BIOECOLOGY AND MANAGEMENT OF MULBERRY LEAF ROLLER *Diaphania pulverulentalis* (HAMPSON) (LEPIDOPTERA : PYRALIDAE)

By

RAMALAKSHMAIAH. C.

THESIS

Submitted in partial fulfillment of the requirement for the degree of

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Faculty of Agriculture
Kerala Agricultural University

Department of Entomology
COLLEGE OF HORTICULTURE
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DECLARATION

I hereby declare that this thesis entitled "**Bioecology and management of mulberry leaf roller *Diaphania pulverulentalis* (Hampson) (Lepidoptera: Pyralidae)**" is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship of other similar title of any other University of Society.

Vellanikkara
22/9/2K5.

Ramalakshmaiah
RAMALAKSHMAIAH. C

CERTIFICATE

Certified that this thesis, entitled "**Bioecology and management of mulberry leaf roller *Diaphania pulverulentalis* (Hampson) (Lepidoptera: Pyralidae)**" is a record of research work done independently by **Sri Ramalakshmaiah. C** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship of associateship to him.

20/09/05

Dr. Jim Thomas
Chairman, Advisory Committee
Associate Professor and Head i/c
Department of Entomology
College of Horticulture
Kerala Agricultural University
Vellanikkara, Thrissur, Kerala

Vellanikkara

CERTIFICATE

We, the undersigned members of the Advisory committee of **Mr Ramalakshmaiah.C**, a candidate for the degree of Master of Science in Agriculture with major in Department of Entomology, agree that the thesis entitled " **Bioecology and management of mulberry leaf roller, *Diaphania pulverulentalis* (Hampson) (Lepidoptera : Pyralidae)"** may be submitted by **Ramalakshmaiah.C**, in partial fulfilment of the requirement for the degree.

19/09/05
Dr. Jim Thomas
(Chairman, Advisory Committee)
Associate Professor and Head (i/c)
Dept. of Entomology
College of Horticulture,
Vellanikkara

19/9/05
Dr. R. Usha Kumari
(Member, Advisory Committee)
Associate Professor
Dept. of Entomology
College of Horticulture
Vellanikkara

20/09/05
Dr. Haseena Bhaskar
(Member, Advisory Committee)
Assistant Professor
Dept. of Entomology
College of Horticulture
Vellanikkara

Dr. Sally K. Mathew
(Member, Advisory Committee)
Associate Professor
Dept. of Plant Pathology
College of Horticulture
Vellanikkara

External Examiner 19/9/05
Dr. C.P. Radhakrishnan Nair
Head & Principal Scientist
CPCRI Reg. Station
Kayangulam - 690533

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Ramalakshmiah

[RAMALAKSHMAIAH.C]

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INTRODUCTION

1. INTRODUCTION

India with its diversified climate and distinct ability to cultivate a variety of flora, produces all the four varieties of silk namely mulberry, tasar, eri and muga. Silk is the "Queen of textiles" playing an important role in determining the status of the country based on ethnicity and its traditional know how.

India ranks next only to China, in the production of silk in the world. Ancient Kasmiri silk and silk textiles of Tamil Nadu have made their presence felt globally. The value of silk textiles and silk goods in 1995- 96 were about 200 crores (CSR&TI, 1996). Compared to China's 1$billion foreign export of Silk fabrics, a lot more is deserved from India in this area. Having favorable agro climatic conditions, the potential for the mulberry cultivation and sericulture industry in the hitherto untapped areas is immense and scopeful.

The SERIFED of the government of Kerala, mandated by the Central Silk Board (CSB) has explored the possibilities of mulberry cultivation in Kerala. One such place identified is Chalakkudy – Mala tract of Thrissur district.

The quality of leaves is the sole criteria for the effective rearing of silkworms. The profitability and productivity in sericulture depends up on the quality and yield of mulberry leaves. The quality and yield can be achieved by integration of ecofriendly management practices. The bottlenecks in the moriculture of Chalakkudy – Mala tract are poor quality of leaves, rampant pest and diseases of mulberry and silkworm, uncertainty in the market prices of cocoon as well as silk products.

Mulberry crop (*Morus alba* var *indica*) is damaged by more than 300 insect pests and non insect pests (Kotikal and Devaiah, 1987 and Birader, 1989). Among the foliage feeders, leaf roller, *Diaphania pulverulentalis* (Hampson) (Lepidoptera : Pyralidae) is well known allover India. It is reported to cause severe damage to mulberry leaves.

The leaf roller incidence in Kerala is of recent origin. No detailed information is available on its biology, natural enemy complex and the effective field management practices. The pest incidence was reported to be higher in October to December months and lower in summer season. The incidence of *D. pulverulentalis* varied in open rice fields and coconut, areca nut intercropped homestead mulberry gardens. Hence, the present investigation was taken up in open and coconut intercropped systems with the following objectives.

1. To study the seasonal incidence of leaf roller in Chalakkudy area of Thrissur district.
2. To study the effectiveness of selected management practices to manage the leaf roller.
3. To identify the potential natural enemies of leaf roller.
4. To study the bioecology of the pest during peak and lean season and to understand the factors responsible for the population dynamics.
5. To understand the influence of weather parameters on shoot damage and larval population to adopt timely management practices.

2. REVIEW OF LITERATURE

The lepidopteran insects are one of the most serious groups of insect pests causing considerable yield loss to major cultivated crops in tropical and temperate countries. The leaf roller *Diaphania pulverulentalis* (Hampson) (Lepidoptera: Pyralidae) is one of the key pests of mulberry as well as forest and horticultural crops.

In India two species of leaf webber *viz.*, lesser mulberry pyralid, *Glyphodes pyloalis* Walker *and Diaphania pulverulentalis* (Hampson) are of special importance because of their wide spread occurrence in the regions from tropical to temperate conditions. The available literature pertaining to the biology, seasonal incidence, bioecology, natural enemies and the different management practices of the pests are discussed in the chapter.

Diaphania spp are known under various names *viz.*, lesser mulberry pyralid (Seol *et al.*, 1986a and 1986b), mulberry pyralid *Glyphodes pyloalis* walker (Siddegowda *et al.*. 1995 and Geethabai *et al.*. 1997) leaf roller *Margaronia pulverulentalis* walker (ESCAP, 1990). But it is commonly referred as mulberry leaf roller.

2.1 SEASONAL INCIDENCE AND DAMAGE POTENTIAL

2.1.1 Distribution

Seol *et al.* (1986a) reported that the mulberry pyralid caused extensive damage to mulberry and hampered the silk production in Japan and Korea. It was at alarming proportions in East Asian countries (Seol *et al.*, 1987). In central and southern parts of Japan, the pest damage was noticed by Watanabe *et al.* (1988). Fodale and Mule (1990) recorded that mulberry pyralid was distributed all over ecological belts of Spain. Peter and David (1991c) reported the incidence of pumpkin caterpillar, *Diaphania indica* a related species whose incidence was also highest during April to September and lowest during November to February.

It was reported that there is a relationship between location of mulberry garden and the incidence of the leaf roller. The percentage infestation was found to be less in the months of April to June. Increase in relative humidity in and around the mulberry plantation, lack of direct sunlight, lack of direct air current, coconut canopy, adjacent rice fields will lead to increased infestation levels of leaf roller (Gowda *et al.*, 2001).

Location specific variation in mulberry leaf roller *D. pulverulentalis* was reported by Gowda *et al.*(2001). The infestation was nil from March to June. The results indicated that increase in moisture / relative humidity in and around mulberry ecosystem increased the pest incidence.

