	Ramani (2000)
93	*Croton sparsiflorus* Morong	"	Karnataka	Mani and Krishnamoorhty (1999)
94	*Croton* sp.	"	Andhra Pradesh	Baskaran and Reddy (2003)
95	*Euphorbia fulgens* Karw.	"	Kerala	Prathapan (1996)
96	*Euphorbia geniculata* Ort.	"	Kerala	Prathapan (1996)
97	*Euphorbia pulcherrima* Willd.	"	Kerala, Karnataka	Prathapan (1996) Mani and Krishnamoorthy (1999)
98	*Euphorbia* sp.	"	Karnataka	Srinivasa (2000)
99	*Excoecaria agallocha* L.	"	Kerala	Prathapan (1996)
100	*Jatropa podagrica* Hook	"	Karnataka	Srinivasa (2000)
101	*Jatropa* sp.	"	Kerala	Prathapan (1996)
102	*Macaranga peltata* M.	"	Kerala	Prathapan (1996) Ranjith *et al.* (1996)
103	*Mallotus philippinensis* (Lam) Muell	"	Karnataka	Muralikrishna (1999)

104	*Manihot esculenta* Crantz	"	Kerala	Palaniswami *et al.* (1995) Prathapan (1996)
			Tamil Nadu	Regumoorthy and Kempraj (1996)
	(=Manihot utilissima Pohl.)	"	Karnataka	Muralikrishna (1999)
			Andhra Pradesh	Baskaran and Reddy (2003)
105	*Manihot glaziovii* Muel	"	Kerala Karnataka	Prathapan (1996) Mani and Krishnamoorthy (1999) Muralikrishna(1999)
106	*Manihot* sp.	"	Karnataka	Srinivasa (2000)
107	*Poinsettia pulcherrima*	"	Andhra Pradesh	Baskaran and Reddy (2003)
108	*Ricinus communis* L.	"	Kerala Karnataka	Prathapan (1996) Mani and Krishnamoorthy (1999) Muralikrishna(1999)
			Lakshadweep	Ramani (2000)
109	*Sauropus androgynus* Merr.	"	Kerala	Prathapan (1996) Ranjith *et al.* (1996)
110	*Sauropus* sp.	"	Karnataka	Srinivasa (2000)
111	*Adenanthera farnesiana* Willd.	Fabaceae	Karnataka	Srinivasa (2000)
112	*Arachis hypogaea* L.	"	Tamil Nadu	Geetha *et al.* (1998 a ,b)
113	*Bauhinia acuminata* L.	"	Kerala	Ranjith *et al.* (1996)
114	*Bauhinia malabarica* Roxb.	"	Karnataka	Muralikrishna (1999)
115	*Bauhinia purpurea* L.	"	Karnataka	Mani and Krishnamoorthy (1999) Muralikrishna (1999)
116	*Bauhinia racemosa* Lam.	"	Karnataka	Muralikrishna (1999)
117	*Bauhinia variegata* L.	"	Karnataka	Muralikrishna (1999)
118	*Bauhinia* sp.	"	Karnataka	Srinivasa (2000)

119	*Butea monosperma* (Lam) Taub.	"	Karnataka	Mani and Krishnamoorthy (1999)
120	*Cajanus cajan* (L.) Millsp.	"	Kerala Karnataka	Prathapan (1996) Muralikrishna (1999)
121	*Calliandra* sp.	"	Karnataka	Srinivasa (2000)
122	*Calapogonium mucunoides* Desv.	"	Kerala	Prathapan (1996)
123	*Cassia fistula* L.	"	Karnataka	Mani and Krishnamoorthy (1999) Muralikrishna (1999)
124	*Cassia spectabilis* DC Cat.	"	Karnataka	Srinivasa (2000)
125	*Clitoria ternatea* L.	"	Karnataka	Muralikrishna (1999)
126	*Crotalaria juncea* L.	"	Karnataka	Muralikrishna (1999)
127	*Dalbergia sissoo* Roxb.	"	Karnataka	Srinivasa (2000)
128	*Desmodium* sp.	"	Karnataka	Srinivasa (2000)
129	*Erythrina subumbrans* (Hassk.) Merrill	"	Karnataka	Srinivasa (2000)
130	*Erythrina variegata* L.	"	Lakshadweep	Ramani (2000)
131	*Gliricidia maculata* L.	"	Kerala Karnataka	Ranjith *et al.* (1996) Muralikrishna (1999)
132	*Gliricidia sepium* (Jacq.) Kunth	"	Lakshadweep	Ramani (2000)
133	*Gliricidia* sp.	"	Karnataka	Srinivasa (2000)
134	*Lablab niger* Medic.	"	Kerala Tamil Nadu	David and Regu (1995)
135	*Leucaena leucocephala* (Lamk.) De Wit.	"	Kerala	Palaniswami *et al.* (1995)
136	*Mucuna pruriens* DC	"	Karnataka	Srinivasa (2000)
137	*Peltophorum ferruginea* Benth.	"	Karnataka	Mani and Krishnamoorthy (1999)
138	*Phaseolus vulgaris* L.	"	Karnataka	Srinivasa (2000)
139	*Pithecolobium dulce* Benth.	"	Kerala	Prathapan (1996)

140	*Pongamia pinnata* (L.)Pierre	"	Kerala Karnataka	Prathapan (1996) Mani and Krishnamoorthy (1999) Muralikrishna (1999)
141	*Pterocarpus marsupium* Roxb.	"	Karnataka	Muralikrishna (1999)
142	*Samanea saman* (Jacq.) Merr. *(=Enterolobium saman* Prain)	" "	Kerala Karnataka	Prathapan (1996) Muralikrishna (1999)
143	*Sesbania grandiflora* Pers.	"	Karnataka	Srinivasa (2000)
144	*Tipuana tipu* Benth	"	Karnataka	Muralikrishna (1999)
145	*Geranium* sp.	Geraniaceae	Karnataka	Srinivasa (2000)
146	*Ocimum basilicum* L.	Lamiaceae	Kerala	Palaniswami *et al.* (1995)
147	*Ocimum sanctum* L.	"	Kerala	Palaniswami *et al.* (1995)
148	*Pentas lanceolatus* (Forsk.)Deflers.	"	Karnataka	Srinivasa(2000)
149	*Salvia* sp.	"	Kerala	Prathapan (1996)
150	*Careya arborea* Roxb.	Lecythidaceae	Tamil Nadu Kerala	David and Regu (1995) Prathapan(1996)
151	*Couroupita guianensis* Aubl.	"	Karnataka	Srinivasa (2000)
152	*Leea indica* (Burm.f.) Merr.	*Leeaceae*	Karnataka	Muralikrishna (1999)
153	*Leea macrophylla* Roxb.	"	Karnataka	Muralikrishna (1999)
154	*Dendrophthoe falcata* (L.F.) Eltingsh	Loranthaceae	Karnataka	Srinivasa (2000)
155	*Lagerstroemia indica* L.	Lythraceae	Karnataka	Srinivasa (2000)
156	*Lagerstroemia parviflora* Roxb.	"	Karnataka	Srinivasa (2000)
157	*Lagerstroemia tomentosa* Presl.	"	Karnataka	Srinivasa (2000)
158	*Lawsonia inermis* L.	"	Karnataka	Muralikrishna (1999)
159	*Woodfordia floribunda* Salisb.	"	Karnataka	Srinivasa (2000)
160	*Magnolia fuscata* Andr.	Magnoliaceae	Karnataka	Srinivasa (2000)
161	*Michelia champaca* L.	"	Kerala, Tamil Nadu Karnataka	David and Regu (1995) Mani and Krishnamoorthy (1999) Muralikrishna(1999)

162	*Michelia nilagirica* Zenk.	"	Karnataka Andhra pradesh	Muralikrishna(1999) Baskaran and Reddy(2003)
163	*Abelmoschus esculentus* (L.) Moench	Malvaceae	Kerala	Palaniswami *et al.* (1995) Prathapan (1996)
164	*Abutilon indicum* Sweet	"	Karnataka	Mani and Krishnamoorthy (1999)
165	*Althea rosea* Hohen	"	Karnataka	Srinivasa (2000)
166	*Dombeya spectabilis* Boj.	"	Tamil Nadu	Geetha *et al.*(1999)
167	*Gossypium hirsutum* L.	"	Karnataka	Mani and Krishnamoorthy (1999)
168	*Hibiscus radiatus* L.	"	Karnataka	Muralikrishna (1999)
169	*Hibiscus rosasinensis* L.	"	Kerala Tamil Nadu Karnataka Lakshadweep	David and Regu (1995) Mani and Krishnamoorthy (1999) Muralikrishna(1999) Ramani(2000)
170	*Hibiscus tiliaceus* L.	Malvaceae	Karnataka Lakshadweep	Mani and Krishinamoorthy (1999) Ramani (2000)
171	*Hibiscus* sp	"	Kerala Karnataka	Palaniswami *et al.* (1995) Srinivasa (2000)
172	*Malvaviscus arboreus* L.	"	Kerala	Prathapan (1996) Muarlikrishna (1999)
173	*Sida acuta* Burm.	"	Kerala	Prathapan (1996)
174	*Sida* sp.	"	Kerala	Prathapan (1996)
175	*Thespesia populnea* (L.) Carr.	"	Karnataka	Muralikrishna (1999)
176	*Urena lobata* L.	"	Kerala	Prathapan (1996) Ranjith *et al.* (1996)
177	*Azadirachta indica* Juss.	Meliaceae	Lakshadweep	Ramani (2000)
178	*Dysoxylum alliaceum* BL.	"	Karnataka	Srinivasa (2000)
179	*Cocculus hirsutus* Diels	Menispermaceae	Karnataka	Srinivasa (2000)
180	*Tinospora cordifolia* (Willd) H & T	"	Karnataka	Srinivasa (2000)

181	*Artocarpus incisa* L.	Moraceae	Lakshadweep	Ramani (2000)
182	*Artocarpus heterophyllus* Lam.	"	Kerala Karnataka	Ranjith *et al.* (1996) Muralikrishna (1999)
183	*Artocarpus hirsutus* Lam.	"	Kerala Karnataka	Prathapan (1996) Muralikrishna (1999)
184	*Ficus benghalensis* L.	"	Karnataka Lakshadweep	Mani and Krishnamoorthy (1999) Ramani (2000)
185	*Ficus carica* L.	"	Karnataka	Muralikrishna (1999)
186	*Ficus elastica* Roxb.	"	Kerala Karnataka	Prathapan (1996) Muralikrishna (1999)
187	*Ficus gibbosa* Bl.	"	Kerala	Prathapan (1996)
188	*Ficus glomerata* Roxb.	"	Kerala	Prathapan (1996)
189	*Ficus pandrata* Sander	"	Karnataka	Srinivasa (2000)
190	*Ficus racemosa* L.	"	Karnataka	Muralikrishna (1999)
191	*Ficus religiosa* L.	"	Kerala Karnataka	Prathapan (1996) Muralikrishna (1999)
192	*Ficus repens* Roxb.	"	Kerala	Prathapan (1996)
193	*Ficus* sp.	"	Kerala Karnataka Lakshadweep	Palaniswami *et al.* (1995) Srinivasa(2000) Ramani(2000)
194	*Morus alba* L	"	Kerala Tamil Nadu Lakshadweep Andhra Pradesh	David and Regu (1995) Sivaprakasm and Chandramohan (1997) Ramani(2000) Baskaran and Reddy (2003)
195	*Strebulus asper* Lour	"	Karnataka	Muralikrishna (1999)
196	*Moringa oleifera* Lam.	Moringaceae	Karnataka	Srinivasa (2000)
197	*Moringa* sp.	"	Karnataka	Muralikrishna (1999)
198	*Heliconia rostrata* Ruis & Pav.	Musaceae	Kerala	Ranjith *et al.* (1996)
199	*Heliconia* sp.	"	Karnataka	Srinivasa (2000)

200	*Musa paradisiaca* L.	"	Kerala Karnataka Lakshadweep Andhra Pradesh	David and Regu (1995) Muralikrishna (1999) Ramani (2000) Baskararan and Reddy (2003)
201	*Musa* sp.	"	Kerala Karnataka	Palaniswami *et al.* (1995) Prathapan (1996) Mani and Krishnamoorthy (1999)
202	*Callistemon citrinus*	Myrtaceae	Karnataka	Srinivasa (2000)
203	*Eucalyptus* sp.	"	Karnataka	Muralikrishna (1999)
204	*Eugenia benthamiana* W.	"	Karnataka	Muralikrishna (1999)
205	*Psidium guajava* L.	"	Kerala Karnataka Andhra Pradesh	Prathapan (1996) Mani and Krishnamoorthy (1999), Muralikrishna (1999) Baskaran and Reddy (2003)
206	*Syzygium aqueum* L.	"	Lakshadweep	Ramani (2000)
207	*Syzygium cumini* (L.) Skeels *(=Eugenia jambolana* Lam) *(=Syzygium jambolanum* DC.)	" " "	Kerala Karnataka	Prathapan (1996) Muralikrishna (1999) Srinivasa (2000)
208	*Syzygium jambos* (L.) Alst.	"	Karnataka	Mani and Krishnamoorthy (1999)
209	*Syzygium* sp.	"	Karnataka	Mani and Krishnamoorthy (1999)
210	*Bougainvillea* sp.	Nyctaginaceae	Karnataka	Srinivasa (2000)
211	*Jasminum grandiflorum* L.	Oleaceae	Karnataka	Mani and Krishnamoorthy (1999)
212	*Jasminum* sp.	"	Kerala	Palaniswami *et al.* (1995)
213	*Piper betel* L.	Piperaceae	Karnataka	Srinivasa (2000)
214	*Piper nigrum* L.	"	Kerala	Ranjith *et al.* (1996)
215	*Plumbago zeylanica* L.	Plumbaginaceae	Kerala Karnataka	Prathapan (1996) Muralikrishna (1999)

216	*Antigonon leptopus* Hook & Arn.	Polygonaceae	Kerala Lakshadweep	Prathapan (1996) Ramani (2000)
217	*Punica granatum* L.	Punicaceae	Karnataka	Mani and Krishnamoorthy (1999) Muralikrishna (1999)
218	*Zizyphus mauritiana* Lamk.	Rhamnaceae	Kerala	Prathapan (1996)
219	*Zizyphus oenoplia* Mill	"	Kerala	Prathapan (1996)
220	*Rosa indica* Lindl.	Rosaceae	Kerala Tamil Nadu Karnataka	David and Regu (1995) Palaniswami *et al.* (1995) Mani and Krishnamoorthy (1999)
221	*Rosa* sp.	"	Karnataka	Muralikrishna (1999)
222	*Coffea arabica* L.	Rubiaceae	Karnataka	Srinivasa (2000)
223	Morinda *sp.*	"	Karnataka	Srinivasa (2000)
224	*Citrus* sp.	Rutaceae	Kerala	Palaniswami *etal.* (1995)
225	*Murraya koenigii* (L.) Spreng	"	Kerala Karnataka Andhra Pradesh	Ranjith *et al.* (1996) Mani and Krishnamoorthy (1999) Muralikrishna (1999) Baskaran and Reddy (2003)
226	*Santalum album* L.	Santalaceae	Kerala Karnataka	Prathapan (1996) Mani and Krishnamoorhty (1999) Muralikrishna (1999)
227	*Cardiospermum halicacabum* L.	Sapindaceae	Kerala	Prathapan (1996)
228	*Filicium decipiens* L.	"	Karnataka	Mani and Krishnamoorthy (1999) Muralikrishna (1999)
229	*Nephelium longana* Camb.	"	Karnataka	Srinivasa (2000)
230	*Schleichera trijuga* Willd.	"	Karnataka	Srinivasa (2000)
231	*Achras zapota* Auct non L.	Sapotaceae	Karnataka	Srinivasa (2000)
	(=Manilkara zapota L.)	"	Kerala	Palaniswami *et al.* (1995)

232	*Chrysophyllum cainito* L.	"	Kerala	Prathapan (1996)
233	*Ailanthus excelsa* Roxb.	Simaroubaceae	Karnataka	Muralikrishna (1999)
234	*Ailanthus malabarica* Roxb.	"	Kerala Karnataka	Prathapan (1996) Muralikrishna (1999)
235	*Simarouba glauca* DC	"	Karnataka	Srinivasa (2000)
236	*Capsicum annuum* L.	Solanaceae	Kerala Karnataka Lakshadweep	Palaniswami *et al.* (1995) Prathapan (1996) Mani and Krishmoorhty (1999) Ramani (2000)
237	*Capsicum frutescens* L.	"	Kerala Karnataka Lakshadweep	Prathapan (1996) Muralikrishan (1999) Ramani (2000)
238	*Capsicum* sp.	"	Karnataka	Srinivasa (2000)
239	*Datura stramonium* L.	"	Karnataka	Muralikrishna (1999)
240	*Datura* sp.	"	Kerala	Prathapan (1996)
241	*Lycopersicon esculentum* Mill.	"	Kerala Karnataka Tamil Nadu Andhra Pradesh	Prathapan(1996) Mani and Krishnamoorthy (1999) Muralikrishna (1999) Geetha (2000) Baskaran and Reddy (2003)
242	*Physalis minima* L.	"	Kerala	Ranjith *et al.* (1996)
243	*Solanum melongena* L.	"	Kerala Karnataka Lakshadweep Andhra Pradesh	Prathapan (1996) Muralikrishna (1999) Ramani (2000) Baskaran and Reddy (2003)
244	*Solanum nigrum* L.	"	Kerala	Prathapan (1996)
245	*Solanum trilobatum* L.	"	Tamil Nadu	Geetha *et al.* (1999)
246	*Solanum torvum* Sw.	"	Karnataka	Muralikrishna (1999)
247	*Solanum seaforthianum* Andr.	"	Karnataka	Srinivasa (2000)
248	*Solanum* sp.	"	Kerala, Tamil Nadu	David and Regu (1995)

