STUDIES ON THE SUGARCANE WOOLLY APHID (SWA) *Ceratovacuna lanigera* Zehntner (Homoptera :Aphididae) AND ITS PREDATOR, *Dipha aphidivora* Meyrick (Pyralidae : Lepidoptera).

Thesis submitted in part of the requirements for the award of the degree of
Master of Science (**Agriculture**) in **Agricultural Entomology** to the
Tamil Nadu Agricultural University, Coimbatore 641003.

By

A.MALATHI,B.Sc.(Ag.)

I.D.No.04-602-009

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
CENTRE FOR PLANT PROTECTION STUDIES
TAMIL NADU AGRICULTURAL UNIVERSITY
COIMBATORE-641003

2006

STUDIES ON THE SUGARCANE WOOLLY APHID (SWA) *Ceratovacuna lanigera* Zehntner (Homoptera :Aphididae) AND ITS PREDATOR, *Dipha aphidivora* Meyrick (Pyralidae : Lepidoptera).

By

A.MALATHI,B.Sc.(Ag.)

I.D.No.04-602-009

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

CENTRE FOR PLANT PROTECTION STUDIES

TAMIL NADU AGRICULTURAL UNIVERSITY

COIMBATORE-641003

2006

ACKNOWLEDGEMENT

I place my heartful thanks to the almighty **"GOD"** for this enormous blessing without which this work would not have seen the light of the day.

It is a moment of great pleasures to place on record my deep sense of gratitude and indebtedness to **Dr.R.Balagurunathan,** Professor,Department of Agricultural Entomology and chairman of the advisory committee for suggesting this problem constant encouragement, constructive criticisms and valuable guidance during the course of the investigation.

I am very happy to express my fervent indebt ness to the members of the advisory committee, **Dr.N.Sathiah,** Professor, Department of Agricultural Entomology and, member of the advisory committee for his innumerable help, constant encouragement, valuable criticisms and keen interest during the progress of my study. I am grateful to **Dr.A.Lakshman,**Associate Professor (Agrl.Microbiology), Department of Environmental Sciences and member of the advisory committee for his constant concern and guidance during the period of study.

I wish to express my sincere and special thanks to **Dr.D.Suresh,** Professor. Department of Agricultural Entomology for timely help during the investigations.

My candid gratefulness is placed to my dear friends **Sathiya** and **Banu** for the moral support rendered during my course.

Words seem inadequate to express my thanks to **Dr.Z.Kavitha,** SRF**,** Department of Agricultural Entomology and **Dr.C.Vijayaragavan,** SRF**,** Department of Agricultural Entomology for their affection and able support during the course of my work.

I also express my thanks with ebullience to my senior friend **Mrs.P.Suganthi** SRF**,** Department of Agricultural Entomology **Mr. Arulnayagam**, AAO, Department of Agricultural Entomology and **Mr.Rajeswaran** Ph.D scholar and also my junior friend **Padmini, Ramesh, Karti, Ranjith and Prakasham** for their affability and for their help rendered during the course of my work.

I also express my thanks to my classmates **Kavitha, Devi, Aruna, Sujay, Bharathi, Kumaran, Madhu, Sakti, Jyothi** and **Anusha** for making my entire stay here pleasant and memorable.

With deep sense of love, I take this opportunity to express my beloved amma **Pattammal**, my beloved sister **Reka**, my beloved brothers **Sunder** and **Amarnath** for their in valuable support and affection towards me.

I also acknowledgement the work carried out by **Sree Kumaran Computers** TNAU, campus, Coimbatore in bringing out my thesis in a neat manner.

A. MALATHI

ABSTRACT

STUDIES ON THE SUGARCANE WOOLLY APHID (SWA) *Ceratovacuna lanigera* Zehntner (Homoptera: Aphididae) AND ITS PREDATOR, *Dipha aphidivora* Meyrick (Pyralidae: Lepidoptera).

By

A.MALATHI

Degree : **M.Sc (Agriculture) in Agricultural Entomology**

Chairman : **Dr. R. BALAGURUNATHAN**

Professor of Agricultural Entomology

Tamil Nadu Agricultural University

Coimbatore-641003

2006

Studies were carried out on the population dynamics of sugarcane woolly aphid (SWA) at Vedapatti, Coimbatore district of Tamil Nadu from September 2005 to January 2006. SWA population was more in September and less in October month. Among the predators of SWA, *Dipha aphidivora* was more predominant than the brown lace wing, *Micromus igorotus*. *D. aphidivora* population was higher during September and less in November.

Rainfall alone showed significant negative influence on the abundance of aphid population. The weather parameters had no significant influence on the population of *D. aphidivora* and *M. igorotus*. Maximum, minimum temperature and sun shine hours had positively influenced the spread of aphid within leaf, whereas, relative humidity and rainfall had negative significant effect on the spreading distance of aphid. The total number of *D. aphidivora* present in SWA colonies was proportional to the total number of SWA affected leaves.

The present study revealed that the preference of the aphid to the leaves present in the top portion of the canopy followed by middle and bottom portions. Similar trend was noticed with the preference of *D. aphidivora* and *M. igorotus*. The spread of aphid within a field patch was observed to be spiral.

Based on the comparison of the growth ratios of head capsules of the *Dipha* larvae, it was revealed that the predator underwent five larval instars. The fecundity and fertility were 91.80 ± 7.46 eggs and 95.57±8.06 per cent. The mean longevity of male and female are 3.30 and 5.87 days respectively. The total duration of life cycle of male and female are 25.33 and 28.93 days respectively.

The predatory potential study showed that the fifth instar larva consumed more aphids than other instars. On an average, the predatory larvae consumed 53.15 aphids per day. Mean feeding potential of first, second; third, fourth and fifth instars was 57.00, 134.95, 174.12, 204.07 and 217.63 aphids respectively.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER I

INTRODUCTION

Sugarcane, (*Saccharum officinarum* L.) is one of the important commercial crops in tropics and serves as the main source of sugar in the world. Globally, it is cultivated in about 19.37 million hectares with an annual production of 1252.91 million tonnes and productivity of 64.69 t/ha. In India, it is cultivated in 3.96 million hectares with an annual production of 265 million tonnes and the average recovery is 10.30 per cent. The average productivity in the country is slightly higher than the global average (66.92 t/ha). In Tamil Nadu, sugarcane is cultivated in 316440 hectares with a productivity of 109 t/ha (Sugar Situation.htm.)

Sugarcane production in India is always under threat from pest and diseases. It is known to be attacked by about 228 insect and non-insect pests in India (David and Nandagopal, 1986). The estimated loss from insects is placed at 20 and 15 per cent in cane and sugar yield respectively (Avasthy, 1977). Among the pest complex, sugarcane woolly aphid (SWA), *Ceratovacuna lanigera* Zehntner (Homoptera: Aphididae) has emerged as a serious pest in India. It is widely distributed in different countries of Asia including China, , Indonesia, Japan, Malaysia, Myanmar, Philippiness, Srilanka, Thailand and Vietnam; in Oceania covering Fiji and Pupa New Guinea (CABI,2002).The pest was reported by Zehntner during 1897 from Java for the first time. Basu and Banerjee (1958) reported that the occurrence of *C. lanigera* from Cooch Bihar in West Bengal. Later, it was reported from Assam (Gupta and Goswami, 1995) and Nagaland (Tripathi, 1995). In Tamil Nadu, SWA was recorded on a variety COG 94077 at Vellore district during April 2004 (Kalaiyarasan, 2005).

Several authors earlier reported the damage potential of this pest. Lopez (1931) reported the stunted growth of sugarcane due to continuous sap sucking by the aphid. The continuous infestation of aphid in susceptible varieties in Vietnam led to reduction in the length, circumference, weight and sugar content of the stalk (Anonymous, 1963) and in India resulted in loss in tonnage and as well as sugar recovery (Tripathi, 1995). Due to 100 per cent infestation of this pest, the juice quality was reduced considerably

(Gupta and Goswami, 1995). The heavy secretion of honey attracted black fungus causing sooty mould development on the upper surface of lower leaves and hindered the photosynthetic process (Kalaiyarasan, 2005). Hill (1993) reported that SWA infestation was so severe and caused kill of young plant in Taiwan. According to Farina (1999) the reduction in cane and sugar content were 26 per cent and 24 per cent respectively. All these reports emphasize the importance of SWA management.

Sugarcane supports many natural enemies in view of stability in its ecosystem and practically non- intervention after third to fourth month of the crop. Since, SWA is a new pest and due to the difficulty of application of insecticides and their harmful effects to the biocontrol agents which are currently used in sugarcane, resorting to non-chemical methods is highly imperative. Earlier studies showed that predators were comparatively more effective than parasitoids in controlling SWA. One such is a moth, *Dipha aphidivora* whose caterpillars feed on the nymphs and adults of the aphid (Thirumurugan *et al*., 2005).

There is an urgent need of evolving suitable control or management strategy for this pest. Considering this, detailed understanding of the ecology, nature of spread and natural enemies and their effectiveness is necessary to evolve effective pest management strategy. Given this background the present study was undertaken with the following objectives.

1. To study the population dynamics of sugarcane woolly aphid (SWA) and its natural enemies.

2. To study the spreading pattern of SWA

3. To study the biology of *D. aphidivora* and its predatory potential

CHAPTER II

REVIEW OF LITERATURE

2.1. Status of sugarcane woolly aphid

The sugarcane woolly aphid (SWA), *Ceratovacuna lanigera* Zehntner (Homoptera: Aphididae) is one of the important sugarcane pests in Southeast Asia (Takano, 1934). The woolly aphid on sugarcane was reported by Zehntner during 1897 from Java for the first time (Kalaiyarasan, 2004) . In India, it was recorded for the first time on sugarcane in Cooch Bihar in West Bengal (Basu and Banerjee, 1958) and was relegated to the status of a pest of little significance and confined to Northeast India. Later, a low level incidence was reported from Assam (Gupta and Goswamy, 1995) and Nagaland (Tripathi, 1995). In Maharashtra, incidence of *C. lanigera* was recorded for the first time in July, 2002 in Sangli district. This was the first instance when SWA attained the major pest status. Later SWA spread to Kolhapur, Satara, Pune, Solapur and Ahmednagar (Sunil Joshi and Viraktamath, 2004). From then on, it is one of the major pest problems of sugarcane growers.