2.1.2 Seasonal Incidence

Beeson (1941) observed that the damage due to *Glyphodes* sp. on mulberry was ranging from 10-100 per cent in the southern part of India. The maximum incidence of *G. pyloalis* on mulberry was observed during the humid seasons in North India (Mathur and Singh, 1983). In Japan *G. perspectalis* Walker caused extensive damage (up to 76 per cent) in box tree *Buxus microphylla* (Maruyama and Shinkog, 1991).In Karnataka, Siddegowda *et al.* (1995) reported that the incidence of *Diaphania* spp. on mulberry was ranging from 0 to 100 per cent. They also observed that the incidence was severe during winter months (October- February) at Koppa, Mandya, Mysore and Kanakapura taluks of Karnataka state. The incidence was 0 to 30 per cent during summer months (March- June) in the above places. At Jammu and Kashmir, the maximum damage (71.26 per cent) due to *G. pyloalis* on mulberry was recorded during October and minimum damage (2.23 per cent) during July (CSR&TI, 1996).

The results of survey carried out by Karnataka State Sericulture Research and Development Institute, Bangalore revealed that the leaf roller, *D. pulverulentalis* (Hampson) occurred on mulberry during June to February months. Initially the incidence was 22 per cent in June, which reached up to 85 per cent by September and cent percent during December. Infestation declined below 50 per cent when the ambient temperature increased during the month of January. Further decline in infestation upto 25 per cent was noticed on the leaves during February and 14 per cent during March (KSSR&DI, 1998).

Bai and Marimadaiah (2002) reported that the leaf roller *D. pulverulentalis* infestation began on mulberry after the commencement of Southwest monsoon during June and was severe during North- East monsoon. It declined by next April.

2.1.3 Nature of Damage

The larvae of leaf tier, *G. pyloalis* Walker devour the mesophyll and lower epidermis of mulberry from the under surface of the leaves, leaving only a transparent layer of upper epidermis, which are often called " Attic windows" (Ishii, 1953). The larvae of leaf roller, *M. pulverulentalis* feed on mulberry leaves and produce spinning filaments when they grow and bind the leaf blades together. Rolled leaves were the specific symptom produced by this pest (ESCAP, 1990). The larvae of mulberry pyralid, *M. pyloalis* bind the leaves with silken threads and cause damage.

Siddegowda *et al.* (1995) reported that the early stage larvae of *Diaphania* sp. inhabit the apical portion and feed on the tender leaves resulting in drying of terminal portion of mulberry shoots. The infested leaves are brought together and bound through silken webs. Sometimes, a single leaf is rolled and within the fold, the larva hides, hence it is known as leaf roller.

The larvae of leaf webber, *D. pulverulntalis* defoliate the mulberry plants. They web the tender leaves with their litter and the apical portions of the plant are the preferred sites for feeding (CSR&TI, 1997).

2.2 Biology

Several workers studied the biology of mulberry pyralid on various crop plants (Ishii, 1953; Nakamura, 1967; Butani, 1979; Inoue, 1981; Mathur, 1980;

Harado and Kikuchi, 1982; Inoue *et al.*, 1982; Mendes and Bertifilho, 1983; seol *et al.*, 1986a, 1986b; Ghorpade and Patil, 1989; Siddegowda *et al.*, 1995).

2.2.1 Egg

In the case of leaf tier, *D. pyloalis*, the female laid creamy eggs only on tender shoots (Hall, 1926). Nakamura (1967) and Harado and Kikuchi (1982) also observed that the eggs were laid by the female moths of *G. pyloalis* singly on the tender shoots. Butani (1979) observed that the eggs were laid on the tender shoots of mulberry. The adult female of leaf webber, *G. pyloalis* laid gelatinous eggs near the terminal buds of mulberry (Mathur, 1980). The eggs were pale green in colour and spherical in shape measuring 0.7 mm in diameter (JOCV, 1983).

Ghorpade and Patil (1989) observed that *G. laticostalis* moth laid on an average 160.3 eggs. The maximum egg laying per moth was estimated to be around 400 eggs. They observed that the incubation period was 5-6 days. Eggs were covered by yellowish green mass and the freshly laid egg measured 0.74 mm in length and 0.54 mm in breadth. The pre-oviposition, oviposition and post-oviposition periods were 2.6, 2.6 and 1.8 days respectively. The female moths of mulberry pyralid, *M. pyloalis* laid on an average 400 eggs. Female deposited the eggs along the leaf-veins on the under surface of the leaves. The leaf roller, *M. pulverulentalis* laid gelatinous eggs on the young leaves near the terminal buds of mulberry (ESCAP, 1990).

Siddegowda *et al.* (1995) observed that *Diaphania* sp. laid eggs in apical portion of the leaves and the eggs were flat in shape and pink in colour. Each female moth laid on an average 156.6 eggs measuring 0.74mm in diameter. The eggs were laid on the apical portion of mulberry shoots at the rate of 1-2 eggs per shoot. The incubation period was 4-5 days.

The eggshell of *D. pulverulentalis* was investigated by scanning electron microscopy. The surface of the pyralid egg shows structural elements, i.e. aeropyles and micropylar rosette around the micropyles. The eggs were longish-oval, 332.80±4.32 μm long, and 218.60±4.71 μm wide, marked by a reticulate pattern of rectangular and pentangular cells (Vineet *et al.*, 2002).

2.2.2 Larva

The larva of *G. pulverulentalis* is pinkish to brown in colour (Ishii, 1953). The newly hatched out larva of *G. laticostalis* Guenee was white in colour, which became yellowish during late larval instars. The body of the larva was covered with hairs, the head was blackish with distinct epicranial suture measuring 2.5mm in length and 0.4 mm in breadth. The larva completed its growth period within 16 days by passing through five larval instars. The average duration of larval instars were 2.3, 3.2, 3.3, 3.5 and 3.8 days for first, second, third, fourth and fifth instars respectively. The final instar larva had two dark brown parallel stripes on the dorsal side of the abdominal segments while the pre-pupa started webbing with white silken material around its body (Ba and Angood, 1979). Inoue (1981) and Inoue *et al.* (1982) observed that initially the larva was green in colour. When it matured it turned to pinkish brown in colour. In the case of *D. nitidalis* Walker the duration of first, second, third, fourth and fifth larval instars averaged about 1.2, 2, 2.20, 1.78 and 2.62 days respectively (Mendes and Bertifilho, 1983).

Seol *et al.* (1986a, 1987) and Honda *et al.* (1990) noticed five larval instars in leaf webber, *G. pulverulentalis*. In the case of mulberry pyralid, *G. pyloalis*, the full-grown larvae measured about 2 cm in body length. The larvae were light brown or pink in colour and moulted four times (ESCAP, 1990). In Japan, Maruyama and Shinkog (1991) observed that mulberry pyralid *G. pyloalis* had 4-7 larval instars.

At KSSR&DI (1999), Bangalore, the workers observed that the colour of the larvae of *D. pulverulentalis* was greenish brown with black marking on the dorsal and lateral region of the abdomen. The head was black in colour. The larval duration was ranging from 15 to 20 days.

The caterpillars of leaf roller *M. pulverulentalis* were green in colour and had numerous black spots arranged serially on the side as well as on the back of the abdominal segments. The matured larvae measured about 2 cm in length. The larval duration of leaf tier *D. pyloalis* was 16-18 days (KSSR&DI, 1999).

2.2.3 Pupa

In *D. nitidalis*, the duration of pre-pupal and pupal stages were 1 to 2 days and 8 to11 days respectively (Mendes and Bertifilho, 1983). Ghorpade and Patil (1989) observed that in *G. laticostalis* the pupation took place within the leaves surrounded by the silken material. The pupal period lasted for 11.5 days. The pupae were dark brown in colour and measured about 11.6 mm in length and 4 mm in breadth. The pupa of mulberry pyralid, *M. pyloalis* was brown in colour and was found in the soil while the pupa of the leaf tier, *D. pyloalis* was found in the folded leaves and protected by a faint fibre of silk produced by the larva(ESCAP,1990).