249	*Browsonetia papyrifolia* (L.) L'Her	Sterculiaceae	Karnataka	Srinivasa (2000)
250	*Guazuma tomentosa* Kunth	"	Karnataka	Srinivasa (2000)
251	*Helicteres isora* L.	"	Karnataka	Muralikrishna (1999)
252	*Callicarpa tomentosa* (L.) Murray	Verbenaceae	Karnataka	Srinivasa (2000)
253	*Clerodendron thomsonae* Balf	"	Kerala	Prathapan (1996)
254	*Holmskioldia sanguinea* Retz.	"	Karnataka	Srinivasa (2000)
255	*Lantana camara* L.	"	Karnataka	Srinivasa (2000)
256	*Petrea volubilis* L.	"	Karnataka	Muralikrishna (1999)
257	*Tectona grandis* L.	"	Kerala Karnataka Andhra Pradesh	Prathapan (1996) Muralikrishna (1999) Baskaran and Reddy (2003)
258	*Vitex altissima* L.f.	"	Kerala	Prathapan (1996)
259	*Vitex negundo* L.	"	Kerala Tamil Nadu	David and Regu (1995)
260	*Hedychium coronarium* Koen.	Zingiberaceae	Karnataka	Srinivasa (2000)

2.3 BIOLOGY OF SPIRALLING WHITEFLY

The life cycle of spiralling whitefly consists of three distinct larval stages and the fourth instar is a pupa. First instar larva is a crawler which is mobile and the subsequent two instars are immobile. The third instar larva moults to form a pupa which is a characteristic feature of the family Aleyrodidae among Hemiptera. The delicate adult though termed as 'fly' has two pairs of wings and is not a true fly. (Waterhouse and Norris,1989;Ragupathy and Jesudasan, 2003)

2.3.1 Egg

According to Paulson and Beardsly (1985) the egg have characteristic pedicel by which it attaches to leaf surface and secure

moisture from leaf. Waterhouse and Norris (1989) reported that eggs are smooth, elliptical and yellow to tan coloured. They were laid on the under surface of leaves and the incubation period ranged from 9 to 11 days under glass house condition at a temperature ranging from 20 to 39°C. Under Kerala condition the egg period was only four to six days on tapioca in summer season (Palaniswami *et al.*, 1995). Mariam (1999) reported that the incubation period ranged from 5.10 to 7.30 days on mulberry in Karnataka The egg period was four to six days on guava in Maharashtra (Sathe, 1999).

Geetha (2000) conducted a detailed study on biology on different crops and found that egg period was 6.40 ± 0.91 days in cassava, 7.40 ± 1.41 days in chilli and 6.20 ± 0.91 days in tomato. Douressamy *et al.* (2002) reported that in cassava var. Co2 the egg period was 7.52 ± 1.034 days and in guava var. Red flush it was 6.30 ± 1.374 days.

2.3.2 Crawler (First instar nymph)

According to Waterhouse and Norris (1989) *A. dispersus* had four nymphal instars in its life cycle and they were called continuous feeders. The first instar larva called 'crawler', is the only immature stage with functional legs and distinct antennae. They also reported that crawlers were 0.32 mm long and showed a tendency to congregate around the patch of eggs from which they hatched out. Duration of the first larval instar varied from six to nine days at 20 to 39°C. Mariam (1999) reported that the duration of crawlers were 5.30 to 7.20 days on mulberry. In cassava crawler duration was 4.25 ± 0.83 days (Geetha, 2000). She also reported that the crawler period on chilli was 4.10 ± 0.85 days and in tomato it was 2.40 ± 0.46 days.

2.3.3 Second Instar Nymph

The second and third instar nymphs were sedentary with atrophied legs and antennae. The duration of second instar was four to five days

under glasshouse condition (Waterhouse and Norris, 1989). Geetha (2000) reported that the duration of second instar was 4.91 ± 0.72 days in cassava, 4.75 ± 0.83 days in tomato and 2.70 ± 0.64 days in chilli.

2.3.4 Third Instar Nymph

The third instar nymph was 0.65 mm long and can be distinguished by numerous evenly spaced short, glass like rods of wax along the sides of the body. The duration of third instar nymph was five to seven days at 20 to 39°C (Waterhouse and Norris, 1989). According to Geetha (2000) the duration of the third instar was 3.85 ± 0.81 days in cassava, 4.60± 1.20 days in chilli and 3.00 ± 1.21 days in tomato.

2.3.5 Fourth Instar Nymph or Pupa

Waterhouse and Norris (1989) opined that the fourth instar was at first a feeding stage like earlier instars but later ceased feeding and undergo internal tissue organisation before moulting into adult. This stage is pupa. Pupa had a copious amount of white cottony secretion extending upward and outward from dorsum. They were fluffy, waxy or ribbon like. They also reported that the young pupa was flat ventrally but when matures the ventral surface became swollen and surrounded by band of wax. Pupal stage showed several diagnostic characters which aid in classification of aleyrodids. (Ragupathy and Jesudasan, 2003).

Palaniswami *et al.* (1995) reported a pupal period of two to three days on cassava. It was 3.00 to 5.50 days on mulberry (Mariam, 1999). Sathe (1999) found that the pupal period was two to five days on guava. Geetha (2000) reported that the pupal period was 6.75 ± 1.02 days in cassava, 7.30 ± 1.91 days in chilli and 6.90 ± 1.88 days in tomato

2.3.6 Total Nymphal Period

According to Palaniswami *et al.* (1995) the total nymphal period was 12 to 14 days in cassava under Kerala conditions. The total nymphal

period in guava in Maharashtra was 14 to 21 days (Sathe, 1999). Douressamy *et al.* (2002) studied the total nymphal period on tapioca and guava and it was 20.18 ± 1.86 and 20.50 ± 1.68 days respectively.

2.3.7 Adult

The adults are similar in appearance but quite larger than many other species of whiteflies. They were white and resemble tiny moths. Both male and female were winged (Waterhouse and Norris, 1989).

According to Gill (1990) spiralling white fly had a body length of 2.00 mm and a wing span of 3.50 to 4.00 mm. Adult emerged out from their pupal case through a 'T' shaped exit. The wings of newly emerged adults were transparent and developed a white powder covering after some hours. They were most active during morning hours and mating occurred during afternoon. Females began egg laying within a day of emergence and continued to lay eggs through out its life time. Unmated females produced only male progeny while mated females produced both sexes (Water house and Norris, 1989).

According to Palaniswami *et al.* (1995) adult oviposited on the lower surface of leaves in irregular waxy lines typically forming the spiralling pattern. Wen *et al.* (1996) reported its fecundity on four host plants *viz.*, poinsettia, *Canna* sp. (*Canna edulis*), guava and papaya as 65.20, 35.80, 51.30 and 58.00 eggs respectively. A female whitefly laid upto 95.84 ± 1.90 eggs on tapioca and 95.52 ± 11.18 eggs on guava (Douressamy *et al.*, 2002).

Adults lived upto 39 days under laboratory condition at 29 to 32°C (Waterhouse and Norris, 1989). Wijesekara and Kudagamage (1990) found that it lived about two weeks at 17 to 26°C at a relative humidity of 63 to 76 per cent. Wen *et al.* (1994) reported that the life span of adults of *A. dispersus* shortened with rise in temperature from 15 to 30°C and both sexes lived upto 17.00 to 18.50 days.

Mariam (1999) conducted experiment on mulberry and showed that adult longevity was 14.20 to 15.70 days. Geetha (2000) studied adult longevity on different host plants and showed that it was 32 days on *Musa* sp, 16 to 27 days on cassava, 7 to 21 days in chilli and 9 to 24 days in tomato.

2.3.8 Total Developmental Period

According to Waterhouse and Norris (1989) the total developmental period from egg to adult was 34 to 38 days at 20 to 39°C. It was 18 to 23 days on tapioca (Palaniswami *et al.*, 1995), and 21 to 32 days on guava (Sathe, 1999). Durey and Sundararaj (2002) studied the developmental period of spiralling white fly on nine tree species and it was maximum on *Acacia mangina* (48.67 days) and minimum on *Bauhinia racemosa* (34.83 days).

2.4 Population Dynamics

Host plants and abiotic factors like temperature, relative humidity and rainfall had significant role in regulating the whitefly population.

2.4.1 Influence of Host Plants on the Population of Spiralling white fly

According to Wen *et al.* (1996) the population density of the pest was higher in a field under monocropping than under mixedcropping. They also reported that high nitrogen fertilizer levels and pruning promoted the development of new shoots and young leaves, which attracted more adults to lay eggs and to feed on them. A survey conducted by Prathapan (1996) revealed that, of the 72 host plants, 19 plant species had only low levels of infestation. In seven plant species only oviposition took place and there was no further development of the pest. Metzler and Laprade (1998) reported that spiralling white fly showed a preference for broad leaved weeds compared to narrow leaved ones.

Kiyindou *et al.* (1999) found that host plant type had a distinct influence on the behaviour of the whitefly. The nymphal period, rate of mortality of immature stages and fecundity were influenced by host plants..

According to Srinivasa (2000), of the total 253 host plants recorded from India, family Fabaceae had highest number of species (65) infested by spiralling whitefly. Geetha (2000) reported that among the different plant families which spiralling whitefly had been reported, Euphorbiaceae had the highest rate of incidence (26.30 to 99.83 per cent) and leaf area damage (10 to 98 per cent). .

Loganathan (2003) reported that tobacco grown adjacent to guava tree was not infested during a severe incidence of whitefly on guava. Baskaran and Reddy (2003) found that mulberry, tapioca and guava were the preferred hosts of spiralling white fly in Andhra Pradesh.

2.4.2 Influence of Temperature on the Population of Spiralling whitefly

Waterhouse and Norris (1989) claimed that the population of spiralling whitefly rose in warmer and dry weather in Hawaii. In Kerala outbreak of spiralling whitefly was noticed in dry season of 1993 and 1994. The infestation started from November, reached peak in February and subsidized at the end of April (Palaniswami *et al.*, 1995). Sathe (1999) reported that the population of spiralling white fly attained peak during January 1997 in Kolhapur district of Maharashtra. Mani and Krishnamoorthy (2000) reported that *A. dispersus* were present in the field through out the year in Bangalore, it was high from March to June and low from October to January. They concluded that the density of the whitefly is significantly and positively correlated with maximum and minimum temperature and their regulatory role is cyclic in every year.

Baskaran and Reddy (2003) reported that the incidence was high during summer when the temperature ranged from 37 to 40°C. Loganathan (2003) observed that the population density of spiralling whitefly on guava in the Erode district of Tamil Nadu was severe during December and January. He also reported that there was no activity of this pest from March to August.

2.4.3 Influence of Humidity on the Population of Spiralling whitefly

Chandrasekara (1990) reported that relative humidity significantly influenced the density of spiralling white fly on guava in Sri Lanka. Mani and Krishnamoorthy (2000) reported that its population was negatively correlated with relative humidity during morning and evening hours in a day. They also reported that population was low during October - January in Karnataka due to high relative humidity of 70 to 79 per cent. According to Baskaran and Reddy (2003) low incidence of spiralling white fly was noted during the months of January to February 2000 in Andhra Pradesh, when the relative humidity was 62.50 per cent.

2.4.4 Influence of Rainfall on the Population of Spiralling whitefly

According to Waterhouse and Norris (1989) heavy sporadic rains resulted in temporary reduction of spiralling whitefly. Ranjith *et al.* (1996) reported that there was decrease in the whitefly population after the pre-monsoon showers in South India. Mani and Krishnamoorthy (2000) suggested that there was a negative relationship between the rainfall and the whitefly population but the influence was not found to be significant.

2.5 NATURE OF DAMAGE

The nymphs and adults of spiralling whitefly are sap feeders. Due to the feeding they caused some direct as well as indirect damages on crop plants. They also caused some nuisance to the public due to the presence of waxy flocculent materials.

2.5.1 Direct Damage

Adults and nymphs of spiralling whitefly damage plants by sucking sap with its piercing and sucking mouth parts (Waterhouse and Norris, 1989).

2.5.2 Indirect Damage

Accumulation of honey dew excreted by both nymphs and adults served as a substrate for the dense growth of sooty mould. This mould, decreased the photosynthetic activity thereby reducing the vigour of the plants (Waterhouse and Norris, 1989). Honey dew also served as an attractant to other pests including flies and ants (Akinlosotu, *et al.*, 1993). Coto and Metzler (1998) studied the effect of sooty mould (*Capnodium* sp.) on banana cv. 'Grannaine' and found that there was significant difference in finger width and needed 10 more days to reach harvesting time. Mariam and Chandramohan (2001) observed mortality of silk worm due to the feeding of mulberry leaves contaminated with waxy materials of spiralling whitefly.

Palaniswami *et al.* (1995) reported that the feeding resulted in yellow speckling, crinkling and curling of leaves when the infestation was severe on tapioca. Due to the heavy feeding of adults and nymphs on groundnut variety TMV-2, premature leaf fall and yellowing of leaves were observed (Geetha *et al*, 1998 a). Sathe (1999) observed yellowing, drying up and dehiscence of leaves of guava infested with spiralling white fly. On coconut heavy infestation of spiralling whitefly resulted in severe yellowing (Razak and Jayaraj , 2002).

2.5.3 Nuisance to Public

The copious white waxy flocculent materials secreted by the nymphs were readily spread by wind and create nuisance to man (Waterhouse and Norris, 1989).

2.6 EXTENT OF DAMAGE

Wen *et al.* (1995) conducted a field study in China and reported that *A. dispersus* on poinsettia caused 98 per cent infestation within a period of 35 days. They also reported that A. *dispersus* caused 80 per cent yield loss in guava.

The study conducted by Narayanaswamy *et al.* (1999) on the economic characters of silk worm reared on spiralling white fly affected mulberry leaves revealed that there was considerable reduction in the fifth instar larval weight, cocoon weight, shell weight, cocoon-shell ratio and filament length. Geetha (2000) reported that heavy incidence of spiralling whitefly on cassava resulted an yield reduction of 53.10 per cent.

2.7 NATURAL ENEMIES OF SPIRALLING WHITEFLY

Natural enemies play an important role in keeping the population of *A. dispersus* under check (Ramani *et al.*, 2002).

2.7.1 Parasitoids

The Aphelinids *Encarsia* (?) *haitiensis* Dozier and *E. guadeloupae* Viggiani were effective in suppressing the pest in Pacific Islands and African countries (Waterhouse and Norris, 1989; D'Almeida *et al.*, 1998).

Kajitha *et al.* (1991) reported that in Indonesia, populations of the spiralling white fly were very low mainly due to heavy parasitism by *E. guadeloupae*. Srinivasa *et al.* (1999) reported a new species of *Encarsia* closely related to *E .(?) haitiensis* and *E. meritoria* Gahan from Kerala. *Encarsia* sp. nr. *meritoria* was first recorded from Kerala in 1998 by Beevi *et al.* (1999).

Ramani (2000) reported *E. guadeloupae* for the first time from Minicoy Island in the Lakshadweep. Mani *et al.* (2000a, b) observed 29 to 70 per cent parasitism due to *E. guadeloupae* and *E.* (?) *haitensis* in different parts of peninsular India. A survey conducted in South India during 2001-2002 indicated that *E. guadeloupae* caused 77 per cent parasitism on papaya, guava and cassia in Bangalore and 79 per cent in Thrissur and *E. guadeloupae* was dominant over *E.* (?) *haitiensis* in these areas (PDBC, 2002).

2.7.2 Predators

Several predators including generalists such as reduviids, spiders and lizards feed on spiralling white fly. There were more than 53 species of predators belonging to 10 families reported from different parts of the world (Mani and Krishnamoorthy, 2002).

In India more than 40 indigenous predators were reported (Table 2) which include 26 coccinellids, five chrysopids, one nitidulid, one cecidomyiid, one chamaemyiid, one drosophilid and spiders (Ramani *et al.*, 2002).

2.7.3 Pathogens

The only pathogen recorded on *A. dispersus* was *Paecilomyces farinosus* (Holm.) Brown and Smith from areas near Bangalore (Mani *et al.*, 2000 a; PDBC, 2001).