In Karnataka, the infestation was first seen in Athani Taluk, Belgaum distrist in September, 2002. Subsequently, it was recorded in Raibag, Chikkodi, Hukkeri and Gokak Taluks. It assumed a serious status on sugarcane in Krishna and Ghataprabha river basin (Lingappa *et al.,* 2003). Apart from Maharashtra and Karnataka, the woolly aphid spread to Uttar Pradesh, Andhra Pradesh, Bihar and Uttaranchal (Sunil Joshi and Viraktamath, 2004). In Tamil Nadu, the SWA was recorded on a cane, COG 94077 cultivated in an extent of 40 cents at L.N. Puram village of Katpadi Taluk of Vellore district during April, 2004 (Kalaiyarasan, 2005).

2.2. Host range of sugarcane woolly aphid

C. lanigera preferred sugarcane as a primary host (Hill, 1993). Bamboo, *Miscanthus sinensis* Andersson and *Cyanodon dactylon* (L.) Pers were reported as secondary hosts by Aoki *et al.* (1984) and Anonymous (2001) respectively. SWA largely on plants of the family Poaceae. There were a few records of the aphid colonizing plants belonging to Bixaceae and Combretaceae. In Japan, the species was recorded on *Miscanthus*, but not on sugarcane (Takahashi, 1958).

2.3. Nature of damage symptoms and economic loss

Initial aphid infestation was usually on the under surface of leaves along the midrib and then over the entire under surface, covering it with flocculent waxy secretion (Ghosh, 1988). Both the nymphs and adults of SWA desapped the leaves from under surface by piercing their stylets through the stomata and caused whitish patches which coalesce and turned yellowish. Yellowing and drying of leaves from tip to downwards along both the margins of leaf was the typical symptom. The heavy secretion of honeydew attracted the black fungus causing sooty mould development on the upper surface of lower leaves, and hindered the photosynthetic process. The occurrence of aphid was noticed from the middle leaves and extended to upper leaves (Kalaiyarasan, 2005).

Mature leaves were more prone to aphid attack compared to young leaves (Uichanco, 1928). Takano (1937) observed that narrow and erect leaves were affected to a great extent while Patil (2002) found that soft, broad and drooping leaves were more suitable for aphid build-up.

Lopez (1931) reported stunted growth of sugarcane due to continuous sap sucking by aphid. The continuous infestation of aphid in susceptible varieties in Vietnam led to reduction in the length, circumference, weight and sugar content of the stalk (Anonymous, 1963) and resulted in loss in tonnage and as well as sugar recovery (Tripathi, 1995). Gupta and Goswamy (1995) assessed the effect of 25 and 100 per cent aphid infested leaves on yield and quality parameters of sugarcane and found that 100 per cent infestation had detrimental effects on the cane length (11.6 % reduction), girth (3.5 % reduction), weight (16.6 % reduction), length of internode (18.4 % reduction) and width of leaf (4.9 % reduction).

Cell-sap concentration was a major factor in inducing susceptibility in different cane varieties (Yamazaki and Arikado, 1939). Varieties with low concentration of cell sap (averaging about 4.5ºBrix) had lower infestation compared to those with high cell-sap concentration (5.9º Brix). Susceptible varieties were attacked less during rainy season due to drop in cell-sap concentration, which was around 2 to 2.7º Brix. There was considerable reduction in sucrose, Brix, glucose, purity and commercial cane sugar

(CCS) was 53.3, 32.3, 25.3, 31.7 and 64.0 respectively (Yamazaki, 1939). A Healthy cane showed 19.32 Brix. But affected cane showed lower Brix (14.25). The cane height, weight was reduced by 24.47 per cent and 22.03 per cent, respectively. The cane girth and internodal length were reduced by 24.11 per cent and 20.14 per cent respectively (Thirumurugan *et al.,* 2005). Recent estimate on the impact on SWA on the yield loss indicate that the loss in cane weight was as 10 per cent .When the incidence occurred in fifth month significant reduction in cane growth, weight and juice content were reported (PDBC Annual Report, 2006).

2.4. Seasonal occurrence

Seasonal occurrence of SWA in Okinawa was briefly described by Azuma and Oshiro (1971). They reported two peaks of abundance for aphid species in temperate regions, a large peak in spring and a smaller one in autumn. They did not find any SWA in the summer and winter. However, Arakaki (1992) observed a slow increase in abundance of aphid during winter and rapidly increased to outbreak levels in April and the outbreak levels were maintained until May. Autumn planted canes were more prone to heavy infestation in Taiwan (Cheng *et al.,* 1992). In Japan it was summer planted canes that were prone to attack (Arakaki, 1992). The colonies started developing in November and December and then gradually increased during winter, with phenomenal increase during summer. Attempts were also made in Taiwan to relate time of planting with infestation levels by comparing the length of aphid colony in spring and autumn-planted crop. The length of the colony developing on autumn-planted cane was higher compared to spring-planted cane. Measurements of the colony increased with decrease in temperature from December to February (Cheng *et al*., 1992). In Uttar Pradesh, the pest occurred during October to March (Chakrabarti *et al.,* 1972). Ghosh *et al*. (1974) reported the time of occurrence of this aphid in India to be September, December, March and April.

Apterae were observed immediately after germination and infestation increased until the minimum temperature reached 23^0C in January-planted canes in Taiwan. The population peaked between the second half of April and the second half of June. Heavy precipitation coupled with high temperatures was the factor causing decline in the aphid population. In addition, typhoons before May were detrimental to the aphid. (Cheng *et al.*, 1994). In Assam, the aphid incidence started in June and increased gradually to reach a maximum of 90.32 per cent in September (Gupta and Goswamy, 1995) and declined by January. The favorability of dry season in increasing the population in Philippines was reported by Uichanco (1928). The severe damage by aphid in Taiwan during high temperature and less precipitation was reported by Takano (1935). In Taiwan, the optimum temperature for development ranged from 20-23ºC and aphid became inactive at temperatures below 15^{o}C and above 28^{o}C. The nymphal developmental period varied under different temperature and photoperiod regimes (Takano, 1941). Suhartawan (1996) reported that an early rainy season was the major cause for infestation in Indonesia. The conduciveness of dry season with high humidity for aphid incidence was reported by Saputro *et al.* (1995).

The woolly aphid emerged before sunset and continued to emerge until early morning (Arakaki, 1989). This helped aphids to escape desiccation due to high day temperatures. The spread of the aphid from one field to another thus took place mainly due to wind. Peak take-off occurred just after sunrise, one day after emergence. Wind velocity of more than 6cm/s increased the number of aphids alighting on the plant (Arakaki, 1992).

2.5. Biology of Sugarcane woolly aphid

2.5.1. Nymphs

C.lanigera formed a colony on the under-surface of sugarcane leaves. Both alate and apterous adults propagate by parthenogenesis (Kurosu and Aoki, 1986). First – instar nymphs produced by alate females were relatively active, have long, elliptical bodies and pale greenish-white, whereas those produced by apterous female had elongated ovoid bodies (0.76mm long and 0.39mm wide) and were pale yellow-white. As nymphs developed the dorsum was gradually covered by a white powdery secretion, which obscured the body segments. The last (fourth-instar) nymph was 9.87 mm long by 1.65 mm wide and densely covered with a thick, white, cotton-like secretion on the dorsum (Noordam,1991).

2.5.2. Adults

The adult female was 1.78 mm long and 1.07 mm wide with a very soft, broad, laterally depressed body which was densely covered by white, cotton-like secretions. After approximately one month it begins the continuous production of nymphs. The cauda were constricted at the base and the anal plate was bilobed. Each lobe had long bristles on the posterior margin (Noordam, 1991).

2.6. Predators of SWA

2.6.1. *Dipha aphidivora* Meyrick (Pyralidae: Lepidoptera)

Arakaki and Yoshiyasu (1988) reported the occurrence of the pyralid throughout the year in the colonies of *C. lanigera* in the Okinawa and Sakishima islands. They opined that *D. aphidivora* could play an important role in suppressing SWA because it was not only abundant but also relatively large in body size. Surveys conducted in China from 1974 – 1984 indicated *D. aphidivora* as one of the most and important aphid – suppressing factors (Cheng *et al.*, 1994). The predator was also reported from Dimapur in Nagaland (Tripathi, 1995). A roving survey conducted by Rabindra *et al.* (2002) at Kolhapur in October, 2002 revealed that, *Dipha* was the only predator which showed promise for use in biological control programme. The efficiency of this predator in suppressing the SWA population was also reported by Shankar and Shitole, (2004).

2.6.2. *Synonycha grandis* Thunberg (Coccinellidae : Coleoptera)

It was recorded as a potential predator of SWA in Philippines (Lopez, 1931), China (Liu, 1933, Deng *et al.*, 1981, 1987), Japan (Yamazaki, 1937), Formosa (Takano and Noda, 1938) and Indonesia (Ishida, 1926). Because of its larger size and high fecundity, this coccinellid was considered as important natural enemy of SWA (Takano, 1934; Azuma and Oshiro, 1971). Rabindra *et al* (2002) observed another coccinellid, *Cheilomenus sexmaculata* Fabricius and *Harmonia octamaculata* Fabricius feeding on SWA in, Maharashtra.

2.6.3. Syrphids (Syrphidae: Diptera)

Rabindra *et al.* (2002) reported three species of syrphids viz., *Dideopsis aegrota* Fabricius, *Ishiodon scutellaris* Fabricius and *Episyrphus balteatus* De Geer to predate on SWA during a survey conducted at Kolhapur.

2.6.4. Micromus igorotus (Neuroptera: Hemerobiidae)

It was recorded as a predator of SWA in north Karnataka (Vidya mulimani, 2004). The winged forms were observed in Gudiyattum and Katpadi Taluks of Tamil Nadu (Thirumurugan *et al.*, 2004).

2.7. Scope of *D. aphidivora*

The predator is fast developing as one of the most important biocontrol agents in the SWA management. Naturally it has been reported to occur in all the cane tracts where SWA was a menace (PDBC Annual Report, 2004). In Maharastra, *D. aphidivora* occurred more in October and effectively suppressed SWA. The fluctuation in temperature in December and January severely hampered the abundance of *D. aphidivora*. In Assam, it showed significant positive correlation with maximum temperature (PDBC annual report, 2006). Attempts have been made to mass culture the predator using simple methods in shade- net condition have given encouraging results. The predator has been reported monophagous on SWA. Preliminary studies have shown that augmentation of the predator effectively reduced the incidence of the SWA in sugar cane field. (PDBC Annual Report, 2005).

2.7.1. Biology of *Dipha aphidivora*

The eggs of *Dipha* were oval and creamy in colour (Tripathi, 1992) or flat elliptical (Arakaki and Yoshiyasu, 1988) and were generally laid on aphid infested leaves either individually or in groups of 3 to 5 eggs in row on ventral surface of leaf (Vidya Mulimani *et al.,* 2004). The incubation period varied from 5 to 7 days with a mean of 6.1 days (Tripathi, 1992). However, differing reports are also available. Newly deposited eggs were milk white coloured and fertilized eggs became pink in two days. The adult laid eggs singly along the marginal part of the undersurface of mature leaf colonized densely by aphid (Arakaki and Yoshiyasu, 1988).