Siddegowda *et al.* (1995) observed the pupal period of *Diaphania* spp. as 10 to 12 days. Workers from KSSR & DI (1998), Bangalore observed that the pupal period was about 8 to 10 days. The pupae of leaf webber, *D. pulverulentalis* were dark brown in colour. Pupation occurred in dried leaves and the pupal duration was 8 to 10 days (KSSR & DI, 1999).

2.2.4 Adult

The adult of the leaf webber, *G. pulverulentalis* was black in colour possessing stripes on the lateral sides of the abdomen. The anal portion of the adult moth contained a tuft of black hairs. The forewings had markings obscured by many number of spots with striae. The antimedial, medial and post medial bands were broader in forewing. The first dentate was found inward on vein two while in the case of second vein, the disco cellular spot was absent. The vein three had a series of pale specks on the outer edges from the vein four to the inner margin. Hind wings were thickly irroarated and striated with oblique black edges (Hampson, 1896; 1898).

The adult of mulberry pyralid, *G. pyloalis* was brown in colour. The vertex of the head, patagia and sides of the abdomen were striped with white colour. The forewings were pale in colour. The inner margin of the wing was white in colour.

The base fuscous contained ante medial oblique white lines followed by a black edged fulvous band. A ring like spot was present on the vein two, possessing a broad marginal pale fuscous band with black inner edge more or less complete sub marginal diffused fuscous band. The inner margin was white with a fine black line (Hampson, 1896; 1898).

The adults of the leaf roller, *M. pulverulentalis* were greyish white in colour with black brown stripes on the forewings and each measured about 10mm in body length and the adults of mulberry pyralid, *M. pyloalis* also measured about 10mm in body length. The body of *M. pyloalis* was greyish white in colour. During the resting stage, the wings were folded behind the body and the whole body appeared in triangular shape. The fore wings were greyish white in colour while the hind wings semi-circular and white (Hampson, 1896; 1898).

. Seol *et al.* (1986a) reported that the life cycle of mulberry pyralid, *G. pyloalis* was 29 to 32 days. Ghorpade and Patil (1989) observed that the survival of the male and female moths of *G. laticostalis* were 6.5 and 8.5 days respectively. The adult moth was medium in size and the body covered with white hairs. Forewings were broad, dark and cupreous brown in color. Larvae posessed prominent black compound eyes. Female was differentiated from male by the presence of tuft of hairs at the tip of the last abdominal segments. The length of the body was 14.5-15.3mm and 16.0-18.0mm for male and female respectively. The size of forewing and hind wing were 34 mm in length.

Siddegowda *et al.* (1995) observed that the life cycle of leaf roller, *Diaphania* spp. was ranging from 31 to 35 days. *Diaphania* spp. completed 10 generations in a year. At Jammu and Kashmir, *G. pyloalis* completed four generations in a year and the life cycle was ranging from 28 to 31 days (CSR&TI, 1997).

2.3 NATURAL ENEMIES

Several hymenopteran parasitoids were reported to be effective in regulating the mulberry pyralids. Pinturean and Voegele (1979) reported that the occurrence of egg parasitoids *viz.*, *Trichogramma oleae* Perkins, *T. evanescens* Westwood and *T. embryophagum* Hartig on *G. unionalis* Hubner. An entomogenous fungal pathogen *Paecilomyces farinosus* Dickson was reported on the larvae of *D. indica* (Kuruvilla and Jacob, 1980). The larval parasitoids *viz.*, *Agathis* sp. and *Phanerotoma* sp.(Braconidae: Hymenoptera) were reported against pulse pyralid *Maruca testulalis* Geyer (Vishakantaiah and Jagadeesh, 1980).

The bethylid *G. emigrattus* Rohwer parasitized the larva of *D. indica* Saunders and laid eggs on the middle segment of the larva. Each female parasitoid laid on an average 10-15 eggs per host. (Gordh and Hawkins, 1981; Gordh *et al.*, 1983). Green muscardine and yellow muscardine fungal pathogens were also identified on the mulberry pyralid *G. pyloalis* (JOCV, 1983). The bethylid parasitoid, *Goniozus* spp. was first identified on *D. indica* by Gordh (1988). Peter and David (1991a; 1991b) recorded twenty species of parasitoids, predators and pathogens against *D. indica.*

At Jammu and Kashmir, Khan *et al.*(1995) observed the egg-larval parasitoid, *Chelonus* spp., ectolarval parasitoids (Braconids), *Bracon hebetor* Say, *Apanteles obliquae* (wilkn.) and *Phanerotoma* spp. and three ichneumonids *Prishtomerus* sp. *Diadegma* spp. and *Phytodietus* spp. on *G. pyloalis* of mulberry.

Apanteles obliquae was the predominant endo-larval parasitoid of *G. pyloalis* present in all the districts of Jammu and Kashmir on mulberry. The parasitoid of *A. obliquae* emerged from the final instar host and started spinning small white cocoon, which remained attached on to the larva of *G. pyloalis*. The numbers of parasitoid cocoons per host larva were 9 to 21(CSR&TI, 1996). Two spider predators' *viz.*, *Tetragnatha* spp. and *Philodromus* spp. were recorded on mulberry pyralid *G. pyloalis* (CSR&TI, 1996).

The workers at KSSR&DI (1998), Bangalore recorded two braconid parasitoid *viz.*, *Apanteles bisulcata* and *A. agilis*, which were abundant during December and January months. The percentage parasitisation of the above parasitoids on *D. pulverulentalis* was 11.1 and 10.5 respectively. The percent

July, August, September and February respectively. In Karnataka a reduvid predator *Isyndus heros* (Fab.) (Hemiptera: Reduviidae) and an unidentified wasp were recorded on *D. pulverulentalis* (KSSR&DI, 1998).

Bai and Marimadaiah (2000) reported a solitary larval endoparasitoid, *Apantales agilis* on *D. pulverulentalis.* Marimadaiah and Bai (2000) observed the emergence of a gregarious larval endoparasitoid *Apantales bisulcata* from mulberry leaf roller *D. pulverulentalis.* The endoparasitoids spun cocoons on the dead larvae pupating on the mulberry leaves. Marimadaiah and Bai (2001) reported a solitary egg- larval endoparasitoid, *Phanerotema noyesi* on *D. pulverulentalis.*

Sathyaseelan and Chandramohan (2002) reported that there were five natural enemies on leaf webber *D. pulveruentalis. Bracon hebetor, Apantales* sp., *Goniozus* sp. were the parasitoids and *Tetragnatha sp., Philodromus* sp. were the spider predators.

A few natural enemies of spider fauna were reported to predate on mulberry leaf roller. *Tetragnatha* sp. and *Philodromus* spp. were the spiders found to prey upon mulberry leaf roller. The experiments conducted in Tamil Nadu have shown that the above-mentioned spiders could be effectively utilized in the biocontrol of mulberry leaf roller (Subramanian, 2002).

Mulberry leaf roller *D. pulverulentalis* (Hampson) was found to attack mulberry plantations of different ages from just sprouted to well grown up plants (from 20 days after sprouting to 70 days old). The pest occurrence was positively related to high humidity, low temperature and availability of good quality leaf. The egg parasitoid *Trichogramma chilonis* Ishii is highly effective against *D. pulverulentalis.* Field release of this parasitoid @ 50,000/ha at 10 days interval is recommended. A pupal parasitoid *Tetrastichus howardi* Olliff has also been reported to parasitise the pupae of the leaf roller (Govindan *et al.*, 2003).