Table 2. Important predators of spiralling whitefly reported from India

Predators	**Reference**
O.Colcoptera **F. Coccinellidae**	
Anegleis cardoni Weise	PDBC (2001)

Anegleis perrotteti Mulsant	Ramani *et al.*(2002)
Axinoscymnus puttarudriahi Kapur and Munshi	Mani and Krishnamoorthy (1999) Ramani (2000)
Cheilomenes sexmaculata F.	Palaniswami *et al.* (1995) Mani and Krishnamoorthy (1999) Geetha. (2000)
Chilocorus nigrita F.	Mani and Krishnamoorthy (1999) Mani *et al.* (2000a)
Cryptolaemus montrouzieri Mulsant	Mani and Krishnamoorthy (1997)
Curinus coeruleus Mulsant	Mani *et al.* (2000a) PDBC (2001)
Horniolus sp.	Ramani *et al.* (2002)
Jauravia dorsalis Weise	"
Jauravia pallidula Motschulsky	"
Jauravia sp.	"
Nephus regularis Sicad	"
Pseudaspidimerus flaviceps Walker	"
Pseudaspidimerus trinotatus Thunberg	"
Pseudoscymnus sp.	"
Rodolia amabilis Kapur	"
Rodolia breviuscula Weise	"
Rodolia fumida Mulsant	"
Scymnus coccivora Ramakrishna Ayyar	"
Scymnus latemaculatus Motschulsky	"

Scymnus nubilus Mulsant	Ramani (2000) PDBC (2001)
Scymnus postieallis Sicard	Ramani *et al.* (2002)
Scymnus saciformis Motschulsky	"
Scymnus (Pullus) sp.	Mani and Krishnamoorthy (1996)
Scymnus sp.	Palaniswami *et al.* (1995)
Serangium parcesetosum Sicard	PDBC (2001), Ramani (2000)
F. Nitidulidae *Cybocephalus* sp.	Mani and Krishnamoorthy (2000) PDBC (2000)
O. Diptera **F. Cecidomyiidae** *Triommata coccidivora Felt*	PDBC (2000)
F. Chamaemyiidae *Leucopis* sp.	PDBC (2000,2001)
F. Drosophilidae *Acletoxenus indicus* Malloch	Mani and Krishnamoorthy (1999) PDBC (2000)
O. Hymenoptera **F. Formicidae** *Oecophylla smaragdina* F.	Gopi *et al.* (2001)
O. Lepidoptera **F. Lycaenidae** *Spalgis epeus* Westwood	PDBC (2001)
O. Neuroptera **F. Chrysopidae** *Apertochrysa* sp.	Mani and Krishnamoorthy (1999) Geetha *et al.* (1999)
Chrysoperla carnea Stephens	Mani and Krishnamoorthy (1999)
Mallada aster Banks	Mani and Krishnamoorthy (1999, 2000)
Mallada boninensis (Okamoto)	Mani and Krishnamoorthy (1999, 2000)
Nobilinus sp.	Mani and Krishnamoorthy (1999, 2000)

F. Coniopterygidae Unidentified	PDBC (2001)
F. Hemerobiidae *Hemerobius* sp.	PDBC (2001)
Notiobiella viridinervis Banks	Mani and Krishnamoorthy (2000) PDBC (2000)
Non insect group	
O. Acarina **F. Erythraeidae** *Leptus* sp.	Geetha (2000)
F. Araneae Indeterminate spiders	Gopi *et al.* (2001)

2.8 MANAGEMENT OF SPIRALLING WHITEFLY

2.8.1 Cultural control

Esguerra (1987) suggested pruning of heavily infested trees and shrubs to minimise the incidence of spiralling whitefly.

2.8.2 Physical control

Srinivasan and Mohanasundaram (1997) recommended a light trap coated with vaseline for trapping large numbers of adults of *A. dispersus* in home gardens in Tamil Nadu. Mariam (1999) tested a fluorescent light trap smeared with castor oil in the mulberry field and found that more number of adults was trapped in the early morning from 4 to 6 am accounted to 97.9 per cent of total catch.

2.8.3 Chemical control

2.8.3.1 Synthetic chemicals

Waterhouse and Norris (1989) reported that dilute aqueous solution of detergents and soaps were useful to manage spiralling whitefly. Egg

mortality and nymphal mortality of spiralling whitefly were maximum with three applications of 5.00 per cent soap solution (Ranjith *et al.*, 1996).

Monocrotophos at 2.5 ml l^{-1} and profenofos + cypermethrin at 2 ml l^{-1} controlled the nymphs and adults of spiralling whitefly (Alam *et al.*, 1998). Mariam and Chandramohan (2001) conducted a lab study to evaluate five chemicals against spiralling whitefly and found that Dichlorvos required least time to induce mortality on spiralling whitefly. Acetamiprid 40 g a.i ha^{-1} was most effective for the control of nymphs and adults of spiralling white fly where as Triazophos controlled egg spirals of spiralling whitefly (Bhaskaran *et al.*, 2003).

Anandkumar *et al.* (2003) reported that bioefficacy of imidacloprid was superior against sucking pests *viz.*, leafhoppers and whiteflies on brinjal. They also claimed that triazophos and profenofos were next to imidacloprid in effectiveness. Kambrekar *et al.* (2003) screened 15 insecticides under laboratory conditions for their residual toxicity against spiralling whitefly and found that triazophos at 0.06 per cent and dimethoate at 0.05 per cent persisted for a longer time and recorded 75.00 per cent adult mortality at 15 days after treatment in both the cases.

2.8.3.2 Botanicals

Coudriet *et al.* (1985) reported that neem seed extract reduced viability of egg by 20 per cent in *Bemisia tabaci* Genn.

According to Reghunath and Gokulapalan (1999) application of the leaf extracts of *Andrographis paniculata* Wall + soap solution + well crushed garlic @ 20 g l^{-1} and *Hyptis suaveolens* extract + soap solution + malathion 0.1 per cent was effective for the management of the sucking pests of chilli *viz.*, thrips, aphids, whiteflies and mites.

Mariam and Chandramohan (2000) reported that the ovicidal action of neem oil, neem seed kernal extract and neem oil + pungam oil registered a mortality percentage of 59.27, 52.08 and 50.99 respectively on spiralling whitefly on mulberry.

Growth and development of *B. tabaci* was suppressed considerably by neem oil 0.5 per cent and 1.0 per cent (Natrajan and Sundaramurthy, 1990). Price and Schuster (1991) found that neem seed extract reduced number of *B. tabacii* nymphs when sprayed on poinsettias. Lababidi (2002) reported that neemazal T/S was effective against the psyllid *Agonoscene targionii* (Licht) especially on the first and second nymphal instars. Silva *et al.* (2003) found that azadirachitin (1.0 per cent) applied at 4 and 8 ml l^{-1} caused 67.83 per cent and 70.13 per cent mortality of *B. argentifolii* adults and 80.36 per cent and 88.10 per cent nymphs in greenhouse and field respectively.

Schmutterer (1990) reported that neem seed extracts (40 or 50 g l^{-1}), neem cake extract (15 g l^{-1}) and formulated neem seed oil (1.0 to 1.5 per cent) showed reduced oviposition due to repellent effect on the adults of *B. tabaci* that lasted for two weeks.

Bandyopadhyay *et al.* (2000) reported that neemoil 1.0 per cent was effective against *Dialeuropora decempunctata*, a whitefly infesting mulberry. Saminathan and Jayaraj (2001) evaluated botanical insecticides against the mealy bug *Ferrisia virgata* Cockrell and found that neem oil 3.0 per cent produced the highest mortality (43.33 per cent). Manu (2002) reported that acetone extract of *Azadirachta indica* showed maximum mean per cent reduction of egg masses of spiralling whitefly (82.15 per cent) followed by its aqueous extract (80.36 per cent) on guava. She also reported that percentage reduction of nymphs by the treatment of acetone extract of *A. indica* was 71.45 per cent.

2.8.3.2.1 Impact of Neem based Formulation on Beneficial Arthropods

Mann and Dhaliwal (2001) studied the effect of commercial neem formulations *viz.* Neemazal 1.0 per cent, Rakshakgold 1.0 and ICIPE neem 1.0 per cent against beneficial arthropods including parasitoids, *Encarsia transvena, E. lutea* and predators, spiders, coccinellids and *Chrysoperla carnea* Stephens in the cotton agroecosystem. The results showed that parasitism of *Bemisia tabaci* by *Encarsia* sp. upon treatment with 2 l of Rakshak gold ha^{-1} was on par with control. The number of spiders per plant as well as coccinellids were maximum upon treatment with 1litre neemazal per ha, Neemark at 0.3 per cent, Achook at 0.3 per cent and Bt formulation (Dipel SL at 0.3 per cent) were safe to natural enemies (Sharma and Kashyap, 2002). Kumar and Singh (2002) reported that synthetic chemicals resulted in resurgence of the spidermite *Tetranychus urticae* Koch on okra, azadirachtin showed better performance than the chemicals and resurgence was negligible.

Materials and Methods

3. MATERIALS AND METHODS

The study was conducted at College of Agriculture, Vellayani during 2003 to 2004 to find out the host range, biology, natural enemies and management of spiralling whitefly with botanicals on tomato.

3.1 HOST RANGE

Survey was carried out in the Instructional Farm, College of Agriculture, Vellayani to study the host range and intensity of infestation of *A. dispersus* during 2003 - 2004.

3.1.1 Host Plants

The details of host plants, stages of pest present and intensity of infestation were recorded.

3.1.1.1 Intensity of Infestation

Intensity of infestation of *A. dispersus* on various host plants were recorded as low, medium and high based on visual observation.

3.2 MAINTENANCE OF STOCK CULTURE OF INSECT

Heavy infestation of *A. dispersus* was noticed on cassava (*Manihot esculenta* Crantz) during the period of study. Hence cassava was selected as the host for mass culturing this pest. A batch of 15 two month old potted (30 x 30 cm) cassava plants (var. Hruswa) were kept in the net house. Field collected adults of *A. dispersus* were released on these potted plants for breeding. Cassava leaves with pupal stages were covered individually with polythene bags for trapping the freshly emerged adults. These adults were used for various experiments.

3.3 MAINTENANCE OF HOST PLANTS

Ten plants each of cassava, tomato and chilli were grown in pots (30 x 30 cm) for studying the biology. Thirty three tomato plants were

grown in similar pots without insecticidal treatments for studying the management practices.

3.4 BIOLOGY OF SPIRALLING WHITEFLY

Biology of spiralling whitefly was studied on cassava, tomato and chilli.

3.4.1 Characteristics of Egg Spiral

The leaves of host plants were covered individually with a leaf cage. Adults of whiteflies were released on each cage with a sex ratio of 1:1 for egg laying. The leaves were examined on every 24 hours for the presence of egg spirals. Ten leaves with egg spirals were tagged with date of egg laying and the adults were removed. Number of spirals per leaf and number of eggs per spiral were observed.

3.4.2 Developmental Period

Duration of egg, first, second and third nymphal instars and pupal period were recorded on the respective host plants and characteristic features of each stage were studied.

3.4.3 Adult Longevity and Fecundity

The insect was reared as described under 3.4.1. Egg spirals were collected and observed under compound microscope to count the eggs. Adult longevity was observed and recorded.

3.5 NATURAL ENEMIES OF *A. DISPERSUS*

Natural enemies associated with *A. dispersus* were recorded during the survey. Whitefly infested plant samples were collected from the field and kept in polythene bags. Emerged adults of natural enemies were collected and preserved for identification.

3.5.1 Predators

Biology of the predators was studied on nymphs of *A. dispersus* under laboratory condition.

3.5.2 Parasitoids

Heavily infested leaves with *A. dispersus* were collected and kept in the laboratory for the emergence of parasitoids.

3.6 MANAGEMENT OF *A. DISPERSUS*

A pot culture experiment was carried out during October 2003 to January 2004 to study the effect of different botanicals for the management of *A. dispersus* on tomato.

Variety : Sakthi

Design : CRD

Treatments : 11

Replication : 3

1. Neemazal (1% Azadirachtin) 2 ml l^{-1}
2. Neemazal (1% Azadirachtin) 4 ml l^{-1}
3. Econeem (0.3% Azadirachtin) 2 ml l^{-1}
4. Econeem (0.3% Azadirachtin) 4 ml l^{-1}
5. Extract of *Andrographis paniculata* 5 %
6. Extract of *Andrographis paniculata* 10 %
7. Extract of *Hyptis suaveolens* 5 %
8. Extract of *Hyptis suaveolens* 10 %
9. Dimethoate (0.05 %)
10. Water spray
11. Untreated control

3.6.1 Preparation of Spray Fluid

3.6.1.1 Commercial formulation

The commercial formulation *viz.* neemazal containing azadirachtin one per cent supplied by M/S EID Parry (India) Ltd. Chennai and econeem containing 0.3 per cent azadirachtin supplied by PJ Margo Pvt. Ltd. were used for the experiment

3.6.1.2 Plant extracts

Plants *viz. Andrographis paniculata* and *Hyptis suaveolens* were collected from Instructional Farm, Vellayani. The fresh plants were weighed to 20 g lots. The weighed samples were chopped and finely ground in a grinder. They were then extracted with 50 ml water. The extract was then filtered twice using a fine muslin cloth and transferred to a volumetric flask and made upto 100 ml. Thus a 20 per cent stock solution was obtained. Then diluted to required concentrations.

3.6.1.3 Dimethoate 0.05 per cent

The commercial formulation Roger 30 EC manufactured by ISA GROASIA, Gujarat was used for the study. 1.6ml of the insecticide was dissolved in one litre of water to get 0.05 per cent spray fluid.

3.6.2 Application of Spray Fluid

Botanicals were applied using a hand sprayer. The spray fluid was directed to the ventral surface of leaves. Spraying was done during early hours of the day and necessary care was taken to prevent drift of spray fluid reaching the adjacent areas.

3.6.3 Observations

The population of *A. dispersus* on top middle and bottom leaves of the plant were recorded. On each leaf, number of egg spirals, nymphs

and adults were counted. The population of *A. dispersus* was recorded as pre treatment count followed by post treatment counts at one, two, three and four days after each spraying. Three sprays were given at 45, 60 and 75 days after transplanting. In egg stage only egg spirals were counted before and after spraying.

After spraying, the egg mortality was ascertained based on the colour change from tan yellow to light brown. Nymphal mortality was also recorded. Healthy nymphs were white with waxy flocculent material and the dead one is brown in colour. Number of live adults were recorded directly.

At harvest, the yield was recorded treatment wise in all replications to observe the over all effect of the treatments.

3.7 STATISTICAL ANALYSIS

Percentage reduction in population was worked out using the formula $\frac{Pre\,treatment\,count - Post\,treatment\,count}{Pretreatment\,count} \times 100$. It ranged from – 25.96 to + 82.14. The analysis of variance for completely randamised design was applied to this data by using the square root transformation after changing the negative percentages to positive values ($\sqrt{x}+50$ transformation).

Results

4. RESULTS

Host plants of *A. dispersus*, its biology, natural enemies and management practices are presented in this chapter.

4.1 HOST PLANTS

Host plants, intensity of damage, and stages of *A. dispersus* on various hosts are presented in Table 3.

A. dispersus was observed to infest a wide range of plants including vegetables, fruits, tubers, oil seeds, medicinal plants, spices, trees, ornamentals and weeds. A total of 50 plant species were recorded as hosts of this insect from Instructional Farm, College of Agriculture, Vellayani. Among them 15 plant species recorded high infestation, 17 plant species showed medium infestation, and 18 plant species recorded low infestation. On 16 plant species only egg spirals were recorded and there was no further development.

Eleven new hosts of *A. dispersus* were recorded during the survey (Plate 1). They were *Averrhoea bilimbi* L., *Capsicum chinense* Jacq., *Vigna unguiculata* (L.) Walp, *Vitis vinifera* Linn, *Passiflora edulis L.*, *Jacquemontia violaceae* Choisy, *Spathoglottis aurea* Lindle, *Ixora chinensis* Lam, *Alysicarpus vaginalis*(L.) *DC*, *Chromolaena odorata* (L.) King and Robinson *and Phaseolus* sp.

Weeds like *Synedrella nodiflora*,*Indigofera enneaphylla* and *Mukia bracteata* have no incidence of *A. dispersus* which were seen nearby *A. dispersus* infested cassava.