The newly hatched larva was greyish white but later turned to greenish and silvery lining developed on the dorsal side of its body. The body was covered with white prominent hairs. The head capsule was pinkish in colour (Tripathi, 1992). Larval period lasted 20 to 26 days (Tripathi, 1992) or 12 to 16 days (Patil, 2005) or 24.8 days (PDBC

Annual Report, 2006). The frequency distribution of head width of the larvae clearly showed four separate peaks (Arakaki and Yoshiyasu, 1988). In India, the larvae were found to possess four larval instars (PDBC annual report, 2006). The larva pupated inside the straw coloured silken cocoon, which was glued to the surface of leaves. The pupal period in October and November was 5.6 and 9.8 days respectively. Adults emerged after a pupal period of 6 to 7 days and mating occurred immediately after emergence. Sex ratio was around 1:1 (Patil, 2005). The adult emergence, mating and egg laying took place during the night. The preoviposition and oviposition periods lasted for 1.5 and 1.0 days respectively. The moth was with greyish forewing and white hind wing measuring, 10 – 13 mm (Tripathi, 1992).

2.8. Feeding behaviour of *Dipha aphidivora*

D. aphidivora showed concealed habit of feeding under laboratory conditions. When the larvae were removed from the natural habitat and released in to the jar with aphids, they started webbing galleries around the body. The predator fed on the aphids entangled in the web. The web was found extended every day till the maturity of the larvae. The larvae could move forward or backward all along the web but not side wards (Patil, 2005). Under field condition, they voraciously fed on both the nymphs and adults of the aphid by making thin silken webs adjacent to the host colony (Tripathi, 1992). Larvae constructed webs and fed on aphids from within the web on ventral surface of leaf, along the midrib. Movement of larvae from one leaf to other or from one plant to other was facilitated while hanging on a silken thread. The feeding potential was 30 to 33 aphids/day and consumed an average of 1006 aphids during its lifetime (Vidya Mulimani *et.al.* 2004).

CHAPTER III

MATERIALS AND METHODS

Investigations were carried out on the population dynamics of sugarcane woolly aphid (SWA) *Ceratovacuna lanigera* Zehntner (Aphididae: Homoptera), its relationship to weather parameters and mode of spread in natural ecosystem. Studies were made on biology and predatory potential of *D. aphidivora* Meyrick (Pyralidae:Lepidoptera) in laboratory conditions and the safety of botanicals to the predator. All laboratory experiments were carried out at the Biocontrol Laboratory of Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore. The different techniques and procedures adopted in these studies are described hereunder.

3.1. Population dynamics

The population dynamics of SWA on sugarcane (cv: CO 86032) was studied in farmer's field at Vedapatti, Coimbatore district during September 2005 to February 2006 in an area of 2.6 ha. The observations were carried out at weekly intervals (Plate.1a,1b). The field was wholly unprotected and agrochemicals for the management of insects and diseases were not applied during the period of study. The crop was observed from third month after planting. The intensity of infestation, influence of abiotic factors on SWA and occurrence of predators were studied. When the incidence commenced, twenty clumps were selected randomly in the test field in five replications for observations. From each clump, one leaf infested with aphids was selected. The aphid population was counted at two equidistant spots in 2.5-cm^2 area of the selected leaf by using a window cut paper.

In addition following grades were adopted to denote the pest intensity, based on area of the leaf covered by aphid.

Grade	Area of leaf covered by aphid (%)
0	No aphids on leaf
1	10 to 20
2	21 to 40
3	41 to 60
4	61 to 80
5	81 to 100

Observations on the number of predators, *D. aphidivora* and *M.igorotus* were carried out in one tiller/clump. Weather data viz., maximum temperature (ºC), minimum temperature (ºC), rainfall (mm), wind velocity (Kmph), relative humidity (%) and sunshine (h) of the Agricultural Meterology Unit of Tamil Nadu Agricultural University, Coimbatore was used for developing correlations as the experimental areas were nearest to the University farms. throughout the period of study.

3.2. Distribution of SWA

In an unprotected planted sugarcane (cv: CO 86032) field in Vedapatti village of Coimbatore district, the distribution of the aphid within plant was studied. The experiments were initiated when the crop was three months old. The spread of aphid, within a leaf, plant and field following initial influx was studied.

3.2.1. Spread within leaf

Thirty clumps were selected at random in a field of size 7.8 ha for observation on spread of SWA. From each clump, in each tiller, a single leaf with one founder colony of SWA was selected and tagged. Initially, the length of the founder colony was measured. Later, the length of increase or decrease in the spread of the aphid colony was recorded at weekly intervals for two months. The length of the colony at which the natural enemies appeared was noted. After the appearance of natural enemies, the extent of decrease in the length of colony was observed. The fluctuations in the population of aphid were correlated with the natural enemy population and weather parameters

3.2.2. Spread within tiller and clump

The observations were carried out on twenty five clumps selected randomly in an area of 2.6 hectares. From each clump, one tiller was selected randomly for observation. From top, bottom and middle portions of the selected tiller, the numbers of SWA infested leaves and natural enemies present were noted. Population data of SWA was correlated with weather parameter was worked out as described in previous section. The observation on the presence of aphid within the clump was carried out in the top, middle and bottom leaves separately and correspondingly the predator activity to understand the presence and sharing of niches.

3.2.3. Spread within field

The study on spreading pattern of SWA from plant to plant after commencement of initial incidence due to immigrant population was initiated in three months age crop. A square plot of (12 x12 m) with ten rows and eight to nine clumps per row was demarcated in the centre of the field of area 7.8 ha and all the clumps were observed daily for the appearance of SWA colony. When the founder colony was first observed, the spot was tagged and the spread of aphid from that spot in different directions in all the clumps was observed at weekly intervals for a period of five weeks. (November to December, 2005). The observations were mapped to understand the spreading pattern.

3.3. Studies on *D. aphidivora*

Laboratory investigations were carried out on biology, predatory potential and safety of botanicals against larval stages of *D. aphidivora* using laboratory – bred population. To obtain uniform batches of the predator, laboratory multiplication was taken up. The procedure followed is described hereunder.

3.3.1. Culturing of *D. aphidivora*

3.3.1.1. Culture establishment

Field collected larvae from SWA infested plots during October – December 2005 were transferred to the plastic containers (17x16 cm) 15 larvae/container and maintained in Biocontrol laboratory of the University at room temperature. Live aphids were dusted inside the containers as feed to the larvae. Four leaf blades (10 cm) of sugarcane were transferred to each of the container (Plate 2.a). The feed was changed alternate days and rearing was continued until the pupation.

3.3.1.2. Adult handling

The pupae obtained from the field population were kept in a 30x30x30 cm adult emergence cage (Plate 2.b). A day after emergence, ten pairs of adults was transferred to containers (17x19 cm) for mating and oviposition. Adults were fed with ten per cent sugar solution enriched with ABDEC vitamins. This was provided in a 5 ml glass vial with a cotton wool wick. The top of the container was covered with black colour muslin cloth, which served as oviposition substrate.

3.3.1.3. Egg and larval handling

The muslin cloths with eggs were collected from fourth day onwards and kept in the plastic containers under saturated atmospheric condition, to prevent desiccation. When the eggs hatched, the aphids were dusted on the muslin cloths itself to prevent the mechanical injury to neonate larvae while handling. When the larvae reached second to third instar stage, they were transferred to plastic containers with aphids for rearing and maintained till pupation. The culture process was repeated thereafter from egg to adult stages continuously. From this stock, insects were used for further studies described in subsequent sections.

3.3.2. Biology studies

The adults obtained from the culture (section 3.3.1.3) were used for conducting the biology studies. Ten pairs of healthy adults were transferred to plastic containers (17 x 19 cm) and maintained as described in previous section. Egg-laden muslin cloths were collected and kept in plastic container for eclosion. Neonate larvae (within 8h) were collected immediately and allowed on leaf blades (10 cm) which were inserted vertically in polypots containing agar - based medium to maintain the turgidity of the leaf as per procedure developed by Sathiah (2005 - unpublished report) (Plate 2.c). Whenever the leaf blades appeared to turned yellow which happened 4 -5 days after implanting, they were replaced with the fresh ones transferring the larva to that fresh leaf blade. The experiment was initiated with 50 larvae.

Observations were recorded on the incubation period and duration of different instars, prepupal and pupal period. After the adult emergence, adult longevity, fecundity, preoviposition, oviposition and egg periods were noted. To determine the number of larval instars and the duration of each instar, the head widths of 15 larvae in three replications maintained separately as described above from eclosion were measured daily using image analyzer (Carl Zeiss®) by destructive sampling. Each of the metamorphic stage was observed randomly.

3.3.3. Predatory potential

The experimental setup (Plate 3.d) consisted of a plastic container with agar-based medium (Sathiah, 2005 unpublished report) and the container was covered with a lid, having a slit (2x4 cm). A sugarcane leaf blade (10 cm) was inserted through the slit of the lid. The part of the leaf inside the container was without the aphid. A filter paper was cut into the size of the lid and was placed on that. The total number of aphids on the leaf bit was counted. Then the larvae of *D. aphidivora* at different instars (I, II, III, IV, and V) were released on the leaf blade at the rate of one per leaf bit. The total set up was covered with another plastic container (15.5x5.5 cm). The leaf bits were changed daily at the time of observation in order to avoid the error in counting by the newly produced aphids. The observation on the number of aphids consumed by each instar was taken regularly at 24 h interval and this was calculated by the following formula.

Number of aphids consumed by each instar = Total number of aphids on the leaf bit before the release of larva- (total number of aphids on the leaf bit after 24 h + number of aphids on the filter paper)

3.3.4. Safety of botanicals

3.4.1. Preparation of extracts

The details of the botanicals tested for their safety to *D. aphidivora* are furnished in Table 1.The leaves and seeds of the botanicals were collected from the premises of Agricultural College and Research Institute, Coimbatore except rhizomes of sweet flag, which were collected from local market, Coimbatore and tested at 5 and 10 per cent concentrations. Aqueous extracts (100ml) were prepared freshly in 0.01 per cent teepol containing distilled water at the time of experiment. Extracts from kernel and rhizomes were prepared by soaking overnight. Coarsely powered material in distilled water and filtered and volume made up to 100 ml.