2.4 COLLATERAL HOSTS OF MULBERRY LEAF ROLLER

Beeson (1941) reported that *Glyphodes* spp. was a serious pest of forest trees in India and mulberry gardens located under higher altitude and sub-tropical condition of Jammu and Kashmir. Alam *et al.* (1964) reported that *Glyphodes* spp. was a serious pest on jack in Bangladesh. It caused a drastic reduction in fruit yield of jack (Rao, 1965). The third instar larvae confined with *Zinnia* leaves did not approach the leaves. When shifted to cucumber leaves they consumed three times more leaf area before pupation. This results show that *Zinnia* lacks some attractant present in cucurbits (Tripathi and Pandey, 1973). Thirty-four plant species representing 10 families were tested in the laboratory as food plants for *D.indica*. Only 14 cucurbitaceous plants were accepted and fed on by third instar larvae (Pandey, 1977).

The effect of different host plants on the duration of life stages of pumpkin leaf caterpillar, *Margaronia indica* was done by Krishnaprasad and Rai (1978). The total duration of egg, larval, pupal stages averaged 19.25 days on ridge gourd (*Luffa acutangula*), 23.00 days on snake gourd (*Trichosanthes anguina*), 23.25 days on pumpkin and 23.75 days on bottle gourd (*Lagenaria siceraria*). No apparent development took place on bitter gourd (*Momordica charantia*).

Butani (1979) also reported that *Glyphodes* spp. was a serious pest on jack in Assam. In Uttar Pradesh, the forest trees were defoliated by *Glyphodes* spp. (Mathur, 1980). Day and Robinson (1981) reported the comparative survival, development and fecundity of the prickle worm *D. nitidalis* reared on artificial diet and on three cucurbit hosts. The prickle worm reared on artificial diet for more than 25 generations based on pinto bean (*Phaseolus vulgaris*) did not lose their ability to survive on natural cucurbit leaves. The larvae reared on squash fruits developed faster and had a higher survival rate.

No differences were noted in the survival and development of larvae of *D. nitidalis* (Stoll) in excised foliage, flowers and fruits of several edible species

(Elsey, 1981). Elsey (1982a) reported the effect extreme temperatures on prickle worm larvae *D. nitidalis*. The larvae exposed to –8°C survived much longer within squash fruits than in petridishes, apparently because the temperature within the fruit didn't fall below 0°C. Exposure of Adults to -8°C for 55 minutes caused 52 per cent mortality, while exposure to 0°C for 24 hours permitted 65 per cent survival but almost with no oviposition. Elsey (1982b) reported the photoperiod and temperature effects on the occurrence and periodicity of mating in prickle worm, *D. nitidalis*. The mating began at the onset of scotophase, peaked towards the middle and declined towards the end.

Seol *et al.*, (1986a) tested the possibility of rearing mulberry lesser pyralid, *Glyphodes pyloalis* on artificial diet. The larvae were reared at 24°C and 60-80 per cent relative humidity. The artificial diet was added with the juice of mulberry leaves. In Maharashtra, *G. laticostalis* Guenee caused severe damage to *Holarrhena antidysenterica*(L.) (Ghorpade and Patil, 1989). Fodale and Mule (1990) observed that *Glyphodes* spp.caused damage to olive trees in Spain. Forester (1990) identified that *Hoya australis* subsp. *sanae* Hill was the habitual host for the pest *Margaronia microta* Meyrick.

Maruyama and Shinkog (1991) reported the life cycle of the box tree pyralid, *G. perspectalis* Walker and its photoperiodic induction of larval diapause. The photoperiodic induction of larval diapause showed typical long day response curves. Maruyama and Shinkog (1991) and Maruyama (1992) reported that *G. perspectalis* Walker infested box trees *viz., Buxus microphylla* (L.) and *B. simeperivirens* (L.) in Japan. Srisuda (1993) reported the ecological studies and the effect of host plants on the development of *D. indica*.

Ravi *et al.*, (1998) reported that the total larval duration of *D.indica* Saunders was delayed on coccinea (*Coccinea indica*) followed by Chow-Chow (*Sechium edule*), gherkin (*Cucumis anguria*) and cucumbers (*Cucumis sativus*). The cucumbers and gherkins were the preferred hosts for *D. indica*. *Diaphania* spp. is an oligophagous pest feeding on mulberry, ficus, jack, olive and box trees, where as *Margaronia* spp. Hubner is restricted to cucurbitaceous family.

2.5 MANAGEMENT

Application of chemical insecticides against mulberry foliage feeders may pose residual problem on leaves, which in turn affect the larvae of silkworm, *Bombyx mori*. Sufficient waiting period must be given to avoid larval mortality for effective rearing (Yokoyama, 1962). Spraying of insecticide endosulfan 0.035 per cent was found to be effective against *G. laticostalis* on the fruits of jack (Rao, 1965). Delplanque and Gruner (1975) reported that laboratory and field experiments of *B. thuringiensis* formulations gave good control of *Plutella maculipennis* on cabbage and *D. hyalinata* on cucumbers, courgettes and melons.

Mathur (1980) reported that the measures recommended to control mulberry defoliator, *G. pyloalis* were burning the leaves on the ground during winter months, raking up the soil or ploughing to destroy over wintering larvae. Binding straw around trunk and large branches of trees to trap hibernating larvae and subsequent destruction by burning followed by insecticidal spray mixed with pyrethrum to HCH emulsion before leaves are rolled up by the larvae and large scale release of the parasitoid *Cedria paradoxa* (Wlkn.) for biological control was also advocated.

The safe waiting period for insecticide sprayed leaves was found to vary from 10 to 15 days (Ullal and Narasimhanna, 1981; Munivenkatappa *et al.*, 1989). Gupta and Vijay (1986) observed that monocrotophos (0.2%) was highly toxic to *G. pyloalis*. Lorini and Forester (1987) reported that prickle worm on cucumber, *D.nitidalis* could be controlled by insecticides aimed at agromyzid *Liriomyza sativae*, as they occur simultaneously on cucumbers. Feeding silkworm with dichlorvos (0.1%) and monocrotophos (0.2%) sprayed leaves required a safety period of 4 and 14 days respectively (Beevi, 1989). Residual toxicity of some insecticides to the larvae of *D. indica* was reported by Peter and David (1989). Foliar spray of 0.2 percent dichlorvos was highly effective against G. pyloalis (Fodale and Mule, 1990). The study conducted in Padappai in Tamil Nadu tested the toxicity of 12 insecticides to larvae of *D. indica*. Cypermethrin was the most effective against the larvae, closely followed by deltamethrin and fenvalerate. In field studies at Guam, treatments with carbaryl, dimethoate and *Bacillus thuringiensis* were effective in reducing the larval population of *D.indica* on cucumbers (Schreiner, 1991). Ali (1995) found that the silkworm fed with insecticide treated leaves suffered severely even after 40days of spraying

Laboratory bioassays were conducted to determine the pathogenicity of 5 entomopathogenic nematodes from the genera *Steinernema* and *Heteorhabdites* against melon worm *D. hylinata*. Among the five traeatments *S. carpocapse* (Mexican strain) was the most pathogenic nematode species, followed by *H. bacteiophora, S. feltiae, S. anomali* and *S. glaseri* respectively (Shannag and Capinera, 1995). Sengupta (1988) reported that depending upon the prevailing weather conditions, parathion spray dissipated within 13 days in mulberry and found to be safer to silkworm, *B. mori*. Spraying the mulberry foliage with dichlrvos 0.2 per cent followed by a second spray when the infestation exceeded 20 per cent was effective against *G. Pulverulentalis* (Shannag and Capinera, 1995).