Table 3 Host plants of Spiralling whitefly

Sl. No.	Common name	Scientific name	Family	Stages of pest present	Intensity
1.	**Vegetables**				
1.	Bhindi	*Abelmoschus esculentus* (L.) Moench	Malvaceae	All stages	Medium
*2.	Bilimbi	*Averrhoea bilimbi*.L.	Oxalidaceae	Egg spiral	Low
3.	Bittergourd	*Momordica charantia* L.	Cucurbitaceae	Egg spiral	Low
4.	Brinjal	*Solanum melongena* L.	Solanaceae	All stages	Medium
5.	Chilli	*Capsicum annuum*. L.	Solanaceae	All stages	High
6.	Bird pepper	*Capsicum frutescens* L.	Solanaceae	All stages	High
*7.	Chilli, hot chilli	*Capsicum chinense* Jacq	Solanaceae	All stages	High
*8.	Cowpea	*Vigna unguiculata* (L.) Walp	Fabaceae	All stages	Medium
9.	Curry leaf	*Murraya koenigi* Spreng	Rutaceae	All stages	Low
10	Ivygourd	*Coccinia cordifolia* (Voight)L.	Cucurbitaceae	All stages	Medium
11	Moringa	*Moringa oleifera* Lam.	Moringaceae	All stages	High
12	Night Shade	*Solanum nigrum* L.	Solanaceae	All stages	Medium
13	Tomato	*Lycopersicon esculentum* Mill	Solanaceae	All stages	High
2.	**Fruits**				
14	Banana	*Musa paradisiaca*	Musaceae	All stages	High
*15	Grapevine	*Vitis vinifera* Linn	Vitaceae	Egg spiral	Low
16	Guava	*Psidium guajava* L.	Myrtaceae	All stages	High
17	Jack	*Artocarpus integrifolia* L.	Moraceae	Egg spiral	Low

18	Mango	*Mangifera indica*.L.	Anacardiaceae	Egg spiral	Low
19	Mulberry	*Morus alba*.L.	Moraceae	All stages	High
20	Papaya	*Carica papaya*. L.	Caricaceae	All stages	High
*21	Passion fruit	*Passiflora edulis*. L.	Passifloraceae	Egg spiral	Low
3	**Tuber**				
22	Cassava	*Manihot esculenta* Crantz	Euphorbiaceae	All stages	High
4.	**Oilseed**				
23	Coconut	*Cocos nucifera*.L.	Palmae	Egg spiral	Low
5.	**Medicinal plants**				
24	Castor	*Ricinus communis*. L.	Euphorbiaceae	All stages	Medium
25	Thulasi	*Ocimum sanctum*. L.	Lamiaceae	Egg spiral	Low
26	Ummam	*Datura metel*. L.	Solanaceae	All stages	Medium
6.	**Spices**				
27	Pepper	*Piper nigrum*. L.	Piperaceae	Egg spiral	Low
7.	**Trees**				
28	Anjili	*Artocarpus heterophyllus* Lam.	Moraceae	All stages	Medium
29	Elavu	*Bombax ceiba* Linn	Bombacaceae	All stages	High
30	Indian almond	*Terminalia catappa*. L.	Combretaceae	All stages	Medium
31	Indian rubber plant	*Ficus elastica* Roxb	Moraceae	Egg spiral	Low
32	Peepal tree	*Ficus religiosa*. L.	Moraceae	Egg spiral	Low
33	Teak	*Tectona grandis*. L.	Verbenaceae	All stages	Medium
8.	**Ornamentals**				
34	Acalypha	*Acalypha godseffiana*	Euphorbiaceae	All stages	High

		Masters			
*35	Blue bell	*Jacquemontia violaceae* Choisy	Convolvulaceae	All stages	High
36	Canna	*Canna indica*. L.	Cannaceae	All stages	High
37	Crossandra	*Crossandra infundibuliformis* Nees	Acanthaceae	All stages	Medium
*38	Ground Orchid	*Spathoglottis aurea* Lindle	Orchidaceae	Egg spiral	Low
39	Kudamulla	*Jasminum sambac* Burm. Aiton	Oleaceae	All stages	Medium
40	Pitchimulla	*Jasminum grandiflorum*.L.	Oleaceae	Egg spiral	Medium
41	Purple wreath	*Petrea volubilis*. L.	Verbenaceae	Egg spiral	Low
42	Rose	*Rosa sp*	Rosaceae	Egg spiral	Low
*43	Thetti	*Ixora chinensis*	Rubiaceae	All stages	Low
9.	**Weeds**				
* 44	--	*Alysicarpus vaginalis* (L.) DC	Papilionaceae	All stages	Medium
*45	--	*Chromolaena odorata* (L) King and Robinson	Asteraceae	Egg spiral	Low
46	--	*Justicia* sp	Acanthaceae	All stages	Medium
*47	--	*Phaseolus* sp	Fabaceae	All stages	High
48	Nettle	*Tragia involucrate*. L.	Combretaceae	All stages	Medium
49	Rangoon Creeper	*Quisqualis indica*. L.	Combretaceae	All Stages	Low
50	Vella Kurun thotti	*Sida acuta* Burm.F.	Malvaceae	All stages	Medium

* New report in India.

Jacquemontia violaceae

Phaseolus sp.

Vitis vinćfera

Vigna unguiculata

Plate 1 Host plants of *Aleurodicus dispersus* - new report

4.2. BIOLOGY

4.2.1 Egg

Eggs were smooth surfaced, elliptical and light yellow to tan coloured. They had a short stalk for attachment to the leaf (Plate 2a). Eggs were laid on the under surface of leaves in characteristic spiral. If infestation is very severe spirals were noticed on the upper surface of leaves also.

Egg period was 5.80 ± 0.60 days on cassava, 7.60 ± 0.49 days on tomato and 6.00 ± 0.45 days on chilli (Table. 4)

4.2.2 Nymph

There were four distinct nymphal instars. The first instar nymph (crawler) was with functional legs and antennae. This is the only stage which possess active movement. Duration of crawler on cassava was 4.60 ± 0.48 days. On tomato it was 5.80 ± 0.40 and in chilli 4.70 ± 0.45 days (Table. 4).

Second instar nymph was oval in shape, which is sedentary with atrophied legs. The duration of second instar nymph on cassava, tomato and chilli was 2.80 ± 0.40, 3.60 ± 0.48 and 3.30 ± 0.45 days respectively. (Table. 4).

Third instar nymph was oval in shape with numerous glass like waxy rods (plate 2b). Its duration on Cassava, tomato and chilli was 2.90 ± 0.30, 3.30 ± 0.45 and 3.40 ± 0.48 days respectively (Table.4).

4.2.3. Pupa

The quiescent fourth instar nymph is called pupa. It is entirely covered with copious amount of white waxy material (Plate2c). Its duration on cassava, tomato and chilli was 5.20 ± 0.40, 6.30 ± 0.64 and 5.30 ± 0.45 days respectively.

Table 4. Biology of *A. dispersus* on cassava, tomato and chilli

Crop	Egg period	Crawler	Second instar nymph	Third instar nymph	Fourth instar nymph (pupa)	Total nymphal period	Adult longevity	Fecundity
Cassava	5.80 ± 0.60	4.60 ± 0.48	2.80 ± 0.40	2.90 ± 0.30	5.20 ± 0.40	15.50 ± 0.67	13.20 ± 2.48	3.71 ± 7.09
Tomato	7.60 ± 0.49	5.80 ± 0.40	3.60 ± 0.48	3.30 ± 0.45	6.30 ± 0.64	1.90 ± 0.77	11.60 ± 1.42	27.60 ± 6.06
Chilli	6.00 ± 0.45	4.70 ± 0.45	3.30 ± 0.45	3.40 ± 0.48	5.30 ± 0.45	16.70 ± 0.90	12.50 ± 2.33	28.30 ± 7.63
CD	0.499	0.435	0.435	0.410	0.485	0.756		5.325

Total developmental period on cassava, tomato and chilli was 21.30 ± 0.64, 26.60 ± 0.92 and 22.70 ± 0.64 days respectively.

4.2.4 Adult

Adult emerged out through T shaped exit hole on the dorsal side of the puparium (Plate2 d). They resembled tiny moths. The wings of newly emerged adults were clear, later get a covering of white waxy powder. The eyes were dark reddish brown and each forewings had a characteristic dark spot.

Female had bigger and broader abdomen and an acute ovipositor (Plate 3). In male abdomen tapers posteriorly and possess claspers for holding the female (Plate 4). Adults were active at early morning hours and fly around the host plants.

Adult female laid eggs on under surface of young leaves in characteristic spiral manner and covered with waxy coat (Plate 5) the hatched out larva did not move considerable distance. So immature stages were always distributed towards the upper region of the canopy and older stages on the lower region. Natural dispersal was by flying adults and by wind.

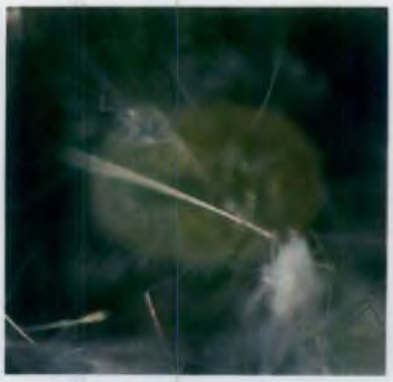
Adult longevity was 13.20 ± 2.48 days on cassava, 11.60 ± 1.42 days on tomato and 12.50 ± 2.33 days on chilli (Table 4). Fecundity on cassava, tomato and chilli was 37.10 ± 7.09, 27.60 ± 6.06 and 28.30 ± 7.63 respectively.

4.3 NATURE OF DAMAGE

4.3.1 Direct Damage

Direct damage was due to the sucking of the plant sap from foliage and tender parts of plants by nymphs and adults.

a. Egg



b. Nymph

d. Adult

c. Pupa

Plate 2 Life stages of *Aleurodicus dispersus*

Plate 3 ***Aleurodicus dispersus*** **- Female**

Plate 4 ***Aleurodicus dispersus*** **- Male**

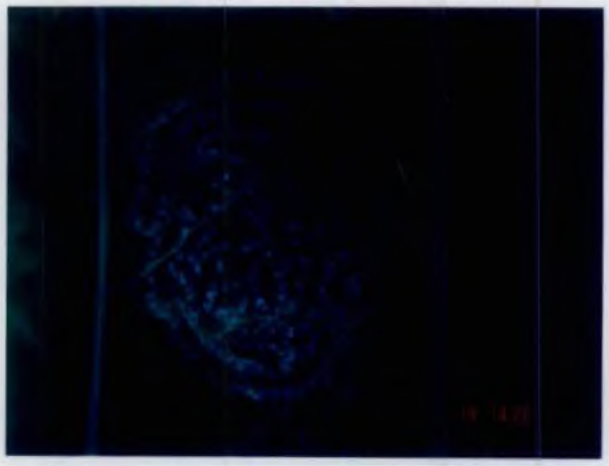


Plate 5 Egg wax spiral

4.3.2 Indirect Damage

Indirect damage was due to the accumulation of honey dew and white waxy flocculent materials. Honey dew served as a substrate for sooty mould development. This decreased the photosynthetic activity and reduced the vigour of the plant. Heavy infestation of *A. dispersus* combined with infection of sooty mould kills the plant at its early stage.

4.4 SYMPTOMS OF ATTACK

Heavy infestation of *A. dispersus* and sooty mould resulted in upward curling of leaves on cassava (Plate 6a). In tomato loss of vital sap resulted in the reduction of plant vigour and curling of leaflets. In chilli due to infestation of *A. dispersus* and consequent development of sooty mould resulted in loss of plant vigour besides the leaves becoming disfigured (Plate 6b). In banana heavy infestation on leaves resulted in crinkling and leaves became brittle due to sap loss (Plate 6c). During heavy infestation symptoms were noticed on fingers also (Plate 6d).

4.5 NATURAL ENEMIES ASSOCIATED WITH *A. DISPERSUS*

Survey carried out to record the occurrence of natural enemies of *A. dispersus* revealed the association of several species of predators *viz* nitidulid, coccinellids, syrphid and spiders.

A syrphid larva was found feeding on the nymphs of *A. dispersus* and was identified as *Allograpta javana* (Wiedeman). It was about one cm size, bluish black with light yellow bands on its abdomen (Plate 7a). There were three larval instars (Plate 7b) and completed its life cycle in 16 to 17 days on nymphs of *A. dispersus*. Pupa was initially green in colour, and later changed to black, pupal period was 7 days (Plate 7c).

Axinoscymnus puttarudriahi. Kapur and Munshi a coccinellid predator was found associated with *A. dispersus* even when the

a. Cassava

b. Chilli

c. Banana leaf d. Finger

Plate 6 Infestation of *Aleurodicus dispersus* on Cassava, Chilli and Banana

a. Adult

b. Larva

c. Pupa

Plate 7 Life stages of Syrphid predator on *Allograpta javana*

Adult

Larva

Plate 8 Coccinellid predator *Axinoscymnus puttarudriahi*

Plate 9 Spider predators of *Aleurodicus dispersus*

population of *A. dispersus* is very low in the field. This coccinellid predator feed mainly on eggs of *A. dispersus* (Plate 8).

Cybocephalus indicus Tian and Ramani, a voracious feeder of eggs and nymphs of *A. dispersus* was also collected from the field during survey. It was abundant when the population of *A. dispersus* reached peak in December – January. Two species of spiders were also found preying on eggs and nymphs of *A. dispersus*.

4.6 MANAGEMENT OF *A. DISPERSUS* USING BOTANICALS

4.6.1 Effect of Botanicals on Egg spirals of *A. dispersus* at 45 Days after Transplanting

Percentage change of egg spirals were recorded, one, two, three and four days after treatment (Table 5). The results revealed that among the formulated botanicals Neemazal 4ml l^{-1} was superior to all other treatments. One day after treatment Neemazal 4ml l^{-1} recorded 15.33 per cent egg spiral reduction and reached upto 26.41 per cent on fourth day after treatment.

Econeem 4ml l^{-1} recorded the egg spiral reduction of 7.98 per cent on one day after treatment. It is increased to 13.17 per cent on second day and reached maximum (17.66 per cent) on fourth day. It was on par with Neemazal 4ml l^{-1}

Aqueous extract of *A. paniculata* and *H. suaveolens* resulted in negligible egg spiral reduction only. One day after treatment, *A. paniculata* 5 per cent and *H. suaveolens* 10 per cent extracts had no effect on egg spirals. *A. paniculata* 10 per cent and *H. suaveolens* 5 per cent recorded 1.75 per cent and 1.3 per cent egg spiral reduction respectively.

Among the plant extracts *A. paniculata* 10 per cent recorded a maximum of 3.5 per cent reduction of egg spiral two days after treatment

Table 5. Effect of botanicals on the development of egg spirals of spiralling whitefly at 45 days after transplanting

Treatment	Percentage reduction			
	1 DAT	2 DAT	3 DAT	4 DAT
Neemazal (1% Azadirachtin) 2 ml l^{-1}	6.58 (7.52)	9.82 (7.73)	12.57 (7.91)	11.44 (7.84)
Neemazal (1% Azadirachtin) 4 ml l^{-1}	15.33 (8.08)	24.23 (8.62)	26.41 (8.74)	26.41 (8.74)
Econeem (0.3% Azadirachtin) 2 ml l^{-1}	2.17 (7.22)	8.08 (7.62)	9.75 (7.73)	11.35 (7.83)
Econeem (0.3% Azadirachtin)4 ml l^{-1}	7.98 (7.61)	13.17 (7.95)	13.17 (7.95)	17.66 (8.23)
Andrographis paniculata 5 %	0.00 (7.07)	-5.21 (6.69)	-6.48 (6.60)	-8.34 (6.46)
Andrographis paniculata 10 %	1.75 (7.19)	3.54 (7.32)	-5.36 (6.68)	-0.73 (7.02)
Hyptis suaveolens 5 %	1.30 (7.16)	1.30 (7.16)	-4.10 (6.78)	-4.10 (6.78)
Hyptis suaveolens 10 %	0.00 (7.07)	-1.90 (6.93)	4.02 (6.78)	-4.02 (6.78)
Dimethoate (0.05 %)	33.78 (9.15)	41.13 (9.55)	45.27 (9.76)	45.27 (9.76)
Water spray	0.00 (7.07)	-4.85 (6.72)	-7.38 (6.53)	-8.95 (6.41)
Untreated control	-14.00 (6.00)	-15.56 (5.87)	-16.34 (5.80)	-17.81 (5.67)
CD (0.05)	0.520	0.631	0.621	0.550

Figures in parenthesis denotes $\sqrt{x+50}$ transformed values

DAT – Days after treatment

there after there was an increase in the number of spirals on the treated leaves.

Presence of new spirals was noticed on all the plants treated with plant extracts on third day onwards. But the population count was significantly low when compared to control.

Dimethoate 0.05 per cent recorded 45.27 per cent egg spiral reduction. When compared to the chemical treatment, Neemazal 4ml l^{-1} resulted moderate effect on egg spirals.

4.6.2 Effect of Botanicals on Nymphs of *A. dispersus* at 45 Days after Transplanting

, Among the botanicals, Neemazal 4ml l^{-1} recorded highest population reduction of nymphs (Table 6). One day after treatment percentage reduction was 22.94. After that there was a steady increase in mortality upto third day and reached upto 34.40 per cent. Second best treatment was Neemazal 2ml l^{-1}. Percentage population reduction was 11.42 one day after treatment and reached upto 24.72 four days after treatment. The treatment effects of Neemazal 2ml l^{-1}Econeem 4ml l^{-1} and Econeem 2ml l^{-1} were statistically on par with percentage mortality of 24.72, 18.24 and 17.79 respectively.