3.9.2. Bioassay

The leaf dip method originally described by Hirano (1979) and improvised by Tabashnik and Cushing (1987) was adopted. Sugarcane leaf blade infested with aphids was dipped in the test solutions for a minute. The excess fluid from blade was drained and shade dried for an hour. Then the leaf bits were transferred to 17x16 cm plastic containers (3/ container) having the agar medium. One hour pre- starved larvae were released 3/ leaf bit. Each treatment had 30 larvae in three replications.

The larvae were allowed to feed on treated aphids for a period of 24 h. Then on, the larvae were provided with fresh, untreated aphids. The mortality of the larvae was observed periodically at 24 h interval. The number of larvae transformed to pupae and the number of adults emerged were observed separately for each treatment. The safety test was carried out for each instar separately.

3.10. Statistical Analysis

Analysis of variance was carried out for the field experiment by Randomized Block Design (RBD).The data gathered were transformed into corresponding angular and square root values wherever necessary (Gomez and Gomez, 1984) and subjected to analysis of variance and the means compared by Least Significant Difference (LSD).

CHAPTER IV

RESULTS

Investigations were carried out on the population dynamics of sugarcane woolly aphid (SWA) and the spread of aphid at Vedapatti, Coimbatore district of Tamil Nadu from September 2005 to January 2006. Studies on the biology, predatory potential of *Dipha aphidivora* and the spread of aphid and safety of botanicals were carried out in the laboratory. The results of the experiment are given below.

4.1. Population dynamics of SWA and its natural enemies

Studies on the population dynamics of sugarcane woolly aphid were carried out at Vedapatti, Coimbatore District, from September 2005 to January 2006 to find out the population fluctuations and also the favorable periods for the activity of the pest and its relation to weather parameters *viz*., maximum temperature°C (x_1), minimum temperature°C (x_2), rainfall mm (x_3), relative humidity per cent (morning x_4 and evening x_5), wind speed Kmph (x_6), and sun shine hours (x_7).

Totally 22 weeks observations were carried out. The data revealed that the population of aphids/2.5 sq. cm ranged 25.01 to 54.68 on monthly basis. Within a month also, there were fluctuations in the density of SWA. Among the different periods September ’05 was found significantly favourable for the aphids followed by November ’05 and January ’06 (Table 1, 2).

Similar trend was observed in the pest intensity rating and percentage clump infestation. The infestation grade was significantly the maximum (2.01 on a scale of 6) during September and November (2.09) months and fluctuated between 1.25-1.84 on a scale of 0-6 during the remaining part of the study period. A maximum of 36.25 per cent clumps were infested during September ’05 only which was followed by 32.92 per cent during November’05 and January’ 06 (31.87%). Throughout the period of study the aphid population/2.5 sq.cm, intensity of infestation and clump infestation were significantly low during October’05 (Table 2) and within the month also there was limited fluctuations (Table 1).

Observations recorded on the predators revealed that, *D. aphidivora* outnumbered *M. igorotus* throughout the season. On monthly average basis, the population of *D. aphidivora* ranged 1.55 to 3.33 larvae/leaf whereas; it was 0.33-0.78/leaf for *M. igorotus*. There were two peaks of activity significantly for the lepidopteran predator (September' 05: 3.33/leaf; January' 06: 2.76/leaf) whereas, three peaks were observed against of the heamarobiid predator (Table 2; Fig.1). The population fluctuations were found to significantly vary within the cropping seasons (Table 2).

Multiple regression analysis of the weather parameters with SWA showed that only rainfall had negative effect on the build up of aphid (slope 'b'= 0.301±0.084; r^2=0.588). Other parameters weakly correlated with the SWA population and were non-significant (Table 3). The behaviour of both the predators appeared independent of weather parameters. The weather parameters had no significant effect on the abundance of *D. aphidivora* (r^2 = 0.460; Table 4) and *M. igorotus* (r^2=0.172; Table 5).

4.2. Spread of SWA

4.2.1. Spread within leaf

Observation recorded on the incidence of the aphid showed that the initial influx commenced at 105 days after planting (DAP) under unprotected condition. During the first five weeks the aphid colony increased in length from 0.42 to 33.14 cm linearly on the vertical surface of leaf blade (Fig.2). The occurrence of *D. aphidivora* was only after the influx of aphid and its activity was noticed from 119 DAP. In the succeeding weeks, corresponding to an increase in prey colony length, the predator population increased from 0.67 to 10.00 larvae per blade which led to reduction of colony size. Seven weeks after incidence the aphid colony length decreased to 4.71cm where is the predator larvae population increased to 10.00 per leaf (Fig.2).

Simple correlation between the weather parameters and this spread of aphid within the leaf showed that the variables maximum temperature, minimum temperature and sunshine were positively correlated. Among them minimum temperature showed highest relationship. Evening relative humidity (%) and rainfall showed negative relationship, in that the former was strongly correlated than latter. Among the variables wind speed and relative humidity (% morning) had not influenced the spread of aphid within the leaf blade (Table 6).

Observations were recorded on the number of SWA affected leaves, and its natural enemies in the top, middle and bottom portions of the tiller. The present study revealed the preference of the aphid to the leaves present in the top portion of the tiller followed by middle and bottom portions (Fig.3). The same trend was noticed with the population of *D. aphidivora* and *M. igorotus* (Fig.4 and Fig.5).

4.2.2. Spread within plant

Similar to the previous experiment the incidence commenced on 105 DAP in the field. Observations recorded from September '05 to January '06 showed that within a tiller 4.04 to 5.83 leaves were colonized by the aphid. Colonization was intense between September '05 to January '06 except October '05 when the SWA colonized leaves decreased marginally. However only october month maximum number of *D. aphidivora* (23.61 larvae/tiller) were noticed which was on par with *D. aphidivora* activity periods during September '05 and January '06. Almost a similar trend was observed with *M. igorotus*, however at lower level ranging from 1.26 to 1.51 grubs/tiller (Table 7). Multiple regression analysis between the total number of affected leaves and other variables indicated that *D. aphidivora* alone showed significant relationship (slope 'b' = 0.1237±0.0412; R^2 = 0.629) whereas with others the relationship was found insignificant (Table 8).

In assessment of the aphid colonization and predator activity in the plant canopy during September '05 and January '06 revealed that within a clump the SWA was found in top leaves except the crown. This was the observed trend irrespective of the crop growth period and the population of the top leaves colonized among the three tiers (top, middle and bottom) ranged from 36 to 61 per cent. The order of preference was top leaves> middle leaves > bottom leaves (Fig.3). Within the canopy the predators *D. aphidivora* and *M. igorotus* were found to co-exist. While, *D. aphidivora* followed the trend of SWA colonization pattern throughout the periods of observation (2.40 – 4.83 larvae/ leaf) on the top leaves in canopy. The activity of *D. aphidivora* was in the order top leaves> middle leaves > bottom leaves (Fig.4) However *M. igorotus* activity was low unlike *D. aphidivora* and it continued to the top and middle leaves (Fig.5).

4.2.3. Spread within a field patch

During the course of study the aphid was found to colonize the field in patches. Hence observations were taken in an unprotected field on the nature of spread. The monitoring commenced in three months old crop. Incidence commenced on 26.11.2005 (112 DAP) in the demarcated plot of size 12 x 12m. The initial immigration occurred randomly and founder colony was observed in one location (Fig. II). During the subsequent weeks of observations newer incidences were observed (P_1 to P_4). However uninfested areas were also observed indicating non-uniformity in infestation. When the spreading pattern was mapped, it emerged that the aphid spread horizontally and vertically was spiral (Fig.6).

4.3. Biology and morphometrics of the predator of SWA, *D. aphidivora*

4.3.1.Egg

The freshly laid eggs were small, oval shaped and creamy white in colour (Plate 3.a). The mean length and breadth of the egg was 1.10±0.32 and 1.09±0.31 mm respectively (Table 10). The incubation period ranged from 3 to 4 days with a mean of 3.27 ± 0.92 .The egg hatchability was 95.57 per cent (Table 9).

4.3.2. Larva

4.3.2.1. First instar

The newly hatched larva was yellowish white in colour and the head capsule was light brown (Plate 5a). The mean length and breadth of the larva were 1.42 ± 0.27 and 1.33 ± 0.19 mm respectively (Table 10). First instar larval duration was completed in 3 to 4 days with a mean of 3.30 ± 1.19 days (Table 9)

4.3.2.2. Second instar

The second instar larva was similar to that of the first instar (Plate 5b). The mean length and breadth of second instar larva was 3.15 ± 1.00 and 1.75 ± 0.31 mm respectively (Table 10). The duration ranged from 3 to 4 days with a mean of 3.30 ± 0.15 (Table 9). The differentiation between head and thoracic regions was not discernable.

4.3.2.3. Third instar

The headcapsule colour intensified to dark brown in this stage. The larva was light green in colour (Plate 5c). The mean length of third instar was 5.70±0.36 mm and the mean breadth was 2.68±0.38 mm (Table10). It took 2 to 3 days to complete this stage with a mean of 3.00±1.53. (Table.9)

4.3.2.4. Fourth instar

The larva resembled the third instar in appearance (Plate 5d). The mean length and breadth of fourth instar was 9.99 ± 0.96 and 3.36 ± 0.50 mm respectively (Table 10). The duration ranged from 2 to 3 days with a mean of 2.40 ± 1.23 days (Table 9)

4.3.2.5. Fifth instar

The fifth instar larva was similar to that of the fourth instar larva (Plate 5e). The mean length and breadth of fifth instar larva was 10.69 ± 0.92 and 3.81 ± 0.0.25 mm respectively (Table 10). The average duration was 2.30 ± 0.92 days. (Table 9)

4.3.2.6. Prepupa

The average length and breadth of the pre pupa was 8.57 ± 0.31 and 4.37 ± 0.08 mm respectively (Table 10). The duration ranged from 1 to 2 days with a mean of 1.33 ± 0.92 (Table 9; Plate 3f).

4.3.2.7. Cocoon

The larvae formed a loose rusty white cocoon (Plate 4c). The average length and breadth of the obtect pupa was 6.25±0.59 and 2.70±0.44 mm respectively (Table 10). The average pupal period was 5.60±1.03 days. The percentage of pupa formed was 98.94. (Table 9).

4.3.2.8. Adult

The adult was ash brown in colour (Plate 4d). The forewings had two black spots one on each, on the posterior region of the wing. Hind wings were transparent, greyish white in colour. In female, the fore and hind wing expanse were measured as 7.45 ± 0.61and 6.09 ± 0.54 mm respectively. In male, the fore and hind wing expanse were measured as 6.05 ± 0.54 and 4.32 ± 0.90 mm respectively (Table 13). The antenna was of setaceous type in both sexes. Males are smaller than females. The body length of the female ranged from 11.69 to 12.85 mm with a mean of 11.99 ± 0.19 mm. Body length of the male ranged from 6.87 to 7.41 mm with a mean of 7.52 0.31 mm (Table 13), The adult emergence occurred during early (19.30 to 20.30 h). The adult emergence percentage was 96.24.