Bai *et al.* (2001) reported that abamectin spray on mulberry afforded good control aganist mulberry white caterpillar, (*Rondotia menciana*) mulberry looper (*Hemerophila atrilineata)*.

3. MATERIALS AND METHODS

Investigation were carried out on the "Bioecology and management of mulberry leaf roller, *Diaphania pulverulentalis* (Hampson) (Pyralidae: Lepidoptera) in the department of Entomology, College of Horticulture, Vellanikkara. Studies were conducted on the biology of the insect, its seasonal incidence in the field, leaf damage and shoot damage. Management practices were carried out to find the best suitable ecofriendly measure to manage the insect.

3.1 SEASONAL INCIDENCE OF MULBERRY LEAF ROLLER AND ITS DAMAGE POTENTIAL

3.1.1 Population Dynamics and Weather Parameters

To understand the population dynamics of the leaf roller and its corresponding shoot damage, a biweekly observation of the number of larvae per plant and the shoot damage were recorded from the Kottat village of Chalakkudy area of Thrissur district. The data was correlated with the weather parameters like maximum and minimum temperature, relative humidity at morning and evening, photo phase and precipitation.

3.1.2 Seasonal Incidence

A detailed survey was conducted in the mulberry fields of Thrissur district in order to assess the damage caused by the mulberry leaf roller, *D. pulverulentalis*. The survey was undertaken to estimate the extent of shoot damage, number of larvae per plant and occurrence of the natural enemies. A detailed proforma was employed to gather the necessary information. 4-5 year old mulberry gardens of different locations were selected to study the incidence of leaf roller. Necessary information was gathered during the period from April 2004 to March 2005. The proforma designated for the survey is attached as appendix 1.

During the observation period 10 plants were randomly selected from a plot for recording the larval number, pupal count if any and the number of leaf damage in the top 8 leaves. Percentage shoot damage was worked out by counting the damaged shoots and total shoots in each plant.

3.1.3 Damage potential

The damage potential of leaf roller infestation on mulberry variety Victory -1 was studied in the Kottat village of Chalakudy area of Thrissur district. The study was carried out in two systems of cultivation *viz.* Open and intercropped system of cultivation. Intercropped systems were within coconut- arecanut plantations under typical homestead situations, while open systems were pure crops raised on converted paddy lands with no shade trees. An area of $200m^2$ each marked for the study in both the garden systems. The age of the plants grown were three years in the open field and four years in the intercropped field. The cultural operations were carried out regularly as per the input guidance from the Department of Agriculture.

In both the systems 10 plants were selected randomly from the field and observations were made at every 15 days interval. Number of damaged leaves and total number of leaves per shoot were recorded from all the plants.

3.1.4 Mass culturing of Leaf Roller

A disease free culture of the test insect was maintained in the laboratory from the healthy larvae collected from the field and maintained on the mulberry variety Victory-1. The rearing was undertaken by the poly bag method.

Plate 1. Rearing of *D. pulverulentalis* - Polybag method

Plate 2. Rearing of *D. pulverulentalis* - Cage method

3.1.4.1 PolyBag Method

Polythene bags of 400 gauge thickness and 20x10 cm size were used for rearing the larvae. The sterilized poly bags were perforated with needle for proper aeration. Freshly plucked mulberry leaves with terminal shoots and the bud leaves were kept inside the poly bag. To prevent drying, a moistened absorbent cotton was wrapped at the end of shoot. In each poly bag, five larvae of uniform age and size were kept in and reared under room temperature of 25+ 2°C and relative humidity of 70-80 per cent. The larvae were provided with fresh shoots daily for feeding till they entered pre-pupal stage. The grown up larvae were allowed to pupate in the bag itself. The pupae were then kept in the darkness in cupboards till the adults were emerged.

The newly emerged adult moths were confined at 1:1 sex ratio to ensure mating in ovipositional cages (60x 30cm) provided with terminal shoots of mulberry plants. The shoots were changed twice a day during morning and evening. The adult moths were provided with 10 per cent honey solution and Vit ABCDE drops. The hatched larvae were transferred on to the mulberry terminal shoots provided afresh for further development and growth.

3.2 STUDIES ON THE BIOLOGY OF MULBERRY LEAF ROLLER

Investigations on the biology of *D. pulverulentalis* were conducted in the Insectary of Department of Entomology, College of Horticulture, Vellanikkara. The studies were done in two seasons coinciding with the peak infestation (October to December) and lean infestation (February to March).

3.2.1 Bionomics of Mulberry leaf Roller

The biology of *D. pulverulentalis* was studied on the mulberry variety Victory-1 under captivity in cages. Pairs of freshly emerged adult male and female moths were confined into 60x30cm size cages. Tender shoots of mulberry were provided for egg laying within the cages. Ten such sets were maintained as replications. The tender shoots were changed twice a day. The numbers of eggs laid on the leaves were counted using a 10x microscope. The adult moths were provided with 10 per cent honey solution mixed with vitamin drops (Park Davies India Limited) for optimum nutrition and performance under captivity conditions. The larvae hatched out were reared in poly bags as mentioned in 3.1.4.1

Observations on the fecundity, egg period, larval period, duration of each instar, per cent pupation, fresh pupal weight, pupal period, adult longevity and total developmental period were recorded. The mating, the larval instars and their durations were examined individually at every three hours based on the colour change and change in size of the head capsule.

3.3 COLLECTION OF THE NATURAL ENEMIES

Observations were made on the natural enemies of *D. pulverulentalis* by collecting larvae from the farmer's fields at kottat village of Chalakudy. The larvae were reared in a poly bag as described in 3.1.4.1. The adult parasitiods emerged from the parasitized larvae and pupae were identified.

The adults were provided with 10 per cent honey solution mixed with vitamin E drops for survival and fecundity. The adult parasitoids after mating were separated and placed in individual glass vials containing third instar larvae of leaf roller for fresh parasitization. The parasitized larvae after 24 hours were removed and reared in poly bags till pupation for the emergence of parasitoids.

3.4 IDENTIFICATION OF COLLATERAL HOSTS

3.4.1 Field Survey

To identify the collateral hosts of mulberry leaf roller, a periodical monitoring of eggs randomly on the leaves of weed flora adjoining mulberry garden was carried out at regular intervals. The weed flora were collected and observed for any stages of *D. pulverulentalis.*

3.4.2 Captivity Feeding Experimentation

A lab experiment was conducted on leaves of Cucumber, Shoe flower and Jack which are known hosts of different *Glypodes* sp. Leaves of the above plants/trees were force-fed to known number of pre-starved larvae. Ten larvae of uniform size and age were taken in each treatment. The larvae were allowed to starve to death on the leaves of above-mentioned plants/trees.

3.5 MANAGEMENT STUDIES ON *D. pulverulentalis*

To identify the factors responsible for varied infestation levels and to manage the pest with a suitable integrated practices an experiment was laid out in the farmers field in Kottat village in the below mentioned manner.

3.5.1 Layout of the Field Experimentation

An experiment for the management of leaf roller was carried out at kottat village of Chalakudy area of Thrissur district. Two systems of cultivation were selected. Open system with no boundary crops and intercropping system of cultivation where the mulberry garden was surrounded by tall boundary shading trees. An experiment with five treatments including one control replicated 4 times was laid out in the Kottat village. The total area of the open field was 0.25 ha and the closed field was 0.2 ha. A 200m^2 plot at the middle of the field leaving 3 rows of boundary was selected as experimental plot. The 200m^2 area was divided into 5 plots

Plate 3. Open system of mulberry cultivation in rice fields at Kottat village near Chalakkudy

Plate 4. Cultivation of mulberry in coconut intercrop system at Kottat village near Chalakkudy

of $40m^2$ area. Each plot was subdivided into 4 subplots of $10m^2$ area each with 12 mulberry plants with a spacing of 0.9x0.9m. Among the 12 plants 10 plants were randomly selected as samples. The treatments planned were

1. Clipping of the top leaves (T1)
2. Pre- heated soil dusting @ 25kg/ha (T2)
3. Dichlorvos spray @ 0.1 per cent (T3)
4. Treatments 1+2+3 (T4)
5. Control (T5)

All the treatments were adopted in both systems simultaneously. The observations were collected in random manner (ten out of twelve plants) from the field. The set of management practices were replicated 5 times from April 2004 to March 2005.