Effect of *A.paniculata* 5 per cent and 10 per cent extracts and *H. suaveolens* 5 per cent and 10 per cent extracts were statistically on par on all the four days of observations. Crude extracts of *H. suaveolens* 5 per cent and 10 per cent recorded maximum population reduction of nymphs (5.99 and 6.09) one day after treatment. Percentage reduction of nymphs was 7.70 and 8.55 in plants treated with *A.paniculata* 5 per cent and 10 per cent respectively at 2 days after treatment. There after the reduction percentage showed a decreasing trend.

Dimethoate 0.05 per cent produced 66.78 per cent reduction of nymphs on fourth day after treatment.

Table 6. Effect of botanicals on nymphs of spiralling whitefly at 45 days after transplanting

Treatment	Percentage reduction			
	1 DAT	2 DAT	3 DAT	4 DAT
Neemazal (1% Azadirachtin) 2 ml l^{-1}	11.42 (7.84)	20.79 (8.42)	23.28 (8.56)	24.72 (8.64)
Neemazal (1% Azadirachtin) 4 ml l^{-1}	22.94 (8.54)	32.03 (9.06)	34.40 (9.19)	34.40 (9.19)
Econeem (0.3% Azadirachtin) 2 ml l^{-1}	9.95 (7.74)	17.79 (8.23)	17.79 (8.23)	17.79 (8.23)
Econeem (0.3% Azadirachtin)4 ml l^{-1}	10.06 (7.75)	18.18 (8.26)	19.65 (8.35)	18.24 (8.26)
Andrographis paniculata 5 %	6.79 (7.54)	7.70 (7.60)	5.61 (7.46)	0.99 (7.14)
Andrographis paniculata 10 %	8.55 (7.65)	8.55 (7.65)	3.77 (7.33)	3.77 (7.33)
Hyptis suaveolens 5 %	5.99 (7.48)	5.99 (7.48)	1.63 (7.19)	1.63 (7.19)
Hyptis suaveolens 10 %	6.09 (7.49)	6.09 (7.49)	2.09 (7.22)	2.09 (7.22)
Dimethoate (0.05 %)	42.93 (9.64)	53.69 (10.18)	59.06 (10.44)	60.78 (10.53)
Water spray	3.49 (7.31)	-3.68 (6.81)	-7.17 (6.55)	-12.30 (6.14)
Untreated control	-9.87 (6.34)	-11.42 (6.21)	-13.58 (6.04)	-15.12 (5.91)
CD (0.05)	0.414	0.417	0.479	0.546

Figures in parenthesis denotes $\sqrt{x+50}$ transformed values

DAT – Days after treatment

4.6.3 Effect of Botanicals on Adults of *A. dispersus* at 45 days after transplanting

The results are presented in Table. 7

In all the treatments, reduction in the number of adults was noticed one day after treatment. Then there was gradual increase in adult population on all treated plants. Among botanicals maximum reduction of adults was recorded on Neemazal 4ml l^{-1} treated plants (54.51 percentage) which was significantly superior to other botanicals.

The treatment second in rank was Econeem 4ml l^{-1} that produced a reduction of 35.85 per cent. This was followed by Neemazal 2ml l^{-1} (30.68 per cent) and Econeem 2ml l^{-1} (23.80 per cent)

In plants treated with aqueous extracts of *A. paniculata* 5 per cent and 10 per cent and *H. suaveolens* 5 per cent and 10 per cent, reduction of adult numbers were significantly low when compared to Neemazal 2ml l^{-1} and 4 ml l^{-1} and Econeem 2ml l^{-1} and 4ml l^{-1} treated plants. From second day onwards there was an increase in adult population on plants treated with aqueous extracts.

Plants treated with Dimethoate 0.05 per cent recorded 80.13 per cent reduction in adult population on first and second day after treatment.

4.6.4. Effect of Botanical on Egg spiral of *A. dispersus* at 60 Days after Transplanting

The results are presented in Table 8.

Among the botanicals tested, Neemazal 4ml l^{-1} caused maximum reduction of egg spirals (29.74 per cent) three days after spraying and was significantly superior to other botanicals. The second in efficacy was Econeem 4 ml l^{-1} that caused 14.26 per cent egg spiral reduction.

Table 7. Effect of botanicals on adults of spiralling whitefly at 45 days after transplanting

Treatment	Percentage reduction			
	1 DAT	2 DAT	3 DAT	4 DAT
Neemazal (1% Azadirachtin) 2 ml l^{-1}	30.68 (8.98)	25.04 (8.66)	19.56 (8.34)	15.45 (8.09)
Neemazal (1% Azadirachtin) 4 ml l^{-1}	54.51 (10.22)	47.88 (9.89)	30.83 (8.99)	30.83 (8.99)
Econeem (0.3% Azadirachtin) 2 ml l^{-1}	23.80 (8.59)	21.27 (8.44)	17.91 (8.24)	11.25 (7.83)
Econeem (0.3% Azadirachtin)4 ml l^{-1}	35.85 (9.27)	31.56 (9.03)	24.06 (8.61)	13.70 (7.98)
Andrographis paniculata 5 %	6.27 (7.50)	-5.44 (6.68)	-8.39 (6.45)	-15.11 (5.91)
Andrographis paniculata 10 %	7.08 (7.56)	2.70 (7.26)	-7.96 (6.48)	-11.13 (6.24)
Hyptis suaveolens 5 %	6.41 (7.51)	-7.51 (6.52)	-11.67 (6.19)	-11.67 (6.19)
Hyptis suaveolens 10 %	9.62 (7.72)	1.21 (7.16)	-2.63 (6.88)	-2.63 (6.88)
Dimethoate (0.05 %)	80.13 (11.41)	80.13 (11.41)	70.19 (10.96)	64.82 (10.72)
Water spray	4.07 (7.35)	-10.32 (6.30)	-15.94 (5.84)	-11.53 (6.20)
Untreated control	-9.08 (6.40)	-13.48 (6.04)	-20.21 (5.46)	-22.61 (5.23)
CD (0.05)	0.777	0.901	0.688	1.233

Figures in parenthesis denotes $\sqrt{x+50}$ transformed values

DAT – Days after treatment

Table 8. Effect of botanicals on egg spirals of spiralling whitefly at 60 days after transplanting

Treatment	Percentage reduction			
	1 DAT	2 DAT	3 DAT	4 DAT
Neemazal (1% Azadirachtin) 2 ml l^{-1}	5.45 (7.45)	10.37 (7.77)	8.70 (7.66)	5.87 (7.48)
Neemazal (1% Azadirachtin) 4 ml l^{-1}	17.26 (8.20)	25.47 (8.69)	29.74 (8.93)	27.58 (8.81)
Econeem (0.3% Azadirachtin) 2 ml l^{-1}	0.00 (7.07)	4.94 (7.41)	4.94 (7.41)	2.94 (7.28)
Econeem (0.3% Azadirachtin)4 ml l^{-1}	0.00 (7.07)	9.88 (7.74)	14.26 (8.02)	15.99 (8.12)
Andrographis paniculata 5 %	0.00 (7.07)	-3.98 (6.78)	-8.09 (6.47)	-9.78 (6.34)
Andrographis paniculata 10 %	0.00 (7.07)	-3.77 (6.80)	-6.75 (6.58)	-6.75 (6.58)
Hyptis suaveolens 5 %	0.00 (7.07)	-2.04 (6.93)	-9.90 (6.33)	-9.90 (6.33)
Hyptis suaveolens 10 %	0.00 (7.07)	-3.46 (6.82)	-6.77 (6.58)	-6.77 (6.58)
Dimethoate (0.05 %)	37.77 (9.37)	49.28 (9.96)	46.88 (9.84)	43.85) (9.69
Water spray	0.00 (7.07)	-6.68 (6.58)	-11.07 (6.24)	-12.40 (6.13)
Untreated control	-10.89 (6.25)	-22.01 (5.29)	-22.01 (5.29)	-23.36) (5.16
CD (0.05)	1.519	0.66	0.706	0.759

Figures in parenthesis denotes $\sqrt{x+50}$ transformed values

DAT – Days after treatment

Econeem 4 ml l^{-1} recorded 15.99 per cent reduction of egg spirals four days after treatment. Neemazal 2 ml l^{-1} recorded maximum egg spiral reduction two days after treatment which was on par with Econeem 4ml l^{-1} (9.88 per cent) and Econeem 2ml l^{-1} (4.94 per cent). Among the formulated products mortality of egg spirals was least in Econeem 2 ml l^{-1} (4.94 per cent).

No egg spiral reduction was recorded on plants treated with aqueous extracts of *A. paniculata* or *H. suaveolens* both at 5 and 10 per cent. Increase of egg spirals noticed on aqueous extract treated plants on second day onwards. But it was significantly low when compared to control.

Dimethoate 0.05 per cent recorded a maximum of 49.28 per cent egg spiral reduction two days after treatment. Plants sprayed with water, no reduction of egg spirals was noticed and new spirals appeared two days after treatment

4.6.5. Effect of Botanicals on Nymphs of *A. dispersus* at 60 Days after Transplanting

The results are presented on Table 9.

Among the botanicals Neemazal 4ml l^{-1} recorded 41.10 per cent nymphal reduction three days after treatment. This was followed by Econeem 4ml l^{-1} (21.27 per cent) and Neemazal 2ml l^{-1} (19.59 per cent). Effect of Econeem 4ml l^{-1} (21.27 per cent) and Neemazal 2ml l^{-1} (19.59 per cent) was on par on three days after treatments.

Econeem 2ml l^{-1} recorded a maximum mortality of 14.76 per cent two days after treatment which was on par with Neemazal 2ml l^{-1} (18.78 per cent) and Econeem 4ml l^{-1} (19.86 per cent)

Effect of aqueous extract of *A. paniculata* 5 per cent and 10 per cent and *H. suaveolens* 5 per cent and 10 per cent was significantly low when compared to formulated products *viz.* Neemazal and Econeem.

Table 9. Effect of botanicals on nymphs of spiralling whitefly at 60 days after transplanting

Treatment	Percentage reduction			
	1 DAT	2 DAT	3 DAT	4 DAT
Neemazal (1% Azadirachtin) 2 ml l^{-1}	17.73 (8.23)	18.78 (8.29)	19.59 (8.34)	20.50 (8.40)
Neemazal (1% Azadirachtin) 4 ml l^{-1}	34.22 (9.18)	36.46 (9.30)	41.10 (9.55)	40.41 (9.51)
Econeem (0.3% Azadirachtin) 2 ml l^{-1}	14.00 (8.00)	14.76 (8.05)	11.97 (7.87)	13.28 (7.96)
Econeem (0.3% Azadirachtin)4 ml l^{-1}	17.58 (8.22)	19.86 (8.36)	21.27 (8.44)	16.98 (8.18)
Andrographis paniculata 5 %	4.43 (7.38)	-0.77 (7.02)	-3.98 (6.78)	-6.15 (6.62)
Andrographis paniculata 10 %	6.20 (7.50)	-1.80 (6.94)	-4.38 (6.75)	-8.12 (6.47)
Hyptis suaveolens 5 %	5.66 (7.46)	-5.42 (6.68)	-7.80 (6.50)	-12.28 (6.14)
Hyptis suaveolens 10 %	8.78 (7.67)	1.02 (7.14)	-8.53 (6.44)	-8.53 (6.44)
Dimethoate (0.05 %)	49.42 (9.97)	64.88 (10.72)	66.10 (10.78)	67.77 (10.85)
Water spray	3.03 (7.28)	-6.11 (6.63)	-11.69 (6.19)	-14.46 (5.96)
Untreated control	-4.37 (6.76)	-13.34 (6.06)	-16.48 (5.79)	-20.25 (5.45)
CD (0.05)	0.432	0.460	0.493	0.508

Figures in parenthesis denotes $\sqrt{x+50}$ transformed values

DAT – Days after treatment

A. paniculata 5 per cent and 10 per cent recorded only 4.43 per cent and 6.20 per cent nymphal mortality one day after treatment. *H. suaveolens* 5 per cent and 10 per cent recorded 5.66 per cent and 8.78 per cent nymphal reduction respectively one day after treatment.

Second day onwards nymphal population increased on aqueous extract treated plants. Dimethoate 0.05 per cent recorded 67.77 per cent reduction of nymphs on fourth day after treatment which was significantly superior to all other treatments.

4.6.6. Effect of Botanicals on adults of *A. dispersus* at 60 Days after Transplanting

The effect of botanicals against adults of *A. dispersus* at 60 days after transplanting of Tomato are presented in Table. 10.

Among botanicals Neemazal 4ml l^{-1} recorded 53.47 per cent reduction of adults one day after treatment which is significantly superior to all other botanical treatments. Second best treatment among botanicals was Neemazal 2ml l^{-1} which recorded 30.68 per cent reduction of adults. This is statistically on par with both Econeem 4ml l^{-1} (29.61 per cent) and Econeem 2ml l^{-1} (21.14 per cent).

In aqueous extracts of *A. paniculata* 5 per cent and 10 per cent and *H. suaveolens* 5 per cent and 10 per cent reduction of adults was significantly low compared to formulated products.

Second day onwards effect of botanicals reduced gradually and population of adults were increased on treated plants.

On fourth day the number of adults exceeded the pre treatment counts. In *A. paniculata* 5 per cent and 10 per cent it was -6.59 and -3.82 per cent respectively. In *H.suaveolens* 5 per cent and 10 per cent it was-10.82 per cent and -2.08 per cent respectively.

Table 10. Effect of botanicals on adults of spiralling whitefly at 60 days after transplanting

Treatment	Percentage reduction			
	1 DAT	2 DAT	3 DAT	4 DAT
Neemazal (1% Azadirachtin) 2 ml l^{-1}	30.68 (8.98)	19.37 (8.33)	16.27 (8.14)	11.11 (7.82)
Neemazal (1% Azadirachtin) 4 ml l^{-1}	53.47 (10.17)	43.85 (9.69)	28.27 (8.85)	22.72 (8.58)
Econeem (0.3% Azadirachtin) 2 ml l^{-1}	21.14 (8.44)	18.19 (8.26)	10.89 (7.80)	7.06 (7.55)
Econeem (0.3% Azadirachtin)4 ml l^{-1}	29.61 (8.92)	25.68 (8.70)	17.44 (8.21)	15.45 (8.09)
Andrographis paniculata 5 %	6.52 (7.52)	1.93 (7.21)	-2.99 (6.86)	-6.59 (6.59)
Andrographis paniculata 10 %	7.07 (7.56)	4.57 (7.39)	1.19 (7.15)	-3.82 (6.80)
Hyptis suaveolens 5 %	5.99 (7.48)	1.35 (7.17)	-5.15 (6.70)	-10.82 (6.26)
Hyptis suaveolens 10 %	10.15 (7.76)	6.89 (7.54)	-1.22 (6.99)	-2.08 (6.92)
Dimethoate (0.05 %)	68.49 (10.89)	74.07 (11.14)	72.39 (11.06)	69.04 (10.91)
Water spray	5.32 (7.44)	1.35 (7.17)	-6.13 (6.62)	-10.93 (6.25)
Untreated control	-15.13 (5.90)	-20.32 (5.45)	-21.36 (5.35)	-25.96 (4.90)
CD (0.05)	0.557	0.778	0.716	0.568

Figures in parenthesis denotes $\sqrt{x+50}$ transformed values

DAT – Days after treatment

Dimethoate 0.05 per cent resulted 74.07 per cent reduction of adults two days after treatment. When compared to Dimethoate 0.05 per cent Neemazal 4ml l^{-1} recorded moderate effect on adults (43.85 per cent).

4.6.7 Effect of Botanical on Egg spirals of *A. dispersus* at 75 Days after Transplanting

The results are presented in Table 11.

Among the botanicals Neemazal 4ml l^{-1} was significantly superior to other treatments with an egg spiral reduction of 14.87 per cent one day after treatment and reached maximum on third day after treatment (23.22 per cent).

Econeem 4ml l^{-1} and Neemazal 2ml l^{-1} recorded 12.75 per cent and 12.32 per cent reduction respectively on second day after treatment.

Plant extracts recorded significantly lower ovicidal action than formulated botanicals. *A. paniculata* 5 per cent and 10 per cent recorded 0.86 per cent and 1.19 per cent reduction respectively. *H. suaveolens* 5 per cent and 10 per cent extracts recorded 2.25 per cent and 2.49 per cent reduction of egg spirals respectively on first day after treatment.

In *A. paniculata* 5 per cent and 10 per cent extracts treated plants, percentage increase of spirals on third day after treatment was -3.25 and -2.96 respectively. In *H. suaveolens* 5 per cent and 10 per cent extract treated plants it was -1.08 and -3.31 respectively. Dimethoate 0.05 per cent recorded 29.74 per cent egg spiral reduction on first day after treatment. Then there was steady increase of mortality which reached maximum on fourth day after treatment (47.71 per cent). When compared to Dimethoate 0.05 per cent Neemazal 4ml l^{-1} recorded only moderate ovicidal action (23.22 per cent).