4.3.2.9. Premating, Preoviposition and Oviposition period

Premating ranged from 1.25to 2.40 hrs with an average of 1.86 ± 1.11. Preoviposition period of *D. aphidivora* ranged from 2 to 3 days with a mean of 2.67 ± 0.98. The oviposition period lasted for 1 to 2 days with an average of 2.33 ± 1.03 days (Table 9).

4.3.2.10. Fecundity and fertility

The total number of eggs laid by a female moth ranged from 59 to 96 eggs with an average of 91.80 ± 77.46. Fertility was 95.57 per cent (Table 9).

4.3.2.11. Longevity

Male longevity ranged from 3 to 4 days with a mean of 3.33 ± 1.03. Female longevity ranged from 5 to 6 days with a mean of 5.87 ± 1.55 (Table 9). Females lived longer than the males.

4.3.2.12. Total life cycle

The total duration of life cycle of male ranged from 25 to 27 days with a mean of 25.53 ± 2.62 days and of female ranged from 28 to 30 days with a mean of 28.93 ± 1.67 (Table 9).

4.4. Determination of larval instars

Data on the width of the headcapsules of *D. aphidivora* are presented in Table14.The series of head capsule width measurements ranged from 0.941 to 2.922 mm throughout the larval period. The mean head capsule widths of first, second, third, fourth and fifth instars were 0.941, 1.299, 1.761, 2.357 and 2.922 mm respectively (Table 11). Headcapsule measurement of fifth instar larva represented an increment of 67.8 per cent over the first instar larva. The larval durations ascertained for first, second, third, fourth and fifth instars were 3.30, 3.30, 3.00, 2.40 and 2.30 days respectively (Table 9).

4.5. Predatory potential of *D. aphidivora*

The data on the number of SWA fed by larvae of *D. aphidivora* is presented in Table17. There was significant difference between prey consumption among the different larval instars of the predator. The feeding potential of *D. aphidivora* larva progressively increased from first to fifth instar. The larva consumed more aphids during the fifth instar stage followed by fourth, third, second and first instar. There was also significant difference between the daily consumption by first and fifth instars. Mean daily consumption by first, second, third, fourth and fifth instar was 28.35, 44.01, 57.66, 66.87 and 78.23, aphids respectively. On an average, the larvae consumed 53.15 aphids per day. The average feeding potential by first, second, third, fourth and fifth instars were 57, 134.95, 174.12, 204.07 and 217.63 aphids respectively (Table12) (Fig.7). During the entire period of development from first to fifth instar, a single larva consumed 812.52 aphids.

CHAPTER V
DISCUSSION

The results obtained from field and laboratory studies conducted on population dynamics and mode of spread of sugarcane woolly aphid (SWA), predatory potential and biology of the predator of SWA, *Dipha aphidivora*, and safety test of botanicals to *D. aphidivora* are discussed in this chapter.

5.1. Studies on the population dynamics of sugarcane woolly aphid (SWA) and its natural enemies

In the present investigation, it was observed that the aphid population, the pest intensity rating and percentage clump infestation were more in September, followed by November, January and December.

Between the standard weeks 40-48 and the 50th week there was intermittent and heavy precipitation and the highest was received during October 2005 (Appendix 1) corresponding the population of aphid, grade of infestation and per cent clumps infested decline insignificantly to a low level than other periods. Multiple regression analysis also confirmed the inverse relationships between rainfall and SWA activity. Other parameters had not exerted significant influence (Table 4-6) following rains. During October ’05 the aphid activity increased (Table 3-4). This indicted that the aphid had high degree of resilience and colonize the crop within a short time span. This is in agreement with the earlier report of Ghosh (1974), that aphids were abundant in India during September, December, March and April. However, Arakaki (1992) observed a slow increase in the abundance of aphid during winter. The present investigation was limited to a brief period. Hence, the dynamics of aphid February to September has to be studied. Further, to ascertain the dynamics in a complete year.

The data on the predators activity showed that *D. aphidivora* and *M. igorotus* were significantly present in SWA infested plots. Both the predators were found to occur simultaneously but *D. aphidivora* colonized in the niche very effectively. Reports in the other parts of the country were SWA was a menace indicated the presence of both these predators in varying degrees of abundance (Rabindra *et al.,* 2002). The occurrence of these predators during 22 weeks observations indicated natural check on the buildup of SWA (Table 2-3). Following intense precipitation during October 2005 (Appendix 1), there was gradual decrease in the activity of predators (Table 3). This could have been due to reduction in the availability of the prey aphid for the two predators rather than due to the abiotic factors which had not relationship with them (Table 5, 6).

This finding is in contrast to Arakaki (1992), who stated that the predator was not abundant during winter. But, Arakaki and Yoshiyasu (1988) revealed the activeness of this predator throughout the year in the colonies of *C. lanigera* in the Okinawa and Sakishima islands without aestivation or hibernation. They also opined that *Dipha* might play an important role in suppressing SWA because it was not only abundant but also relatively large in body size. Other finding in India, (Saputro *et al.* 1995), indicated conduciveness of dry season with high humidity for aphid incidence. Further, the severe damage by aphid during high temperature and less precipitation was also reported by Takano (1935) in Taiwan and by Uichanco (1928) in Philippines.

One of the founding principles in nature is the ability of natural enemies to be present in the ecosystem, might be in low numbers in the absence or meager presence of their host or prey species. These two predators in the present study were present through out with limited oscillations. A viable strategy for exploiting these predators is sound augmentation programme. Sugarcane is a semi- perennial crop with least disturbance among all the commodity crops can fit very well for such augmentation abilities. Laboratory bred predators of these kinds can be augmented to accelerate the natural check already being exercised by the native predatory fauna.

In the present study, it was found that the aphid preferred the leaves present in the top portion of the tiller followed by middle and bottom portions and the same trend was noticed with the occurrence of *D. aphidivora* and *M. igorotus*. The total number of *D. aphidivora* present on the leaves was directly proportional to the total number of SWA affected leaves.

5.2. Spread of the aphid

Studies conducted under unprotected condition in field indicated that SWA appeared first and colonized leaf blades. The appearance of *D. aphidivora* was found sequential and its activity resulted in reduction of colony size (Fig. 2). The spread of aphid was determined significantly by weather parameters (Table 6). This is in corroboration with finding of Cheng *et al*., (1992) who reported the increase in the length of colony with the decrease in temperature. Within the tillers per plant the infestation was closely followed by predators (Table 7) and extent of colonization was influenced by *D. aphidivora* (Table 8 'b'= 0.124 ± 0.0041; R^2= 0.629). Within clumps the aphids before to infest the top leaves during the grand growth phase than the middle and bottom leaves (Fig. 3). This could be due to several factors such as succulence of leaves, nutritional status and favourable physical conditions of the leaves. Patil (2002) found that soft, broad and dropping leaves were more suitable for aphid – buildup. In the present study withsin a patch the aphids were found to spread radically from plant to plant upon initial influx (Fig. 6). Observations indicated that the spread occurred in quick succession. Two important points have emerged in the study. The rate of colonization within the leaf, blades was influenced more by certain abiotic factors and when colonies have established, the spread was influenced by biotic forces particularly *D. aphidivora* that shared this same niche as that of the prey. The predator was also found to behave independent of weather factors (Table 4). The asynchrony in occurrence could be manipulated through controlled release of *D. aphidivora* in the zones of occurrence before they colonize intensely and spread rapidly.

5.3. Biology and morphometrics of the pyralid predator of SWA, *D.aphidivora* Egg

The freshly laid eggs were small, oval shaped and creamy white in colour. A similar description of egg was reported by Tripathi (1992) and Vidya Mulimani *et al.* (2004). The eggs of *Dipha* were flat and elliptical. Newly deposited eggs were milk white coloured and fertilized eggs became pink in two days (Norio Arakaki and Yutaka Yoshiyasu, 1988). The mean length and breadth of the egg was 1.10 ± 2.32and 1.09 ± 0.31 mm respectively. The incubation period ranged from 3 to 4 days. In contrast, Tripathi (1992) recorded 5 to 7 days incubation period. This may be due to the regional and seasonal variation.

Larva

The neonate larva was yellowish white in colour and the headcapsule was light brown. In tests by (Tripathi,1992). Newly hatched larva was grayish white but later turned to greenish and a silvery lining developed on the dorsal side of its body. The body was covered with white prominent hairs. The head capsule was pinkish in colour. The mean length and breadth of the larva was 1.42 ± 0.27 and 1.33 ± 0.19 mm respectively. First instar larval duration was completed in 3 to 4 days. The second instar larva was similar to that of the first instar. The mean length and breadth of second instar larva was 3.15 ± 1.00 and 1.75 ± 0.31 mm respectively. The duration ranged from 3 to 4 days.

The head capsule colour intensified to dark brown in the third instar stage and the hairs were visible to the naked eye. The larva was light green in colour with a mean length and breadth of 5.70 ± 0.36 mm 2.68 ± 0.38 mm respectively. It took 2 to 3 days to complete this stage. The second instar larva resembled the third instar in appearance. One exception is that the abdomen ended bluntly. The mean length and breadth of fourth instar was 9.99 ± 0.96 and 3.36 ± 0.50 mm respectively with duration of 2 to 3 days. The mean length and breadth of fifth instar larva were 10.69 ± 0.92 and 3.81 ± 0.0.25 mm respectively. The average duration was 2.30 ± 0.92 days. The predator completed its larval period in 14.3 days. This is in consonance with the earlier finding of Patil (2005) who stated that the larvae matured in 12 to 16 days. However, Tripathi (1992) reported that the larval period of *Dipha* lasted for 20 to 26 days.

Pupa

The pupal cocoons were dusty white and the obtect pupa was deep mahogany brown to reddish brown in colour and formed a loose white cocoon around it. Tripathi (1992) described it as straw coloured silken cocoon. According to Arakaki and Yutaka Yoshiyasu (1988), pupation took place in a thick cocoon. The average length and breadth of the pupa was 6.25 ± 0.59 and 2.70± 0.44 mm respectively. The average pupal period was 5.60 ± 1.03 days. This is in close agreement with Tripathi (1992), who observed the pupal period of 5.6 days in October. Further, 6 to 7 days of pupal period was reported by Patil (2005).