The observations were taken at 0, 7 and 15 days after the treatment. Observations were made in the same field apart from the treated plot at every 15 days to monitor the general incidence of the pest on mulberry. The observations taken were larval, pupal count and number of damaged leaves in each plant.

The clipping of leaves was restricted to unopened buds and just opened leaves. The pre-heated soil dust was applied to know the physical abrasive action of dust on the insect body. The chemical treatment was done using high volume knapsack sprayer with a spray volume of 500 litre/ ha with 0.1 per cent teepol as wetting agent applied uniformly to the tank mixture and sprayed during cool hours. In the integrated treatment the timing of practices were, clipping of the leaves, followed by dichlorvos spray and pre-heated soil dusting.

3.6 BIOEFFICACY OF DICHORVOS ON LEAF ROLLER

3.6.1 Determination of LC_{50} and LT_{50} Value of Dichlorvos on Leaf Roller, *D. pulverulentalis*

Bioefficacy of dichorvos against leaf roller, *D. pulverulentalis* was carried out under laboratory condition as foliar residue bioassay/ boquet method.

Mulberry shoots of variety V-1 were taken and the top eight leaves were plucked and rinsed in sterilized distilled water and shade dried for 5 minutes. The shoots were dipped in solutions of different concentrations of diclorvos (DDVP) 76WSC for about 30 seconds and the excess fluid was drained out. The concentrations tested were 0.01, 0.05, 0.1, 0.15, 0.2, 0.3, 0.4, 0.5 per cent respectively. The petiole of the leaves were wrapped with moistened cotton swab and kept in shade for drying for 10 mins. Ten uniform and second instar larvae were taken in a treatment. Each treatment was replicated three times. The larvae were kept in a polybag and the treated leaves were offered as food. Known numbers of treated leaves were offered to the larvae Mortality at 12 hours after the treatment was taken to determine the LC50 value as per probit analysis by Finney(1964) after deducting the control mortality.

The median lethal time value (LT_{50}) value was also determined for dichlorvos at 0.1 per cent concentration over mortality at 6, 12, 24, 48, 72hours after the experiment. The larvae were allowed to feed on the treated leaves for 5 hours and then fed with untreated leaves. A separate untreated check was also maintained along with the treatments.

3.7 DETERMINATION OF FOOD CONSUMPTION AND UTILIZATION INDICES

To understand the food consumption pattern and the efficiency of digestion of food, consumption studies were conducted on the leaf roller. Uniform sized thirty third instar larvae were collected from field. The larvae were confined one each in 30 poly bags. Each larva was provided with pre-determined quantity of leaves. After every 24 h the remaining leaves were taken and the weight determined. The initial weight of each larva and the weight of the excreta every day was also determined. Before prepupal stage the weight of individual larva was measured and the following food consumption and utilization parameters were determined.

1. Approximate digestibility (AD) =

$$\frac{\text{Weight of food injested- weight of the faeces}}{\text{Weight of food injested}} \times 100$$

2. Efficiency of conversion of food to body substance (ECI) =

$$\frac{\text{Weight gained}}{\text{Weight of food ingested}} \times 100$$

3. Efficiency of conversion of digested food to body tissue (ECD)

$$= \frac{\text{Weight gained} \quad \times 100}{(\text{Weight of food ingested} - \text{Weight of faeces})}$$

All the above indices were calculated on fresh weight basis.

The digestion and food conversion efficiency indices of the larvae were calculated according to Waldbauer (1968).

3.8 OVICIDAL ACTION OF DICHLORVOS

Two days old eggs were subjected to the determination of ovicidal action of dichlorvos. Adult moths were reared in the laboratory and allowed to lay eggs on the tender leaves. Each egg along with little leaf portion was cut and was dipped for one minute in various concentrations of dichlorvos solution in water 0.01, 0.05, 0.1, 0.15, 0.2, 0.5 per cent respectively. The leaf bits with eggs were shade dried for a 5 minutes. Ten eggs were taken in each treatment. Each treatment was replicated thrice. Eggs dipped in water served as control. The unhatched eggs were counted three days after treatment and the hatching percentage was worked out.

3.9 STATISTICAL ANALYSIS

Observation under each experiment (except biological studies) were tabulated and analysed statistically in a Randomised Block Design (RBD) as proposed by Panse and Sukhatme (1967). The treatments were ranked accordingly to Duncan Multiple Range Test (DMRT). LC50 and LT 50 values were calculated by probit analysis of Finney (1952).

4. RESULTS

Laboratory and field studies were conducted at College of Horticulture, KAU and in Kottat village of Chalakkudy area in Thrissur district from April 2004 to March 2005, to assess the incidence of leaf roller, *Diaphania pulverulentalis* on mulberry *Morus alba* var *indica*. Studies on the bioecology of the leaf roller in peak season (October to December) and in lean season (February to March) were also carried out. Field experimentation to manage the leaf roller with integrated management practices involving the combination of cultural, mechanical and chemical practices and the three practices individually were also carried out. Studies were carried out on the bioefficacy of dichlorvos on leaf roller.

4.1 SEASONAL INCIDENCE AND DAMAGE POTENTIAL

The data on the seasonal incidence of leaf roller, *D. pulverulentalis* in open system of cultivation and intercropped system of cultivation in Kottat village of Chalakudy area of Thrissur district are presented below.

4.1.1 Population of Mulberry Leaf Roller in Open Cultivation System

4.1.1.1 Effect of weather parameters on larval population

A perusal of Table 1 reveals a significant negative correlation between larval population and relative humidity at morning (-0.709) and relative humidity at evening (-0.645). An insignificant, negative correlation was observed between the larval population and maximum temperature (-0.082) and minimum temperature (-0.261).

The effect of photophase on the larval population was significant and positive (0.5), where as precipitation showed a positive but insignificant correlation (0.0511).(Table 1)

Table I Effect of Weather parameters on the larval population in the open cultivation system

S.No	Weather parameters	Correlation coefficient	Partial regression coefficient	R^2
1	Max. temperature(°c)	-0.082[NS]	0.63	0.5025**
2	Min.Temperature(°c)	-0.261[NS]	1.35	
3	RH morning	-0.709*	-0.57	
4	RH evening	-0.645*	0.31	
5	Photophase (hrs)	0.5*	0.98	
6	Precipitation(mm)	0.511*	-0.17	

* P (0.05) Constant term = Ä = 60.2

**P(0.01) NS = Non significant

The multiple regression equation for the weather parameters was

$Y= 60.2 + 0.63x_1 + 1.35x_2 - 0.57x_3 - 0.31x_4 + 0.98x_5 -0.17x_6$

The multiple regression equation explained the variability in larval population due to weather parameters up to 56.6 per cent.

x_1, x_2, x_3, x_4, x_5 and x_6 are the variables for the weather parameters. The numbers with variables correspond the partial regression coefficients.