Table 11. Effect of botanicals on egg spiral of spiralling whitefly at 75 days after transplanting

Treatment	Percentage reduction			
	1 DAT	2 DAT	3 DAT	4 DAT
Neemazal (1% Azadirachtin) 2 ml l^{-1}	7.25 (7.57)	12.32 (7.89)	12.32 (7.89)	11.06 (7.81)
Neemazal (1% Azadirachtin) 4 ml l^{-1}	14.87 (8.05)	19.59 (8.34)	23.22 (8.56)	23.22 (8.56)
Econeem (0.3% Azadirachtin) 2 ml l^{-1}	6.08 (7.49)	7.20 (7.56)	8.67 (7.66)	8.67 (7.66)
Econeem (0.3% Azadirachtin)4 ml l^{-1}	9.25 (7.70)	12.75 (7.92)	11.71 (7.86)	11.71 (7.86)
Andrographis paniculata 5 %	0.86 (7.13)	0.86 (7.13)	-3.25 (6.84)	-3.25 (6.84)
Andrographis paniculata 10 %	1.19 (7.15)	1.19 (7.15)	-2.96 (6.86)	-2.96 (6.86)
Hyptis suaveolens 5 %	2.25 (7.23)	2.25 (7.23)	-1.08 (6.99)	-1.08 (6.99)
Hyptis suaveolens 10 %	2.49 (7.25)	2.49 (7.25)	-3.31 (6.83)	-3.31 (6.83)
Dimethoate (0.05 %)	29.74 (8.93)	42.50 (9.62)	45.11 (9.75)	47.71 (9.89)
Water spray	-1.45 (6.97)	-1.45 (6.97)	-5.35 (6.68)	-5.35 (6.68)
Untreated control	-2.76 (6.87)	-6.62 (6.59)	-7.78 (6.50)	-10.43 (6.29)
CD (0.05)	0.393	0.426	0.392	0.425

Figures in parenthesis denotes $\sqrt{x+50}$ transformed values

DAT – Days after treatment

4.6.8 Effect of Botanicals on Nymphs of *A. dispersus* at 75 Days after Transplanting

The results are presented on Table 12.

Among botanicals Neemazal 4ml l^{-1} recorded 21.58 per cent nymphal reduction one day after treatments. On third day nymphal reduction reached 33.38 per cent on Neemazal 4ml l^{-1} treated plants. Second best treatment was Neemazal 2ml l^{-1} that caused 15.46 per cent nymphal reduction one day after treatment and increased upto 24.96 per cent on fourth day after treatment.

Econeem 4ml l^{-1} recorded maximum reduction of 20.91 per cent on fourth day after treatment which was on par with Neemazal 2ml l^{-1} (24.96 per cent).

Aqueous extract of *A.paniculata* 5 per cent and 10 per cent recorded 5.64 per cent and 5.52 per cent nymphal reduction on first day after treatment and they were statistically on par. *H.suaveolens* 5 per cent and 10 per cent aqueous extracts recorded 4.06 per cent and 8.11 per cent nymphal reduction respectively.

The effect of *A. paniculata* 5 per cent and 10 per cent and *H.suaveolens* 5 per cent and 10 per cent were on par on first, Second and third days after treatment. Water spray reduced the nymphal population by 3.04 per cent on first day after treatment. Then there was an increase of nymphal population.

4.6.9. Effect of Botanicals on Adults of *A. dispersus* at 75 Days after Transplanting

The result are presented in Table 13

All the treatments recorded a maximum reduction of adults on first day after treatment. Among botanicals, Neemazal 4ml l^{-1} recorded 46.07 per cent reduction of adults on first day after treatment, which was

Table 12. Effect of botanicals on nymphs on spiralling whitefly at 75 days after transplanting

Treatment	Percentage reduction			
	1 DAT	2 DAT	3 DAT	4 DAT
Neemazal (1% Azadirachtin) 2 ml l^{-1}	15.46 (8.09)	24.03 (8.60)	24.03 (8.60)	24.96 (8.66)
Neemazal (1% Azadirachtin) 4 ml l^{-1}	21.58 (8.46)	29.65 (8.92)	33.38 (9.13)	33.38 (9.13)
Econeem (0.3% Azadirachtin) 2 ml l^{-1}	10.75 (7.79)	13.91 (7.99)	14.73 (8.05)	15.64 (8.10)
Econeem (0.3% Azadirachtin)4 ml l^{-1}	12.87 (7.93)	17.60 (8.22)	18.40 (8.27)	20.91 (8.42)
Andrographis paniculata 5 %	5.64 (7.46)	4.94 (7.41)	2.41 (7.24)	-1.93 (6.93)
Andrographis paniculata 10 %	5.52 (7.45)	3.88 (7.34)	3.11 (7.29)	2.22 (7.23)
Hyptis suaveolens 5 %	4.06 (7.35)	4.85 (7.41)	4.02 (7.35)	2.45 (7.24)
Hyptis suaveolens 10 %	8.11 (7.62)	5.83 (7.47)	3.89 (7.34)	3.89 (7.34)
Dimethoate (0.05 %)	39.96 (9.49)	52.41 (10.12)	58.70 (10.43)	58.70 (10.43)
Water spray	3.04 (7.28)	-2.55 (6.89)	-5.47 (6.67)	-6.94 (6.56)
Untreated control	-3.68 (6.81)	-4.90 (6.72)	-8.73 (6.42)	-8.64 (6.43)
CD (0.05)	0.368	0.367	0.370	0.333

Figures in parenthesis denotes $\sqrt{x+50}$ transformed values

DAT – Days after treatment

Table 13. Effect of botanicals on adults of spiralling whitefly at 75 days after transplanting

Treatment	Percentage reduction			
	1 DAT	2 DAT	3 DAT	4 DAT
Neemazal (1% Azadirachtin) 2 ml l^{-1}	23.32 (8.56)	20.10 (8.37)	17.24 (8.20)	15.67 (8.10)
Neemazal (1% Azadirachtin) 4 ml l^{-1}	46.07 (9.80)	43.93 (9.69)	42.98 (9.64)	40.27 (9.50)
Econeem (0.3% Azadirachtin) 2 ml l^{-1}	15.91 (8.12)	16.54 (8.16)	14.08 (8.01)	10.76 (7.80)
Econeem (0.3% Azadirachtin)4 ml l^{-1}	22.32 (8.50)	17.89 (8.24)	16.74 (8.17)	13.54 (7.97)
Andrographis paniculata 5 %	8.45 (7.65)	7.11 (7.56)	5.30 (7.44)	1.35 (7.17)
Andrographis paniculata 10 %	10.25 (7.76)	8.80 (7.67)	3.38 (7.31)	1.48 (7.18)
Hyptis suaveolens 5 %	4.48 (7.38)	1.30 (7.16)	-2.44 (6.90)	-7.00 (6.56)
Hyptis suaveolens 10 %	9.05 (7.68)	4.82 (7.40)	3.43 (7.31)	1.10 (7.15)
Dimethoate (0.05 %)	71.66 (11.03)	68.83 (10.90)	68.83 (10.90)	65.88 (10.77)
Water spray	6.06 (7.49)	3.08 (7.29)	-5.15 (6.70)	-5.15 (6.70)
Untreated control	-3.98 (6.78)	-6.73 (6.58)	-7.54 (6.52)	-12.32 (6.14)
CD (0.05)	0.509	0.447	0.514	0.453

Figures in parenthesis denotes $\sqrt{x+50}$ transformed values

DAT – Days after treatment

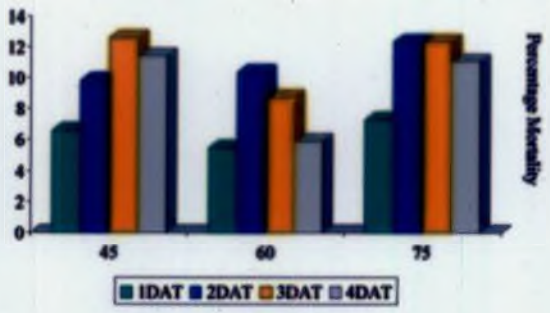
significantly superior to all other treatments. It was followed by Neemazal 2ml l^{-1} (23.32 per cent) and Econeem 4ml l^{-1} (22.32 per cent) and these two treatments were on par with each other. Econeem 2ml l^{-1} resulted only 15.91 per cent reduction of adults which was significantly lower when compared to above three treatments. Three days after treatments there was considerable increase in adult population on *H. suaveolens* 5 per cent and water sprayed plants (-2.44 per cent and -5.15 per cent respectively).

Dimethoate 0.05 per cent recorded a maximum of 71.66 per cent adult reduction one day after treatment.

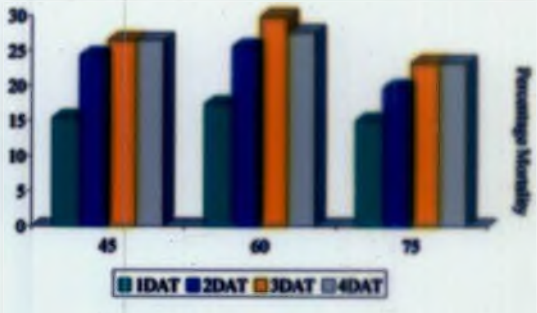
4.6.10. Persistent Toxicity of Botanicals on Egg Spirals of *A. dispersus*

4.6.10.1. Formulated Products

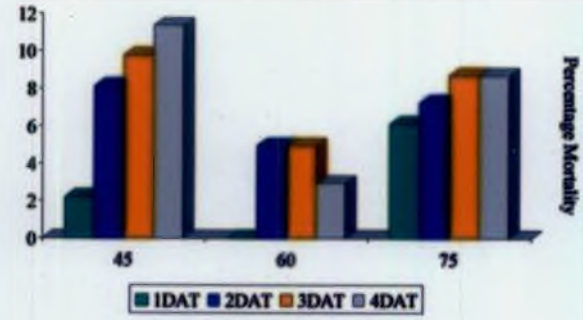
Toxicity of Neemazal 2ml l^{-1} was maximum on third day of treatment at 45 days after transplanting and 75 days after transplanting (Fig. 1). Thereafter there was reduction in percentage mortality of egg spiral. On 60 days after transplanting highest toxicity was recorded on second day of treatment. Neemazal 4ml l^{-1} showed maximum toxicity on the third day of treatment. It remain steady for one more day at 45 days after transplanting and 75 days after transplanting where as on 60 days after transplanting, there was a reduction in a mortality percentage on fourth day of treatment. Maximum toxicity of Econeem 2ml l^{-1} noticed on fourth day at 45 days after transplanting and it remained steady for third and fourth day of treatment at 75 days after transplanting. At 60 days after transplanting highest toxicity recorded on third day and then the effect reduced gradually. Toxicity was highest on fourth day in the case of Econeem 4ml l^{-1} at 45 and 60 days after transplanting, whereas it was highest on second day at 75 days after transplanting.



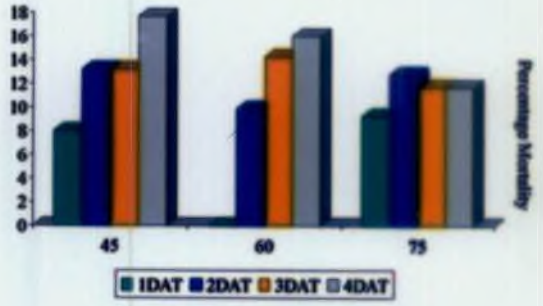
Neemazal 2ml l^{-1}



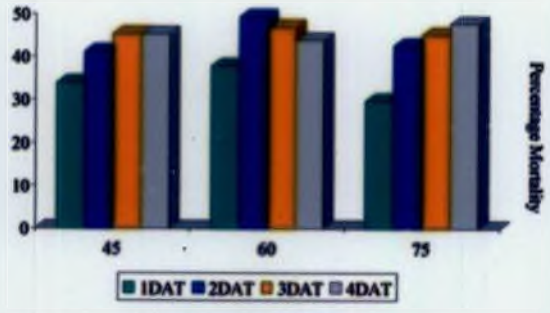
Neemazal 4ml l^{-1}



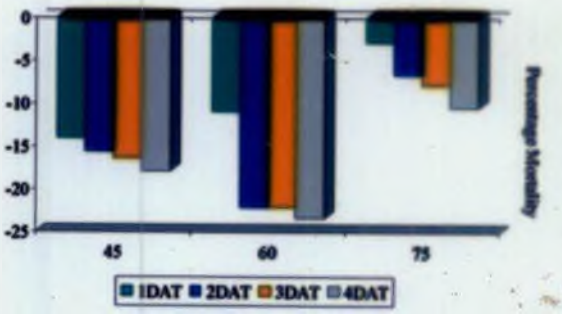
Econeem 2ml l^{-1}



Econeem 4ml l^{-1}



Dimethoate 0.05%



Control

Fig 1 : Persistent toxicity of botanical formulations on egg spirals of spiralling whitefly at 45, 60 and 75 days after transplanting

4.6.10.2. Plant Extracts

No toxic effect was noticed on egg spirals of *A. dispersus* when treated with *A. paniculata* 5 per cent at 45 and 60 days after transplanting (Fig.2). At 75 days after transplanting, on first and second day of treatment application there was egg spiral reduction. In the higher concentration of 10 per cent also toxic effect was noticed on first two days at 45 and 75 days after transplanting. There was no toxic effect at 60 days after transplanting. In the case of *H. suaveolens* 5 per cent also there was egg spiral reduction on two days after treatment at 45 and 75 days after transplanting, and no toxic effect on 60 days after transplanting. For the higher concentrations of *A. paniculata* and *H. suaveolens*, toxicity was recorded only on 75 days after transplanting for first two days.

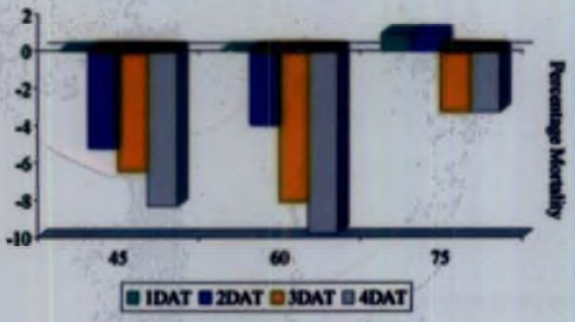
4.6.11. Persistent Toxicity of Botanicals on Nymphs of *A. dispersus*

4.6.11.1 Formulated Products

Neemazal 2ml l^{-1} showed a gradual increase of nymphal mortality and the toxicity was highest on fourth day of treatment at 45, 60 and 75 days after transplanting (Fig. 3). A higher concentration of Neemazal 4ml l^{-1} recorded highest toxicity three days after treatment and was same on fourth day also. Econeem 2ml l^{-1} recorded highest nymphal mortality on second day and was same for third and fourth day at 45 days after transplanting. 60 days after transplanting toxicity was highest on second day. There was a gradual increase in mortality from first to fourth day at 75 days after transplanting when the plants were treated with Econeem 4ml l^{-1}. The highest nymphal mortality was on third day at 45 and 60 days after transplanting and was on fourth day at 75 days after transplanting.