Adult

The forewings of the adult had two black spots one on each and the hind wings were transparent and greyish white in colour. A similar description was reported by Tripathi (1992). In female, the fore and hind wing expanses were measured as 7.45 ± 0.61and 6.09 ± 0.54 mm respectively. In male, the fore and hind wing expanses were measured as 6.05 ± 0.54 and 4.32 ± 0.90 mm respectively. Males are smaller than females. Premating period of *D. aphidivora* ranged from 1.25 to 2.40 h. Mating occurred mostly during night, which is in agreement with Tripathi (1992). The mean preoviposition and oviposition periods lasted for 2.67 and 2.33 days respectively. This is in conformity with the finding of Tripathi (1992), who observed 1.5, and 1.0 days of preoviposition and oviposition periods respectively. The total number of eggs laid by a female moth ranged from 59 to 96 eggs. Male longevity ranged from 3 to 4 days, while of females ranged from 5 to 6 days.

5.4. Determination of larval instars

By comparing the growth ratios of the head widths of the *D. aphidivora*, it was found that the predator underwent five larval instars and the larval durations ascertained for first, second, third, fourth and fifth instars were 3.30, 3.30, 3.00, 2.40 and 2.30 days respectively. In contrast with the present finding, Norio Arakaki and Yutaka Yoshiyasu, 1988, indicated that the larval stages have four instars. Reports from Karnataka also indicated that the larvae passed through five instars (PDBC Annual Report, 2006).

5.5. Predatory potential of *D. aphidivora*

The feeding potential of *D. aphidivora* larva progressively increased from first to fifth instar. The per day consumption of first, second, third, fourth and fifth instars was 28.35, 44.01, 57.66, 66.87 and 78.23 aphids respectively. On an average, the predatory larvae consumed 53.15 aphids per day. During the entire period of development from first to fifth instar on an average, a single larva consumed 812.52 aphids. Vidya Mulimani *et al.* (2004) reported that the feeding potential of *Dipha* was 30 to 33 aphids / day and on an average and it consumed 1006 aphids during its lifetime.

One of the desirable attributes of the predators used in biological pest suppression is sustained predation which needed to progress with advancement of age. The increase in predation between first and the final instar was 275.94 per cent in the present investigation and it indicated high degree of voracity. *D. aphidivora* has been reported monophagous under natural conditions. Hence, the advantage of higher levels of predation and prey specification in augmentation (Rabindra, *et al*., 2004).

CHAPTER VI

SUMMARY

Investigations were carried out on the population dynamics of sugarcane woolly aphid (SWA) at Vedapatti, Coimbatore district of Tamil Nadu from September 2005 to January 2006. Studies on the biology and predatory potential of *Dipha aphidivora* were carried out in the laboratory. The salient findings are summarized here.

- The population of SWA was more in September, 2005 and low in October, 2005. Similar trend was noticed in pest intensity rating and percentage clump infestation. Among the predators of SWA, *D. aphidivora* was more predominant in this region than the brown lace wing, *Micromus igorotus*.

- Among the weather parameters the rainfall showed significant negative influence on the aphid population. The weather parameters had no significant effect on the abundance of the predators.

- There was asynchrony in the occurrence of SWA and predator *D. aphidivora*. On a leaf blade SWA appeared first and subsequently it was followed by the predator.

- The preference of the aphid was to the leaves present in the top portion of the tiller followed by middle and bottom portions. Similar trend was noticed with the incidence of *D. aphidivora* and *M. igrotous.*

- The spread of aphid within a patch was in spiral manner.

- Among the weather parameters maximum, minimum temperature and sun shine hours had positively significant effect on the spreading distance of aphid, whereas relative humidity and rain fall had negative significant effect.

- The eggs of *D. aphidivora* were laid singly under laboratory condition. The incubation period ranged from 3 to 4 days with a mean of 3.27 ± 0.92.

- *D. aphidivora* has five instars based on the headcapsule measurement. The mean head capsule widths of first, second, third, fourth and fifth instars were 0.941, 1.299, 1.761, 2.357 and 2.922 mm respectively. The larval durations ascertained for first, second, third, fourth and fifth instars were 3.30,3.30,3.00,2.40,and 2.30 days respectively.

- Premating period ranged from 1.25 to 2.40 days with an average of 1.86 ± 1.11 days. Preoviposition period ranged from 2 to 3 days with an average of 2.67± 0.98.Oviposition period lasted for 1 to 2 days with an average of 2.33 ±1.03.

- Male longevity ranged from 3 to 4 days with a mean 3.33 ±1.03.Female longevity ranged from 5 to 6 days with a mean of 5.87 ±1.55.The total duration of life cycle of male ranged from 25 to 27 days and of female ranged from 28 to 30 days.

- The fifth instar of *Dipha* consumed maximum number of aphids. The average feeding potential of first, second, third, fourth and fifth instars were 57.00, 134.95, 174.12, 204.07 and 217.63 aphids respectively. During the entire period of development from first to fifth instar on an average, a single larva consumed 812.52 aphids.

REFERENCES

Anonymous. 1963. Annual work progress report on crop improvement program of rice, sugarcane, vegetable and field crops. Directorate of Rural Affairs, Vietnam. p. 266.

Anonymous. 2001. Sugarcane pests and their control in the Philippines recommends for sugarcane. A publication of Philippines Sugar Research Institute Foundation, inLos Banos, Laguna. Philippines, series No **99**:139-186.

*Aoki, S., U.Kurosu. and S.Usuba. 1984. First instar larvae of the sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner (Homoptera : Pempigidae) attack its predators .*Kontyu*, **52**: 458-460.

Arakaki, N. 1989. Flight Periodicity and the Effect of Weather Conditions On the Take-off of *Ceratovacuna lanigera* zehntner (Homoptera: Aphididae). *Appl. Ent. Zool.* **124**(3): 264-272.

Arakaki, N. and Y.Yoshiyasi. 1988. Notes on biology, taxonomy and distribution of the aphidophages pyralid. *D. aphidivora* (M). Comb. Nov. (Lepidoptera: Pyralidae). *Appl. Ent. Zool.* **23**(3):234-244.

Arakaki, N. 1992. Seasonal occurrence of the sugar cane woolly aphid, *Ceratovacuna lanigera* (Homoptera: Aphididae), and its predators in sugar cane fields of Okinawa Island. *Appl. Ent. Zool*. **27**(1): 99-105.

Avasthy, P.N. 1977. Integrated control of sugarcane pests and diseases. *Sugar News*, **9:**72-74.

*Azuma, S. and Y.Oshiro. 1971. Studies on the insect pests of sugarcane in the Ryukyu Islands. On the sugarcane woolly aphid, *Certavacuna lanigera* Zehntner, *Bull. Okinawa Agric. Exp. Sta***. 5**: 9-27.

Basu, A.N. and S.N.Banerjee. 1958. Aphids of economic plants of west Bengal. *Indian Agriculturist* , 2: 89-112.

*Blackman, R.E. and V.F.Eastop. 2000. Aphids on the World's Crops. John Wiley. Chichester, p 466.

CABI, 2002. *Crop Protection Compendium*. Global Module. Wallingford, UK, CAB International.

Chakrabarti, S., A.K.Ghosh and D.N.Raychaudhuri. 1972. A new genus, a new species and further records of aphids (Homoptera : Aphididae) from the Kumaon hills, North West Himalayas, India .*Orient. Insects*, **6**: 387-400.

Cheng, W.Y., Z.T.Wang, T.H.Hung and J.K.Hung. 1994. Factors and their effect on the occurrence of sugarcane woolly aphid. *Rep. Taiwan Sugar Res*. *Inst*, **145:**1-24.

Cheng, W.Y., S.M.Chen and Z.T.Wang. 1999. Seasonal occurrence of sugarcane woolly aphid and its predators in spring canes. *Rep. Taiwan Sugar Res. Inst.,* **166**: 1-18.

Cheng, W.Y., Z.T.Wang, T.H.Hung and J.K.Hung. 1992. Seasonal occurrence of the sugarcane woolly aphid and its predators on autumn planted canes. *Rep. Taiwan Sugar*. *Res. Inst.,* pp: 19-31.

*Cheu, S.P. 1947. Field experiments on the use of tea seed oil soap against sugarcane wooklly aphid. Nung Pao, **12**: 14-16.

David, H. and V.Nandagopal. 1986. Pests of sugarcane distribution symptomatology of attack and identification. In: Sugarcane Entomology in India (Edn.) David, H. and V.Nandagopal. S.B.I. (ICAR), Coimbatore Publication. pp: 1-29.

Deng,G.R., H.H.Yang and M.X.Jin. 1981. A study of utilizing *Synonycha grandis* (Thunberg) to control sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner. *Natural Enemies of Insects*, **3**:1-2.

Deng ,G.R., H.H. Yang and M.X.Jin. 1987. Augmentation of coccinellid beetles for controlling sugarcane woolly aphid. *Chinese Journal of biological control*. **3**: 166-168.

*Farina, S.R. 1994. Problems on WSCA and strategies for its control at Takalar sp. Report to the manager of Takalar sp, Takalar Sugar Plantation (unpublished), p 9.

Ghosh, A.K. 1988. Homoptera: Aphididae, 4. Subfamily Phloemyzinae, Anoeciinae and Hormaphidinae. In the fauna of India and Adjacent countries, Zoological Survey of India, Kolkata, p 429.

Ghosh, M.R., P.K.Pal and B.N.Raychadhuri. 1974. Studies on the aphids from Eastern India. 21. The genus Astegopteryx and other related genera. *Pro. Zool. Soc. (Calcutta*), **27**: 429.

Gomez, K.A. and A.A.Gomez. 1984. Statistical procedure for agricultural research. John Wiley and Sons, New York. p 690.

Guenther, E. 1976. Oil of Calamus: *Acorus calamus* (L.) In: The essential oils, vol VI, (Edn.) A.E.Robert, Krieger Publishing Company, New York, pp: 109-117.

Gupta, M.K. and P.K.Goswamy. 1995. Incidence of sugarcane woolly aphid and its effect on yield attributes and juice quality. *Indian Sugar*, **44**: 883 - 885.

Hill, D. 1993. Major tropical pests (description, biology and control). In Agricultural Insect Pests of Tropics and Their Control (2nd Edn). Cambridge University Press. Cambridge. p 209.

Hirano, M. 1929. Influence of post-treatment on the toxicity of fenvalerate. *Appl. Entomol. Zool.*, **14**: 404:409.

Ishida, M. 1926. *Oregma lanigera* en hare parasieten. Arch.Suikerind. Ned-Indie Meded Profst. Java Suikeriend. **13**: 379 - 401.