4.1.1.2 Effect of weather parameters on the leaf damage

A significant negative correlation was observed between the number of damaged leaves and relative humidity at evening (-0.649). The effect of maximum temperature on the damage was significantly negative (-0.5). The effect of minimum temperature (0.139), relative humidity at morning (0.368) and precipitation (0.3) was insignificant but positive.

The effect of photophase on the number of damaged leaves was insignificant, but negative (-0.117) The multiple regression equation for the weather parameters was

$Y = 48.2 + 1.47x_1 - 1.26x_2 - 0.747x_3 + 0.665x_4 + 5.841x_5 + 0.349x_6$

The multiple regression equation explained variability in leaf damage due to weather parameters upto 48 per cent. (Table 2)

4.1.1.3 Seasonal variations in shoot damage

The per cent shoot damage was 28.5 in June. It reached the maximum in December (75.83). It came down drastically to 45.46 per cent by the following March. The damage increased almost 3 fold from June to December. (Table 3)

Table 2. Effect of Weather parameters on the leaf damage in open cultivation system

S.No	Weather parameters	Correlation coefficient	Partial regression coefficient	R^2
1	Max. temperature(°c)	-0.5*	0.818	0.419**
2	Min.Temperature(°c)	0.139^{NS}	1.105	
3	RH morning	0.368^{NS}	-1.01	
4	RH evening	0.649*	0.82	
5	Photophase (hrs)	-0.117^{NS}	3.65	
6	Precipitation(mm)	0.3^{NS}	0.27	

* P(0.05) A = 48.6

**P(0.01) NS = Non significant

Table3 Shoot damage and larval population in open cultivation system

S.No	Month ($)	% shoot damage	% larval population
		Mean	Mean
1	*June*	28.5^{g}	1.56^{f}
2	*July*	27.93^{g}	2.41^{e}
3	August	37.56^{ef}	4.03^{c}
4	September	40.6^{e}	4.06^{c}
5	October	48.93^{d}	3.95^{c}
6	November	58.16^{b}	4.75^{bc}
7	December	75.83^{a}	5.37^{a}
8	January	60.23^{b}	5.00^{b}
9	February	55.33^{c}	3.35^{d}
10	March	45.46^{de}	1.47^{f}
		CD 4.32	*CD 0.3*

Alphabets with same letter didn't differ significantly at P(0.05)

$ Fortnightly sampling

4.1.1.4 Seasonal variations in larval population

The larval population ranged from 1.56 in June to 5.37 per plant in December. The population ascended proportionately from June to December but then it declined drastically. Population came down to 1.47 per plant in March. (Table 3)

4.1.1 Population of Leaf Roller in Intercropping System

4.1.2.1 Effect of weather parameters on larval population

A significant negative correlation between larval population and relative humidity at morning (-0.75), at evening (-0.57) and also precipitation (-0.539) was observed under coconut intercropping system.

A significant positive correlation was observed between larval population and photophase (0.55). The effect of maximum temperature (0.232) and minimum temperature (-0.3) was insignificant on larval population.

The multiple regression equation for weather parameters was

$Y = 52.27 + 0.99x_1 + 0.67x_2 - 0.48x_3 + 0.21x_4 + 0.76x_5 - 0.076x_6$

The variation in larval population due to weather parameters was explained up to 52.27 per cent by the equation. (Table 4)

4.1.2.2 Effect of weather parameters on leaf damage

A significant negative correlation between the leaf damage and relative humidity at morning (- 0.63) and evening (-0.637) was observed.

An insignificant positive correlation was observed between leaf damage and photo phase (0.311) and rainfall (0.064). There was an insignificant negative

Table 4. Effect of Weather parameters on the larval population in inter cropping system

S.No	Weather parameters	Correlation coefficient	Partial regression coefficient	R^2
1	Max. temperature(°c)	0.232^{NS}	0.99	0.564**
2	Min.Temperature(°c)	-0.3^{NS}	0.67	
3	RH morning	-0.75*	-0.48	
4	RH evening	-0.57*	0.21	
5	Photophase (hrs)	0.55*	0.76	
6	Precipitation(mm)	-0.539*	-0.076	

* P (0.05) A = 52.27

**P (0.01) NS = Non significant

Table 5. Effect of Weather parameters on the leaf damage in inter cropping system

S.No	Weather parameters	Correlation coefficient	Partial regression coefficient	R^2
1	Max. temperature(°c)	-0.172^{NS}	1.47	0.419**
2	Min. Temperature(°c)	-0.1178^{NS}	-1.26	
3	RH *morning*	-0.63*	-0.747	
4	RH *evening*	-0.637*	0.665	
5	Photophase (hrs)	0.311^{NS}	5.841	
6	Precipitation(mm)	0.064^{NS}	0.349	

*P(0.05) A= 39.4

**P(0.01) NS = Non significant

Table 6. Per cent shoot damage and larval population in inter cropping system

S.No	Month($)	% shoot damage	% larval population per plant
		Mean	Mean
1	June	37.13^{f}	1.94^{gh}
2	July	37.86^{f}	2.84^{f}
3	August	50.4^{e}	3.92^{e}
4	September	49.26^{e}	5.89^{c}
5	October	55.03^{cd}	6.72^{b}
6	November	65.63^{b}	6.7^{b}
7	December	72.83^{a}	7.26^{a}
8	January	58.26^{c}	6.57^{bc}
9	February	49.00^{e}	5.13^{d}
10	March	36.96^{f}	2.25^{g}
		C.D 4.26	CD 0.35

$ fortnightly sampling

Alphabets with same letter didn't differ significantly at P(0.05) correlation between leaf damage and maximum temperature (-0.17) and minimum temperature (-0.1178) with the leaf roller infestation.

The multiple regression equation for weather parameters was

$$Y = 39.4 + 0.818x_1 + 1.105x_2 - 1.01x_3 + 0.82x_4 + 3.65x_5 + 0.27x_6$$

The regression equation established 39.4 per cent variation in leaf damage due to weather parameters. (Table 5)

4.1.2.3 Seasonal variations in shoot damage

The per cent shoot damage was 37.13 per cent in June. It went up to 72.83 per cent by December. Shoot damage increased two fold between June to December. It came down drastically to 36.96 by following March. (Table 6)

4.1.2.4 Seasonal larval population variation

The larval population per plant was less in June (1.94). It recorded the maximum in December (7.26). There was an increase of 3.74 times in the larval population. The larval population came down to 2.25 by the following March.(Table 6)

4.2 BIOLOGY STUDIES ON LEAF ROLLER

The biological studies on leaf roller, *D. pulverulentalis* were done in two seasons coinciding with the peak infestation (October to December) and lean infestation (February to March) to the actual field situation. Accordingly the results presented here too are in two season *i.e* peak season and lean season.

Plate 5. Egg of *D. pulverulentalis* just before hatching

Plate 6. I, II, III, IV and V larval instars of *D. pulverulentalis*

4.2.1 Biology of Mulberry Leaf roller, *D. pulverulentalis* in Peak Season

The results of the study made on the biology of leaf webber on mulberry variety Victory-1(V-1) were as follows.

4.2.1.1 Fecundity

The egg laying capacity of leaf roller was observed to be 157 eggs with a range of 117 to 211 eggs per female.

4.2.1.2 Eggs

The eggs were flat or oval or spherical in shape and semitransparent to yellow in colour. They turned to pinkish red at the time of hatching. The incubation period of the egg of the leaf roller, *D pulverulentalis* was 3.94 days with a range of 2.5 days to 5.5 days.

4.2.1.3 Larval period

I instar : The larval body was fluorescent yellow colour with small veins. Head capsule was in pale brown with 0.35mm width. Very minute with a size range of 1.5 to 2.0 mm. On the dorsal side of the larva the markings were absent.