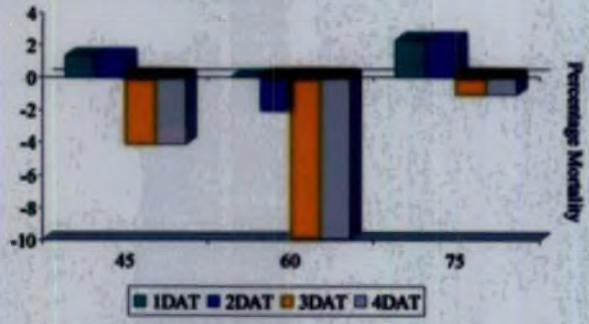
4.6.11.2 Plant Extract

A. paniculata at 5 per cent and 10 per cent concentrations recorded highest mortality of nymphs on first two days (Fig. 4) at 45 and

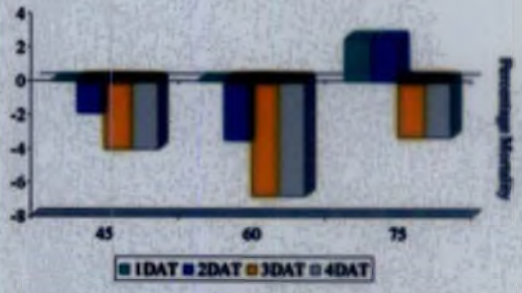


Andrographis paniculata 5%

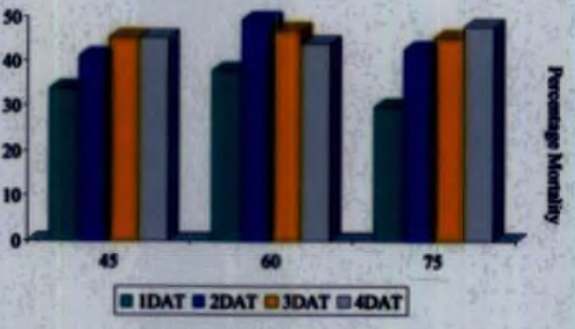
Andrographis paniculata 10%



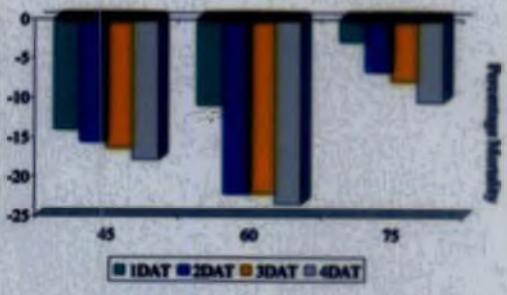
Hyptis suaveolens 5%



Hyptis suaveolens 10%

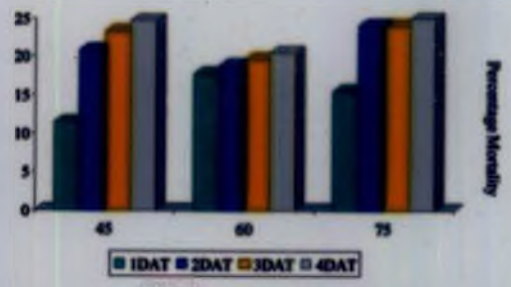


Dimethoate 0.05%



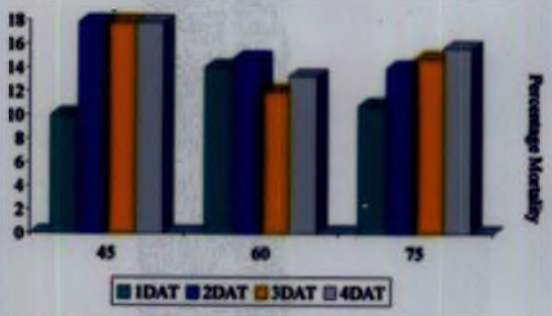
Control

Fig 2 : Persistent toxicity of plant extracts on egg spirals of spiralling whitefly at 45, 60 and 75 days after transplanting

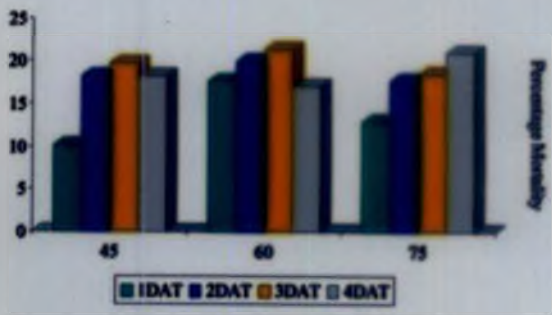


Neemazal 2ml l^{-1}

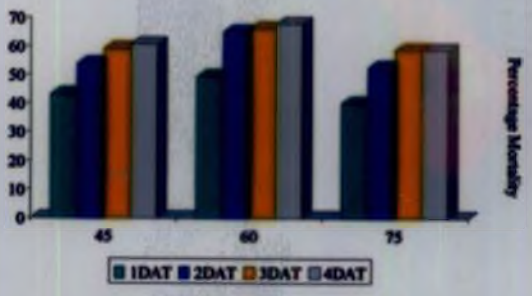
Neemazal 4ml l^{-1}



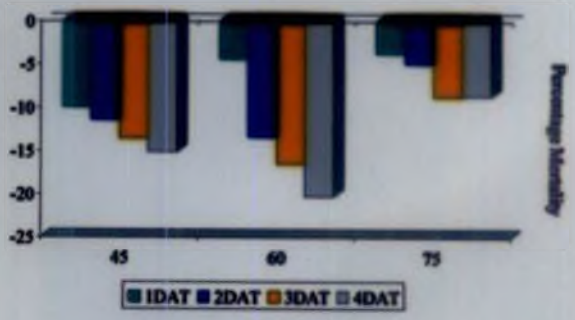
Econeem 2ml l^{-1}



Econeem 4ml l^{-1}

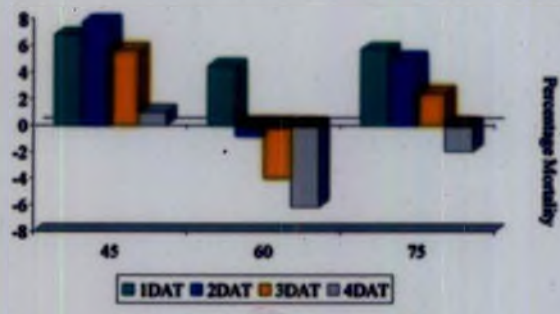


Dimethoate 0.05%

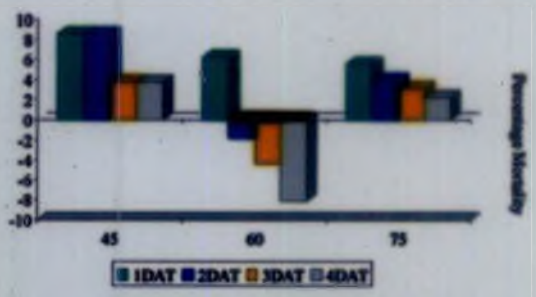


Control

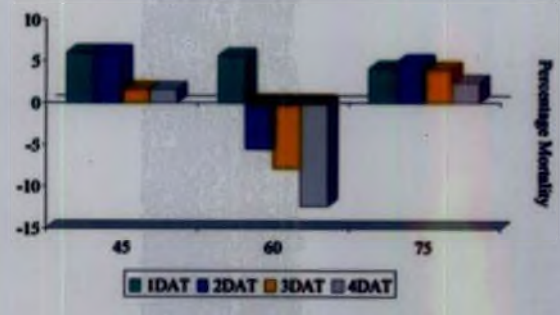
Fig 3 : Persistent toxicity of botanical formulations on nymphs of spiralling whitefly at 45, 60 and 75 days after transplanting



Andrographis paniculata 5%



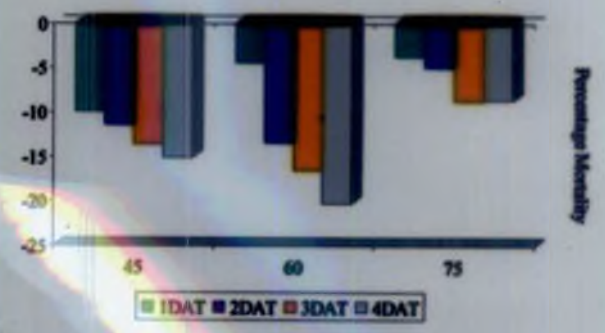
Andrographis paniculata 10%



Hyptis suaveolens 5%

Hyptis suaveolens 10%

Dimethoate 0.05%



Control

Fig 4 : Persistent toxicity of plant extracts on nymphs of spiralling whitefly at 45, 60 and 75 days after transplanting

70 days after transplanting. At 75 days after transplanting in both cases the toxic effect was noticed only for one day. Same trend was noticed for *H. suaveolens* 5 per cent and 10 per cent at 45, 60 and 75 days after transplanting.

4.6.12. Persistent Toxicity of Botanical on Adults of *A. dispersus*

4.6.12.1 Formulated Products

The adult mortality was highest on first day and thereafter there was a gradual decrease in the case both formulated products *viz.*, Neemazal and Econeem at both concentrations (Fig. 5).

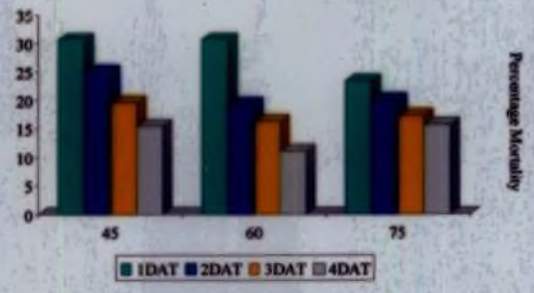
4.6.12.2 Plant Extracts (Fig. 6)

The toxic effect of *A. paniculata* was recorded only for one day at 45 days after transplanting and for two days at 60 days after transplanting. At 75 days after transplanting the toxic effect reduced gradually from first to fourth day. Adult mortality was recorded only on first day when the plants were treated with *H. suaveolns* 5 per cent at 45 days after transplanting. At 60 and 75 days after transplanting the toxic effect recorded for two days. For the higher concentration of 10 per cent, the toxic effect observed for two days at 40 and 60 days after transplanting and for four days at 75 days after transplanting.

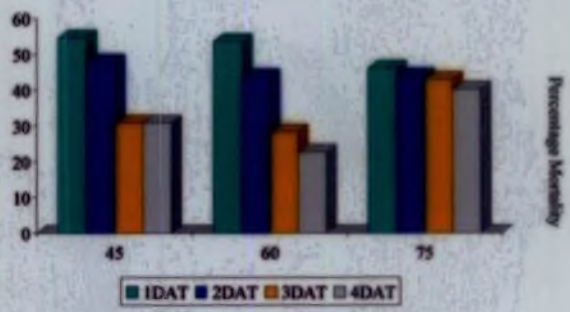
4.6.13. Effect of Botanicals on Yield and Yield Attributes of Tomato

The results are presented in Table 14.

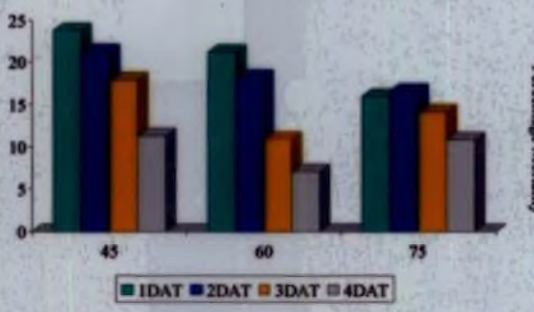
Among botanical treated plants, maximum yield was recorded on plants treated with Neemazal 4ml l^{-1} (823g/plant). All other treatments were on par. On control plants fruit yield was only 623 g/ plant which were significantly lower than Neemazal 4ml l^{-1} and Dimethoate 0.05 per cent (933 g/plant) treated plants.



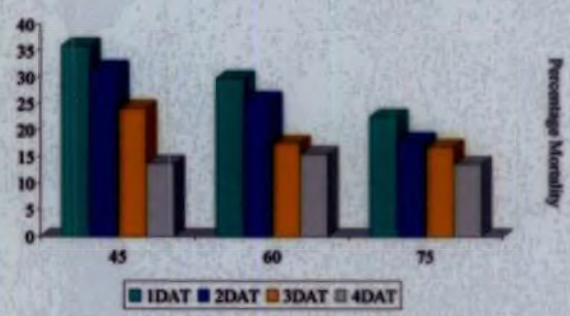
Neemazal 2ml l^{-1}



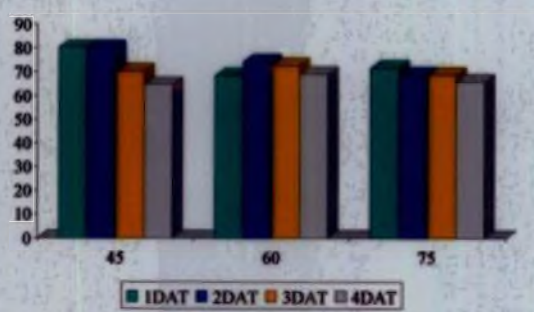
Neemazal 4ml l^{-1}



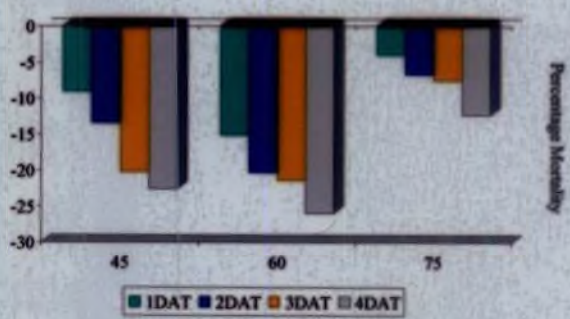
Econeem 2ml l^{-1}



Econeem 4ml l^{-1}

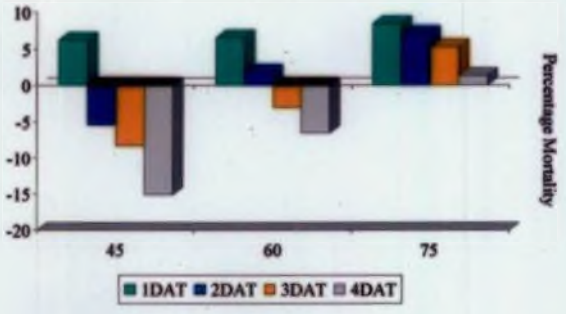


Dimethoate 0.05%

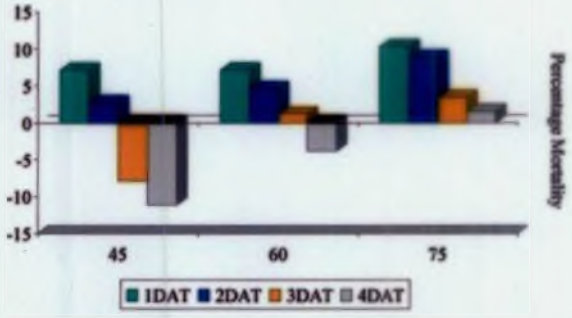


Control

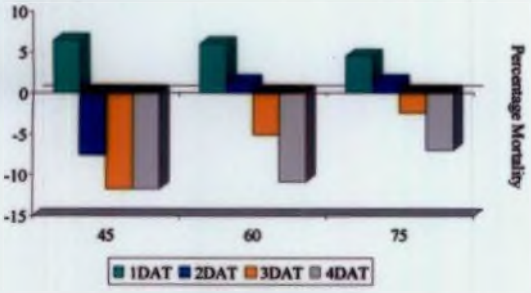
Fig 5 : Persistent toxicity of botanical formulations on adults of spiralling whitefly at 45, 60 and 75 days after transplanting



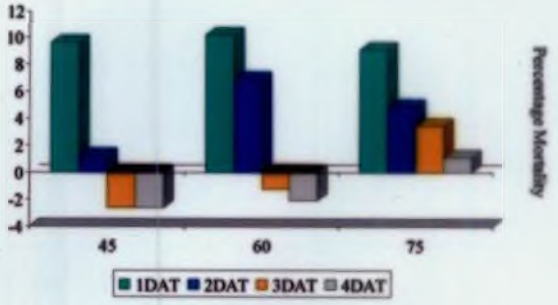
Andrographis paniculata 5%



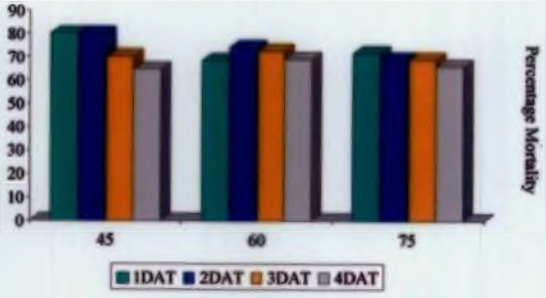
Andrographis paniculata 10%



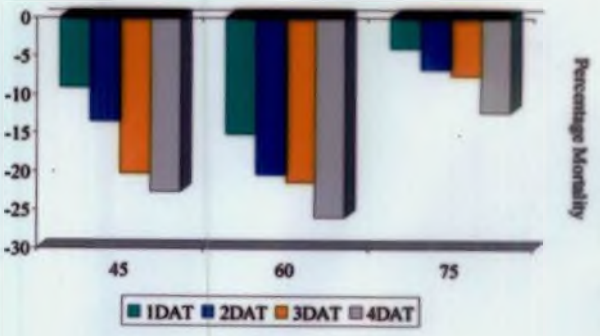
Hyptis suaveolens 5%



Hyptis suaveolens 10%



Dimethoate 0.05%



Control

Fig 6 : Persistent toxicity of plant extracts on adults of spiralling whitefly at 45, 60 and 75 days after transplanting

Table 14. Yield and Yield Attributes of Tomato

Treatment	Yield (g/plant)	Fruits (No.)	Height (cm)
Neemazal (1% azadirachtin) 2ml l^{-1}	723	55.00	84.33
Neemazal (1% azadirachtin) 4ml l^{-1}	823	63.00	84.66
Econeem (0.3% azadirachtin) 2ml l^{-1}	680	52.33	85.00
Econeem (0.3% azadirachtin) 4ml l^{-1}	727	56.00	85.00
Andrographis paniculata 5%	665	51.00	83.00
Andrographis paniculata 10%	673	52.00	82.33
Hyptis suaveolens 5%	658	50.33	81.66
Hyptis suaveolens 10%	660	50.33	83.00
Dimethoate (0.05%)	933	71.00	84.33
Water spray	623	48.00	82.66
Untreated control	633	48.33	83.33
CD (0.05)	49	3.25	-

Discussion

5. DISCUSSION

The spiralling whitefly *A. dispersus* is one of the most important polyphagous pests that invaded India. It has established throughout Kerala due to its rapid rate of multiplication and dispersal. *A. dispersus* has multitude of host plants and majority of them are wild in nature. Management of such a polyphagous pest becomes very difficult as the perennial source of its inoculam is always present in nature. As research work done on this insect in Kerala is scanty, studies were taken up on the bioecology and management of the pest.