Kalaiyarasan, S. 2005. Occurrence of sugarcane woolly aphid, *ceratovacuna lanigera*, Zehntner in sugarcane - A first record in Tamil Nadu. *Indian. J. plant prot*., **33**(1): 139 - 140.

Kurosu, U. and S.Aoki. 1986. Sexuparae of the sugarcane woolly aphid, Ceratovacuna lanigera, *Kontyu*, **54**(3): 523 - 524.

Lingappa, S., K.A.Kulkarni, R.K.Patil, P.S. Tippananavar and Shekharappa. 2003. Status of sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner. on sugarcane in Karnataka. Paper presented in brain storming session on woolly aphid, MPKV, Rahuri, Maharashtra during10th May.

Liu, C.Y., 1933. Notes on the biology of two giant Coccinellidsin Kwangsi (*Caria dialatata* Fabr. and *Synonycha grandis* Thunbg.) with sepical reference to the morphology of *Caria dialatata* Yearb.

Lopez, A.W. 1931. Ann. Rep. Res. Bur. Phillipp. Sugar Assoc., Entomology Department Report, p 273.

Mazza, G. 1985. Gas chromatographic and mass spectrometric studies of the constituents of the rhizome of Calamus. In: the volatile constituents of the essential oil. *J. Chromatography*, **328**: 179-194.

Noordan, D. 1991. Hormaphidinae from Java (Homoptera, Aphididae). *Zoologische Verhandlingen.* **270**: 525.

PDBC, 2004. *Annual report*.All India Co-ordinated Research Project on Biological Control of Crop Pests and Weeds.Project Directorate of Biological Control.Bangalore.India.

PDBC, 2005. *Annual report*. All India Co-ordinated Research Project on Biological Control of Crop Pests and Weeds.Project Directorate of Biological Control.Bangalore.India.

PDBC, 2006. *Annual report*.All India Co-ordinated Research Project on Biological Control of Crop Pests and Weeds.Project Directorate of Biological Control.Bangalore.India.

Patil, A.S. 2002. Pandhrya lokari mavyapasan us wachavinyasathi. Rathnagiri Sthani. Sheti puravani, 26th Sep.

Patil, N.G. 2005. Feeding Behaviour of Two Aphidophagous Predator on Sugarcane Woolly Aphid. *Insect. Environ*. **10**(4): 158 - 159.

Rabindra, R.J., P.Mohanaraj, J.Poorani, S.K.Jalali, S.S.Joshi, and S.Ramani. 2002. Sugarcane wooly aphid, *Ceratovacuna lanigera* Zehnther (Homoptera : Aphididae) - A serious pest of sugarcane in Maharashtra and attempts at its management by biological means . *J. Biol. Control*, **16**: 171 - 172.

Saputro, S.E., B.Trijantro and R.M.Harhap. 1995. Fogging with a mixture of basalin 60 EC and sunshine to control sugarcane wooly aphid, *Ceratovacuna lanigera*, Zehntner in the Camming sugar manufacturing region . Benta Pusat Panelitian. Perkebunan. Gula indones, **12**: 23.

Shankar, G. and D.M.Shitole. 2004. Management of sugarcane woolly aphid, *Ceratovacuna lanigera*. *Pestology*, **28**(4): 25-26.

Snedor,G.W.and Cochran, W.G. 1967. Statistical Methods. Oxford and IBH, New Delhi. p 593.

Sugar Situation in India 2002. Sugar Situation htm.

Suhartawan.1996. Population fluctuation of sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner (Homoptera: Aphididae) in Takalar Sugar Mill. Majalah Penelitian, Gula, **32**: 1 - 2.

Sunil Joshi and C.A.Viraktamath. 2004. The sugarcane woolly aphid, *ceratovacuna lanigera* Zehntner (Homoptera: Aphididae) its biology, pest status and control. *Curr. Sci*., pp: 307 - 316.

Tabashink, B.E. and N.L. Cushing. 1987. Leaf residue vs. tropical bioassays for assessing insecticides resistance in diamond back moth *Plutella xylostella* (L.). *FAO Plant Prot. Bull.,* **35** : 11-14.

*Takahashi, R. 1958. On the aphids of *Ceratovacuna* in Japan. *Kyontyu*, **26**: 187-190.

Takano, S. 1934. On the morphology and biology of *Ceratovacuna lanigera* Zehntner and the relation of its outbreak of environmental conditions in Formosa. *J. Formosan Sug. Pl. Ass*. **11**: 481 - 528.

Takano, S.1937. Relation of sugarcane varieties to insect pests. *J.Sugarcane Plant. Assoc*. **15**:195-198.

Takano, S. and I.Noda. 1938. A morphological and ecological study of *Synonycha grandis* (Thunberg) in Formosa . *Rep . Govt . Sug. Exp. Sta. Formosa*. **5**:116-138.

Takano, S. 1935. On the distribution, status of outbreak and control methods of the important sugarcane insect in Formosa. *Rep. Jpn. Assoc. Adv. Sci.,* **10**: 840-845.

*Takano, S. 1941. On the biological control of sugarcane woolly aphid, *Ceratovacuna lanigera*, *Kyontyu*, pp: 523-524.

Thirumurugan, A., K.Koodalingam and T.L.Bhaskaran. 2005. Incidence of sugarcane wooly aphid, *Ceratovacuna lanigera* in northern districts of Tamil Nadu. **In**: National symposium on Bio-diversity and insect pest management, Feb. 3-4. Entomology Research Institute, Loyola College, Chennai – 600043, p 51.

Thirumurugan, A., S.Enayathullah and K.Koodalingam. 2004. First time occurrence of woolly aphid on sugarcane in Tamil Nadu. *TNAU News letter*.

Tripathi, G.M.1992.Biology of *Conobathra aphidivora* (Meyrick), a pyralid predator of sugarcane woolly aphid in Nagaland, *J. Appl. Zool. Res*., **3**(1): 99-100.

Tripathi, G.M. 1995. Record of parasite and predator complex of sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner in Nagaland. *Indian Sugar*, pp: 839-841.

Uichanco, L.B.1928. Rep. Comm.. Cane varieties and Fertilizers. 6th Annual Conv. *Philipp. Sugar Association*, p 16.

Vidya Mulimani, R.K.Patel, S.Lingappa and Malatesh S.Puttannavar. 2004. Sugarcane woolly aphid (SWA), *Ceratovacuna lanigera* Zehntner and its predators. *Insect. Environ*., **10** 3):116-117.

Yamazaki, M.1937. On the life history of *Synonycha grandis* Thunb. *Oya Dobuts. Zasshi*, **9**: 3-99.

Yamazaki, M and H.Arikado, 1939.Resistant Sugarcane Varieties to *Ceratovacuna lanigera* Zehntner and the concentration of cell sap. *Rep. Jan. Assoc. Adv. Sci.*, **14**:155-157.

* Originals not seen

Table 1. Population of *Ceratovacuna lanigera* (SWA) and its natural enemies during September'05-January'06 (cv: Co 86032; village- Vedapatti, Coimbatore)

Standard week	No.of. Aphid/ $2.5cm^2$	Pest intensity rating	clump infestation (%)	*Dipha*/ leaf (No)	*Micromus* / leaf (No)
36	50.70	2.0	31.32	3.20	0.65
37	46.20	2.85	36.41	3.25	0.80
38	43.65	2.25	39.52	3.60	0.70
39	78.15	2.05	37.86	3.25	0.80
	54.68	**2.29**	**36.25**	**3.33**	**0.74**
40	24.90	1.75	24.67	1.85	0.35
41	22.65	1.10	23.52	2.90	1.00
42	29.80	1.15	24.31	2.20	1.30
43	23.40	1.13	24.69	2.50	0.60
44	24.30	1.12	25.21	2.95	0.65
	25.01	**1.25**	**24.48**	**2.48**	**0.78**
45	43.70	2.20	28.35	1.25	0.80
46	48.95	2.00	32.56	1.35	0.05
47	51.40	2.30	34.32	1.75	0.20
48	53.20	2.05	36.56	1.85	0.25
	49.31	**2.09**	**32.92**	**1.55**	**0.33**
49	36.70	1.85	28.97	1.40	0.25
50	37.5	1.35	29.65	1.95	0.15
51	36.5	1.73	28.55	2.95	0.20
52	38.20	1.52	27.63	2.20	1.30
	37.23	**1.64**	**28.70**	**2.13**	**0.38**
1	49.10	2.25	32.65	3.25	0.70
2	48.30	1.26	32.42	2.50	0.80
3	41.30	2.35	31.43	2.90	0.20
4	38.45	1.25	28.22	2.95	0.60
5	36.20	2.05	34.65	2.20	1.30
	42.67	**1.83**	**31.87**	**2.76**	**0.72**

Figures in the bold letters represent monthly means.

Table 2. Population dynamics of *C. lanigera* and its natural enemies (September'05-January'06)

Month	Population of SWA/2.5 cm^{2} *	Pest intensity rating *	Clump infestation (%) **	*Dipha*/ leaf (No.) *	*Micromus*/ leaf (No.) *
September	59.04 $(7.68)^{a}$	2.27 $(1.51)^{a}$	35.30 $(5.94)^{a}$	3.59 $(1.88)^{a}$	0.76 $(0.87)^{a}$
October	27.59 $(5.25)^{d}$	1.24 $(1.11)^{c}$	25.37 $(5.04)^{d}$	2.70 $(1.69)^{ab}$	0.76 $(0.86)^{a}$
November	46.92 $(6.85)^{b}$	2.11 $(1.45)^{a}$	33.07 $(5.75)^{b}$	1.90 $(1.39)^{c}$	0.35 $(0.59)^{c}$
December	36.25 $(6.02)^{c}$	1.55 $(1.24)^{b}$	27.57 $(5.25)^{c}$	2.88 $(1.63)^{b}$	0.36 $(0.60)^{c}$
January	42.55 $(6.52)^{b}$	1.59 $(1.26)^{b}$	32.48 $(5.70)^{b}$	3.00 $(1.73)^{ab}$	0.71 $(0.84)^{b}$

In column means followed by similar letters are not statistically different by ($p = 0.05$) LSD.
*- figures in parentheses represent $\sqrt{x+0.5}$ transformed values

**- figures in parentheses represent angular transformed values

Table 3. Multiple regression analysis of population dynamics of SWA and weather factors (September'05-January'06)

Factors	Regression co efficient	Standard error	't' value	R^2
Max Temp (°C)	- 1.724	2.473	-0.697^{NS}	
Min Temp (°C)	1.246	2.803	0.444 ^{NS}	
RH%(morning)	-1.491	0.829	-1.799 ^{NS}	
RH%(evening)	0.723	0.691	1.047 ^{NS}	0.588
Rain fall (mm)	-0.301	0.084	-3.576*	
Wind speed(Kmph)	-0.388	1.623	-0.239 ^{NS}	
Sunshine (h)	0.822	2.206	0.373 ^{NS}	