5.1 HOST RANGE

One of the most important factors which decide the severity of a pest is its multitude of host plants. To ascertain the host range of *A. dispersus* a survey was conducted throughout the area of Instructional Farm, College of Agriculture, Vellayani for a period of one year during 2003-2004. The survey revealed that the pest attacked 50 host plants belonging to 30 plant families. The host range of the pests included vegetable crops, fruit crops, tuber crops, oil seeds, medicinal plants, spices, ornamental plants, trees and weeds. Heavy population of *A. dispersus* was observed during summer months. This may be the reason for the severity of the pest in tropical and subtropical areas of the world. Reports on the wide host range of this pest were made from several countries (Russel 1965; Chandrasekara, 1990; Kajitha *et al.*, 1991; Wen *et al.*, 1994; Lambkin, 1999). In Kerala severe incidence of *A. dispersus* was recorded on several crops by various workers (Palaniswami *et al.*, 1995; Prathapan, 1996; Ranjith *et al.*, 1996).

Among the host plants reported, the infestation of the pest was severe on 15 plant species, moderate on 17 plant species and low in 18

plant species. Weeds like *Synedrella nodiflora, Indigofera ennaphylla, Mukia bracteata* seen near in the highly infested field of cassava were free from the incidence of *A. dispersus*. Baskaran and Reddy (2003) reported that cassava was a preferred host of the insect in Andhra Pradesh. The difference in host plant preference may be due to many factors, the difference in the food value of plants to the insects (Dhaliwal and Arora, 2001), physical characters of the plants like leaf hairiness which influence the oviposition and feeding behaviour of whiteflies (Mound, 1965) being the importance.

5.2 BIOLOGY

A. dispersus adults laid elliptical eggs, covered with wax spirals. A mass of eggs were found in each spiral and each egg had a short stalk for attachment with the leaf. This stalk was hollow extension of the chorion, which was inserted into host plant stomata during oviposition through which it gets moisture from host plants (Paulson and Beardsely, 1985). The eggs were laid in typical spirals on the undersurface of leaves (Palaniswami *et al.*, 1995). The presence of egg spirals on upper surface of leaves was due to the heavy infestation of spiralling whitefly on the plants.

Incubation period showed slight variation among different host plants tested. On cassava it was 5.80 ± 0.60 days which was in confirmation with findings of Palaniswami *et al.* (1995). Incubation period on tomato was 7.60 ± 0.490 days and on chilli it was 6.00 ± 0.45 days. Incubation period may be varied with host plants and climatic conditions.

First instar nymph of *A. dispersus* is called crawler, which is the only stage with functional legs and distinct antennae (Waterhouse and Norris, 1989; Geetha, 2000). Crawler showed a tendency to congregate in a patch near the egg spiral from which they hatched out. According to Walker (1985), its movement was quick in warmer days over the leaf

surface. The crawler period was more in tomato (5.80 ± 0.40 days) when compared to cassava (4.60 ± 0.48) and chilli (4.70 ± 0.45 days). This may be due to host plant characteristics, like leaf hairiness and cuticle thickness. Second instar nymph was oval in shape and sedentary. Third instar nymph had numerous glass like waxy rods where as the fourth instar nymph pupa was soon covered with copious amount of white waxy material dorsally as tuffs (Waterhouse and Norris, 1989). Total developmental period on cassava, tomato and chilli was 21.30 ± 0.64, 26.60 ± 0.92 and 22.70 ± 0.64 days respectively. The low developmental period on cassava indicated the higher susceptibility of the crop over tomato and chilli.

Among the whiteflies, *A. dispersus* is larger with complex wing venation. Immediately after emergence adults had no waxy coat and later they were covered with white wax powders. After the emergence from the puparia adults took two to three hours for complete covering with waxy coat. It had characteristic black spots on its forewings (Gill, 1990). Adults were active during morning hours. Females lay eggs one day after emergence (Waterhouse and Norris, 1989). The circular egg pattern are produced by the concurrent feeding and oviposition and the female rotates around the point where her stylets are inserted into the leaf (Noldus and Lenteren, 1986). Adults tend to oviposit on younger leaves, thus regulating later developmental life stages to progressively older leaves. This showed that the vertical distribution is distinctly stratified with respect to different developmental stages (Ohnessorge *et al.*, 1980; Narayanaswamy *et al.*, 1999). The adult longevity and fecundity were more in cassava which once again indicated the suitability of host plant for the development of the pest.

5.3 NATURE OF DAMAGE

Spiralling whitefly caused both direct and indirect damages to the crop plants. Direct damage was caused by sucking the plant sap from

tender parts of plants by nymph and adult stages of whiteflies (Waterhouse and Norris, 1989). Indirect damage was due to the presence of sooty mould.

5.4 SYMPTOMS OF ATTACK

Heavy infestation of spiralling whitefly and sooty mould resulted upward curling of leaves in cassava. Palaniswami *et al.* (1995) reported that the feeding resulted yellow speckling, crinkling and curling of leaves.

Heavy infestation on leaf resulted crinkling and leaves became brittle due to sap loss. Coto and Metzler (1998) studied the effect of sooty mould on banana fingers. Due to heavy infestation there were significant differences in finger width and they took 10 more days for maturity.

5.5 NATURAL ENEMIES ASSOCIATED WITH SPIRALLING WHITEFLY

A total of 43 natural enemies including 40 predators, two parasitoids and a fungus were reported from spiraling whitefly (Ramani *et al.*, 2002). The predators belonging to nitidulid, coccinellid, syrphid and spider groups were recorded as natural enemies of spiralling whitefly. A very rich parasitoid and predatory entomofauna is frequently present in the country of origin of whiteflies (Waterhouse and Norris, 1989; D'Almeida, 1998). In India during the initial period of pest occurrence, only few predators were found preying on *A. dispersus*. Later, several indigenous natural enemies have expanded their host range to include this invading pest also (Mani and Krishnamoorthy, 2000; PDBC 2001). During the survey, along with the population of spiralling whitefly, *C. indicus* appeared abundantly on cassava field. It was a voracious feeder of eggs and early stages of spiralling whitefly. It was reported as predacious on diaspidid scale insects throughout the tropical, subtropical and temperate regions of the world (Blumberg and Swirski, 1974: Wang *et al.*, 1984).

Kajitha *et al.* (1991) recorded it from Indonesia on guava plants. It was reported from Minicoy Islands by Ramani *et al.* (2002). In India it was first reported by Geetha (2000) from the cassava fields of Tamil Nadu.

The syrphid predator *Allograpta javana* was reported for the first time in India on spiralling whitefly. Initially it was reported as aphidophagous in Lablab (Patro and Behera, 2002). The larva was found to be a heavy feeder of nymphs of spiralling whitefly.

A dispersus was known to be predated by about 20 species of coccinellids in many areas (Mani and Krishnamoorthy 1991). During the survey, the coccinellid predator, *A. puttarudriahi* was found feeding on the eggs of spiralling whitefly. It is whitefly specific and occurs throughout the year. The same species had been recorded earlier from Sri Lanka (Wijesekara and Kudagamge, 1990) and India (Mani and Krishnamoorthy, 1999).

Several spiders were also found associated with egg spirals of spiralling whitefly. Along with them the natural enemies in the field reduced the spiralling whitefly population to low levels.

5.6 MANAGEMENT OF SPIRALLING WHITEFLY

Synthetic chemicals do not adequately control spiralling whitefly population since the nymphs are covered with heavy waxy flocculent materials and waxy threads produced by the insect, which function as defence against chemicals (Waterhouse and Norris, 1989; Neuenschwander, 1994). Contact and systemic insecticides recommended for other pests temporarily reduce spiralling whitefly populations and at the same time they destroy the natural enemies also (Waterhouse and Norris, 1989).

Results of the present study indicated that among the formulated botanicals Neemazal 4 ml l^{-1} recorded highest reduction of egg spiral

(26.41 per cent) and nymphal population (34.40 per cent) on three days after treatments during the first spray. Adult mortality was maximum (54.51 per cent) on first day after treatment in all the treatments. During second spray at 60 days after transplanting of tomato Neemazal 4 ml l^{-1}. recorded the egg mortality of 29.74 per cent and nymphal mortality of 41.10 per cent at three days after treatment. Adult mortality recorded was 53.47 per cent, on one day after treatment. Neemazal 4 ml l^{-1} recorded the egg spiral reduction of 23.22 per cent on 75 days after transplanting and nymphal mortality of 33.38 per cent on third day after treatment. Adult mortality was the highest on one day after treatment and it was 46.07 per cent.

Eventhough Dimethoate 0.05 per cent recorded highest mortality of spiralling whitefly there are difficulties in managing them with chemical insecticides. It is reported that application of insecticides reduces the whitefly abundance only temporarily. Kajita *et al.* (1991) reported that chemical control is impracticable because of the abundance of host plants, including large trees and the widespread distribution of the spiralling whitefly.

Among the different life stages of the pest, egg stage was the least susceptible and the reduction in the population of nymphs and adults were much higher than that of egg. Waxy coating of the egg probably imparts protection by preventing them from coming into direct contact with the spray fluid.

Figures 1-6 indicated that the action of neem products was rather slow compared to that of Dimethoate which produced considerable reduction in the pest population on the first day after treatment. There after only marginal increase in effect was noticed. In the case of neem products, action was delayed and significant reduction in pest population occurred only after two days of treatment. It is well known that the organophosphorus compounds have their action on the target organism

immediately after treatment by impairing the function of the nervous system. But several plant products interfere with the growth and development by acting on the endocrine system (Retnakaran *et al.*, 1985) and by their deterrent and antifeedant properties. The delayed effect of botanicals compared to chemical insecticides is rather due to their basic difference in the mode of action.

High efficiency of Dimethoate compared to commercial neem formulations or crude plant extracts underscores the importance of conventional chemical insecticides as a vital component in the management strategies of *A. dispersus* especially in high intensity infestations. The moderate efficacy of neem products in reducing the various life stages of the pest over a period of four days indicated that neem is also a potential component in any integrated management programme. Further, lack of mammalian toxicity and safety towards beneficial organisms are added advantages of neem products (Mann and Dhaliwal, 2001).

A. paniculala and *H. suaveolens* though effective against some insect pests (Reghunath and Gokulapalan, 1999), turned out to be the least effective against *A. dispersus*. Among the neem products, Neemazal which contains more azadirachtin than Econeem was found to be more effective with significantly higher impact in majority of the treatments. The above observations regarding the impact of the treatments on the pest populations had reflected in the yield too with similar trend.

Though there was no significant difference in plant height in any of the treatments over control, there was marginal increase in height of plants which received treatments with neem products.

Based on the results of the study, destruction of weed host plants, use of neem products and there by the conservation of the natural enemies can be recommended for the management of the pest. However in high intensity infestation on economically important crops, insecticidal interventions may be necessary.

Summary

6. SUMMARY

The spiralling whitefly *A. dispersus* is one of the most important polyphagous pests that invaded India. Management of this pest is difficult because of the multitude of host plants and its rapid rate of multiplication and dispersal. The salient findings of the investigations on the bioecology and management of *A. dispersus* are summarized below.

Survey conducted in the Instructional Farm, College of Agriculture, Vellayani for a period of one year revealed that *A. dispersus* attacked 50 host plants belonging to 30 families.

Averrhoea bilimbi L, *Capsicum chinense* Jacq., *Vigna unguiculata* (L.) Walp., *Vitis vinifera* Linn, *Passiflora edulis* L., *Jacquemontia violaceae* Choisy, *Spathoglottis aurea* Lindle, *Ixora chinensis* Lam, *Alysicarpus vaginalis* (L.) DC, *Chromolaena odorata (L.)* King and Robinson and *Phaseolus* sp. were found first time in India as host plants of spiralling whitefly in the present study.

Studies on the biology of *A dispersus* on cassava, tomato and chilli revealed that cassava was the most susceptible crop when compared to tomato and chilli. In cassava, developmental period is (21.30 $\pm$ 0.64 days) low where as adult longevity (13.20 $\pm$ 2.48 days) and fecundity (27.60 $\pm$ 6.06) were high compared to tomato and chilli.

Eggs were stalked, elliptical and light yellow to tan coloured and laid in typical spiral manner on the under surface of the leaves. There were four immature stages, three nymphal and one pupal stage. First instar nymph was crawler with functional legs and antennae. Second instar nymph was sedentary with atrophied legs and the third instar nymphs with numerous glass like waxy rods. The pupa was entirely covered with white waxy material.

The spiralling whitefly caused damage to the plants by feeding plant sap from the foliage and tender parts. The indirect damage was due to the accumulation of honey dew and white waxy flocculent materials. Honey dew served as substrate for the development of sooty mould. This decreased the photosynthetic activity and reduced the vigour of the plant. Heavy infestation of *A. dispersus* combined with infection of sooty mould on host plants resulted in loss of plant vigour, unsightly appearance and reduction in yield.

During the survey, three predators were recorded from the eggs and nymphs. They were syrphid predator *Allograpta javana* (Wiedeman), coccinellid predator *Axinoscymnus puttarudriahi* (Kapur and Munshi) and a nitidulid predator *Cybocephalus indicus* (Tian and Ramani). Several species of spiders were also found preying on the eggs and nymphs.

From the management trials, it was found that among the formulated botanicals, Neemazal 4 ml l^{-1} recorded highest reduction of egg spirals, nymphal and adult population at 45, 60 and 75 days after transplanting.

Though it is efficient, the use of Dimethoate compared to commercial neem formulations or crude plant extracts underscores the importance of chemical insecticides in the management of *A. dispersus*. The moderate efficacy of neem products in reducing various life stages of the pest coupled with the environment safety indicated that it is a potential component in the integrated management programme.

Based on the results of the present study, strategies *viz.*, destruction of weed host plants, use of neem products and there by the conservation of natural enemies can be recommended for the management of *A dispersus*.

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*Original not seen

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

RANI, J.

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Department of Agricultural Entomology
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM - 695 522

ABSTRACT

A study on bioecology and management of spiralling whitefly, *Aleurodicus dispersus* Russell was carried out in laboratory and pot culture experiments at the Department of Entomology, College of Agriculture, Vellayani, Thiruvananthapuaram during the period 2003-2004.

The survey conducted in the instructional Farm, College of Agriculture, Vellayani for a period of one year revealed that *Aleurodicus dispersus* attacked 50 host plants belonging to 30 families. *Averrhoea bilimbi* L., *Capsicum chinense* Jacq., *Vigna unguiculata* (L.) Walp., *Vitis vinifera* Linn, *Passiflora edulis* L., *Jacquemontia violaceae* Choisy, *Spathoglottis aurea* Lindle, *Ixora chinensis* Lam., *Alysicarpus vaginalis* (L.) DC, *Chromolaena odorata* (L.) King and Robinson and *Phaseolus* sp. were reported for the first time in India as host plants of spiralling whitefly in the present study.

Biology of *A. dispersus* on cassava, tomato and chilli revealed that cassava was the most susceptible host plant with shorter developmental period and longer adult period and higher fecundity.

The eggs were laid on the under surface of leaves in characteristic spiral manner. Eggs were stalked, elliptical and light yellow to tan coloured. There were three nymphal instars and a pupal stage. Adult resembled tiny moths. The wings were clear first, later covered with a waxy powder.

The nymphs and adults caused damage to the plants by sucking cell sap from the tender parts of the plants. They excrete honeydew, which served as the substrate for the development of sooty mould. Heavy infestation of *A. dispersus* combined with sooty mould infection resulted in loss of plant vigour, unsightly appearance and reduction in yield.

The predators reported during the survey were *Allograpta javana* Wiedemann (Diptera : Syrphidae), *Axinoscymnus puttarudriahi* Kapur and Munshi (Coleoptera : Coccinellidae), *Cybocephalus indicus* Tian and Ramani (Coleoptera : Nitidulidae) and spiders.

Two doses each of the formulation *viz.*, Neemazal, Econeem, and plant extract of *Andrographis paniculata and Hyptis suaveolens* were evaluated with Dimethoate 0.05 per cent as check against *A. dispersus* on tomato. Three sprayings were given at 45, 60 and 75 days after transplanting. Among the formulated neem products, Neemazal 4 ml l^{-1} recorded highest population reduction of eggs, nymphs and adults of *A. dispersus* on tomato.

The neem products were of only moderate efficiency in reducing various life stages of the pest compared to Dimethoate. However, the products can be included in the integrated management of this whitefly, considering the lower toxicity to the natural enemies and environmental safety.

Based on the results of the present study, destruction of weed host plants and use of neem products can be suggested for the management of *A. dispersus*, as an adhoc recommendation.