NS - Non significant
* - Significant at 5 % level

Table 4. Multiple regression analysis of population dynamics of *Dipha aphidivora* and weather factors (September'05-January'06)

Factors	Regression co efficient	Standard error	't' value	R^2
Max Temp (°c)	0.202	0.157	1.288 NS	
Min Temp (°c)	-0.08	0.178	-0.438 NS	
RH%(morning)	0.01	0.053	0.126 NS	
RH%(evening)	-0.02	0.044	-0.059 NS	0.460
Rain fall (mm)	0.004	0.005	0.668 NS	
Wind speed(Kmph)	0.172	0.103	1.661 NS	
Sunshine (h)	-0.006	0.140	-0.040 NS	

NS - Non significant

Table 5. Multiple regression analysis of population dynamics of *Micromus igorotus* and weather factors (September'05-January'06)

Factors	Regression co efficient	Standard error	't' value	R^2
Max Temp (°C)	-0.047	0.107	-0.446 NS	
Min Temp (°C)	0.069	0.121	0.575 NS	
RH%(morning)	0.008	0.036	0.229 NS	
RH%(evening)	-0.013	0.030	-0.428 NS	0.172
Rain fall (mm)	0.002	0.04	0.531 NS	
Wind speed(Kmph)	0.017	0.070	0.245 NS	
Sunshine (h)	0.061	0.095	0.647 NS	

NS - Non significant

Table 6. Correlation between the spreading distance of SWA and weather parameters (November'05-December'05)

Factors	Spreading distance of SWA (cm)
Max Temp (°c)	0.448*
Min Temp (°c)	0.777**
RH% (morning)	-0.325NS
RH% (evening)	-0.763**
Rain fall (mm)	-0.562**
Wind speed(Kmph)	0.059NS
Sunshine (h)	0.675**

NS - Non significant
* - Significant at 5 % level
** - Significant at 1 % level

Table 7. Within plant incidence of SWA and its natural enemies September'05-January'06: Vedapatti village, Coimbatore.

Standard week	**SWA colonized leaves/ tiller (Nos.)**	***D.aphidivora* / tiller (Nos.)**	***M.igrotous* / tiller (Nos.)**
36	6.76	20.83	0.00
37	5.88	16.13	1.02
38	4.96	15.98	0.00
39	5.72	13.65	5.03
Mean (September '05)	**5.83**[a]	**16.65** [a]	**1.51** [a]
40	5.76	23.86	2.25
41	4.98	24.02	2.64
42	4.73	24.15	0.00
43	4.62	25.17	0.00
44	5.52	20.86	1.85
Mean (October '05)	**5.12** [a]	**23.61** [a]	**1.35**[ab]
45	4.03	7.25	1.32
46	3.72	8.03	2.34
47	4.28	9.12	0.00
48	4.13	10.16	1.71
Mean (November '05)	**4.04**[b]	**8.64** [b]	**1.34** [b]
49	5.32	11.98	2.42
50	5.63	9.83	0.00
51	4.98	8.06	0.00
52	4.72	9.72	2.63
Mean (December '05)	**5.16** [a]	**9.90** [b]	**1.26** [b]
1	4.73	19.38	2.98
2	6.42	17.63	1.24
3	5.73	15.42	0.00
4	5.85	18.55	1.42
5	5.73	18.72	1.65
Mean (January '05)	**5.69** [a]	**17.94** [a]	**1.46** [a]

In a column bold means followed by

Table 8. Multiple regression analysis of total number of SWA colonized leaves, its natural enemies and weather parameters

Factors	Regression co efficient	Standard error	't' value	R^2
D.aphidivora	0.123	0.0411	3.005*	
M.igrotus	-1.236	0.7794	-1.585 NS	
Max Temp (°C)	-0.002	0.1725	-0.013 NS	
Min Temp (°C)	-0.063	0.2002	-0.316 NS	0.629
RH% (morning)	-0.027	0.0571	-0.479 NS	
RH%(evening)	-0.018	0.0508	-0.356 NS	
Rain fall (mm)	-0.010	0.0073	-1.449 NS	
Wind speed(Kmph)	0.059	0.1164	0.509 NS	
Sun shine hours	-0.182	0.1529	-1.195 NS	

NS - Non significant
* - Significant at 5 % level

Table 11. Relationship between head capsule width of different larval instars of *D. aphidivora*

Instar	Mean head capsule width (mm) ± SE*
I	0.941 ± 0.017
II	1.299 ± 0.036
III	1.761 ± 0.034
IV	2.357 ± 0.060
V	2.922 ± 0.024

* - Values are mean of 30 observations.

Table 9: Duration of different developmental stages and reproductive performance of *D. aphidivora*

S.No	Particulars/stage	Duration		
		Maximum†	Minimum†	Mean
1.	Premating period	2.40	1.25	1.86 ± 1.11
2.	Preoviposition period	3.00	2.00	2.67 ± 0.98
3.	Oviposition period	3.00	2.00	2.33 ± 1.03
4.	Incubation period	4.00	3.00	3.27 ± 0.92
5.	**Larval period** a)First instar	4.00	3.00	3.30 ± 1.19
	b)Second instar	4.00	3.00	3.30 ± 0.15
	c)Third instar	4.00	3.00	3.00±1.53
	d)Fourth instar	3.00	2.00	2.40±1.23
	e)Fifth instar	3.00	2.00	2.30±0.92
6.	**Total larval period**			14.30
7.	Prepupal period	2.00	1.00	1.33±0.92
8.	Pupal period	6.00	5.00	5.60±1.03
9.	**Longevity** a)Male	4.00	3.00	3.33±1.03
	b)Female	6.00	5.00	5.87±1.55
10.	**Total life cycle (egg to adult emergence)** a)Male	27.00	25.00	25.53±2.62
	b)Female	30.00	28.00	28.93±1.67
11.	Pupation (%)	95.32	98.36	98.94±13.3
12.	Adult emergence (%)	95.86	96.01	96.24±10.91
13.	Fecundity (No. of eggs)	59.00	219.00	91.80±7.46
14.	Fertility (%)	93.67	94.23	95.57±8.06

† Mean of 20 values.
1 = Premating period in hours.
2 t0 10 = All the rest of the durations in days.

Table 10. Morphometric details of *D.aphidivora*

S.no	Particulars	Measurement (mm)		
		Maximum*	Minimum*	Mean
1.	**Egg**			
	a)Length	1.12	0.98	1.10 ±0.32
	b)Breadth	1.03	0.96	1.09 ± 0.31
2	**First instar**			
	a) Length	1.54	0.98	1.42 ± 0.27
	b) Breadth	1.21	0.88	1.33 ± 0.19
3.	**Second instar**			
	a) Length	3.59	2.34	3.15 ± 1.00
	b) Breadth	1.42	1.88	1.75 ± 0.31
4.	**Third instar**			
	a) Length	5.82	4.65	5.70 ± 0.36
	b) Breadth	2.72	2.24	2.68 ± 0.38
5.	**Fourth instar**			
	a) Length	10.82	9.63	9.99 ± 0.96
	b) Breadth	5.12	3.65	3.36 ± 0.50
6.	**Fifth instar**			
	a) Length	11.56	10.36	10.69 ± 0.92
	b) Breadth	3.82	3.71	3.81 ± 0.25
7.	**Prepupa**			
	a) Length	8.82	7.73	8.57 ± 0.31
	b) Breadth	4.39	3.74	4.37 ± 0.08

Table 10. Contd…

S.no	Particulars	Measurement (mm)		
		Maximum*	Minimum*	Mean
8.	**Pupa** a) Length b) Breadth	 6.73 2.42	 5.62 1.74	 6.25 ± 0.59 2.70 ± 0.44
9.	**Adult** **Male** Wing expanse			
	a)Fore wing	5.88	4.91	6.05 ± 0.54
	b)Hind wing	4.93	3.73	4.32 ± 0.90
	c)Body length	7.41	6.87	7.52 ± 0.31
10.	**Female** Wing expanse			
	a)Fore wing	7.73	6.78	7.45 ± 0.61
	b)Hind wing	6.24	5.96	6.09 ± 0.54
	c)Body length	12.85	11.69	11.99 ± 0.19

*Mean of 20 values.

Table 12. Predatory potential of various larval stages of *D. aphidivora*

Instar	Total number of SWA consumed		Mean number of SWA consumed	Mean number of SWA consumed/day
	Minimum	Maximum		
I	63	79	85.57^{d}	28.35^{d}
II	119	127	134.95^{c}	44.01^{c}
III	151	168	174.12^{b}	57.66^{b}
IV	186	195	204.07^{a}	66.87^{a}
V	204	216	217.63^{a}	78.23^{a}
Total	723	785	816.34	275.12

Mean of fifteen replications.
In a column, means followed by common letters are not significantly different (P=0.05) by LSD.

APPENDIX I

WEATHER PARAMETERS FOR THE EXPERIMENTAL PERIOD (2005-06)

Standard week	Max Temp ˚C	Min Temp˚C	RH%(morning)	RH% (evening)	Rain fall (mm)	Wind speed **(**Kmph**)**	Sun shine (h)
36	32.9	23.3	91	63	11	5.6	4.6
37	29.9	23.5	91	59	8	10.6	4.2
38	31.6	21.7	90	47	0	11.1	8.6
39	32.9	21.6	79	50	2.4	5	8.3
40	32.3	22.2	83	53	49.4	4.2	6.3
41	29.8	22.3	90	66	125.8	3.4	4.1
42	31.5	22.1	90	58	34.8	4.5	8.3
43	29.1	21.9	94	69	122.8	2.8	2.7
44	30.3	21.8	91	65	86.8	3.7	5.5
45	28.4	19.4	94	69	32.6	3.2	2.1
46	28.8	19.7	93	60	22.3	2.4	5.6
47	26.6	20	93	73	54.4	4.3	4.4
48	28.4	19.3	92	60	1	3.3	5.2
49	29.2	20.2	91	54	53.5	2.9	6.0
50	27.7	18.2	92	64	6.6	4.3	3.7
51	30.7	18	94	53	0	2.6	7..3
52	28.7	17.8	92	50	0	3.5	6.9
1	28	19.4	90	55	0	3.8	5.3
2	29.3	19.8	94	56	28.2	4.7	6.7
3	30.7	16.6	91	42	0	4.3	7.2
4	31.1	16.5	85	38	0	3.9	9.7
5	29.3	17.1	90	42	0	5.2	8.5