II instar: The larva colour changed to light yellowish orange with small square black spots surrounded by white patches. The head capsule was in brown, measured 0.58mm width. The mid dorsal white line was slightly visible. In this stage the hairs were seen on the body. The mean larval size was 3.1 to4.5mm in length.

III instar: The larva was deep orange in colour. The dorsal mid line and spots were clearly visible and expanded. The head capsule width was 0.98mm and the size of the larva ranged from 8.3 to 9.0 mm in length.

Plate 7. Pupae of *D. pulverulentalis*

Plate 8. Adult moth of *D. pulverulentalis* on mulberry

IV instar: The larva colour was dark greenish brown and head capsule became very dark and highly sclerotized. The head capsule width was 1.2mm. The average size of the larva ranged from 9.7 to 12.5mm in length.

V instar : The larva colour was dark pinkish brown and the size was 17.5 to 19.3mm. The width of the head capsule was 1.36mm in length.

The series of head capsule width measurements ranged from 0.35 to 1.36mm. The average head capsule measurement of 5^{th} instar larva represented an increment of 73 per cent over the first instar larva. The head capsule measurements were 0.35, 0.58, 0.98, 1.2 and 1.36mm for the I, II, III, IV and V instar larva

4.2.1.4 Pupal period, per cent pupation and pupal weight

The pupal period varied significantly from 8 to 10.5 days with an average of 9.44 days. The percentage pupation was found to be in the range of 58.5 to 76.27 per cent with an average of 65.5 per cent. The pupal weight was more in females compared to males. The pupal weight of female was in the range of 0.05 to 0.064. The pupal weight of male was in the range of 0.04 to 0.06g.

4.2.1.5 Growth index, total development period and per cent adult emergence

The growth index ranged from 4.83 to 2.93 with a mean value of 4.2. The total developmental period was observed to be 28.01 days. The mean percentage adult emergence was calculated to be at 67.7 per cent.

Plate 9. Neonate larval feeding symptoms within the mulberry leaf rolls – a ventral view

Plate 10. Neonate larval feeding symptoms within the mulberry leaf rolls – a dorsal view

Table 7. The biology of mulberry leaf roller, *D .pulverulentalis*

S.No	Stage	Growth period (Days)			
		Peak season (Oct – Dec)		Lean season (Feb – Mar)	
		Range	Mean	Range	Mean
1	Egg	2.5-5.5	3.94	2.75-4.25	3.3
2	Larva				
	I instar	1.50 - 2.00	1.71	1.25 - 2.0	1.51
	II instar	2.0 - 3.25	2.50	1.5 - 2.25	2.00
	III instar	2.75 - 3.75	3.21	2.0 - 3.25	2.47
	IV instar	3.00 - 4.00	3.28	2.5 - 3.5	2.52
	V instar	3.25 - 4.5	3.92	2.5 - 4.25	3.51
	Larval period	11.50- 17.50	14.62	9.75-15.25	12.01
3	Pupa	8.00-10.50	9.44	6.275-9.79	7.95
4	Adult				
	Male	8.20-12.15	9.70	7.50-9.50	8.15
	Female	10.4 -15.15	11.50	8.91-13.45	10.22
	Total life cycle	28.00			23.25

respectively. The larval duration for the I, II, III, IV and V instars was 1.714, 2.5, 3.214, 3.28 and 3.92 days respectively. (Table 7)

4.2.2 **Biology of Mulberry Leaf Roller, *D. Pulverulentalis* in lean Season**

The results of the study made on the biology of leaf roller in the lean (February to March) season were given in Table 7.

4.2.2.1 Egg

The eggs were flat or oval or spherical in shape and pale yellow in colour. At the time of hatching they turn to pinkish red in colour. The egg period was observed to be 3.3 days, with a range of 2.75 days to 4.25 days respectively.

4.2.2.2 Larval period

The larval duration for I, II, III ,IV and V instars were 1.55, 2.09, 2.47, 2.52 and 3.4 days respectively(Table 7). The larval period ranged from 9.34 days to 14.95 days. The mean larval period was found to be 12.0 days.

4.2.2.3 Pupal period, per cent pupation and pupal weight

The pupal period varied from 6.275 days to 9.79 days, with a mean value of 7.95 days. The per cent pupation was in the range of 33 to 76.4.

4.2.2.4 Total developmental period and per cent adult emergence

The total developmental period was found to be 23.25 days. It ranged from 18.36 days to 28.99 days. The per cent adult emergence was 46.7 to 83.24.

Table 8. List of natural enemies of *D. pulverulentalis*

S.No	Name	Family	Order	Host stage attacked
1	*Bracon hebetor*	Braconidae	Hymenoptera	IV, V instars
2	*Apanteles* sp	Braconidae	Hymenoptera	I, II. III instars
3	*Chelonus* sp	Braconidae	Hymenoptera	I, II, III instars
4	*Tetrastichus howardii*	Eulophidae	Hymenoptera	Pupa
5	*Mermithid*	Mermithidae	Nematoda	I, II, III instars
	Spiders			
1	*Tetragnatha* sp	Tetragnathidae	Araneae	Larvae
2	*Philodromus* sp	Philodromidae	Araneae	Larvae

Plate 11. The cadaver of *D. pulverulentalis* infested with Mermithid EPN

Plate 12. *Chelonus* sp.,a larval parasitoid of *D. pulverulentalis*

4.3 NATURAL ENEMIES OF MULBERRY LEAF ROLLER

The natural enemies were collected either from parasitized larvae from field during survey or larvae were collected and reared in laboratory, so as to collect the natural enemies emerged out from the larvae. The parasitoids *Bracon hebetor* (Braconidae: Hymenoptera) were found to parasitize on late larval instars. A braconid *Apanteles* sp. was also observed on the early larval instars. An unidentified mermenthid was also recorded from the early instars of larvae.

A pupal parasitiod *Tetrastichus howardii* (Hymenoptera: Eulophidae) was also recorded. The predatory spiders *Tetraghatha* sp. and *Philodromus* sp.were also recorded. (Table 8)

4.4 COLLATERAL HOSTS OF MULBERRY LEAF ROLLER

An experiment to determine the collateral hosts of *D. pulverulelalis* was carried out with Cucumber, Shoe flower and Jackfruit leaves under no choice test. Larvae were observed to scrape on the leaves, but there was no sustained feeding by the larvae.

Weed flora in and around of mulberry gardens were collected and observed for the oviposition and feeding signs of larvae. The weed flora identified was as follows, *Cyperus rotundus, Cynodon doctylon, Euphorbia hirta, Michenia micrantha, Chromolena oderata, Lantana sp., Brachiaria mutica, Panicum repens*. But no larvae were found feeding on the same.

4.5 MANAGEMENT STUDIES ON LEAF ROLLER

The results of the study conducted at the Kottat village of Chalakkudy area from April 2004 to March 2005 were as follows. Management studies were divided

Plate 13. *Tetrastiches howardii*, a pupal parasitoid of *D. pulverulentalis*

into monsoon season(June of September) and post monsoon season (October to April). To initiate the treatments one larvae / plant was taken as taken as arbitrary ETL level. The observations were recorded at pre-treatment(0DAT), post treatment at 7 and 15 days after treatment. The effects of treatments were compared at 0, 7 and 15 days after treatment to the control values of the corresponding dates.

4.5.1 Management Studies in Open system of cultivation

The treatments were applied five times in the year starting from April,2004 to March,2005. In monsoon season two treatments and in post- monsoon season three treatments were taken up.

4.5.1.1 Effect of management practices on larval population

4.5.1.1.1 Monsoon season

The effects of management practices on the larval population in the month of July, 2004 were as follows. The population at pre-treatment did not varied significantly. The larval population at 7 DAT varied significantly. Among the management practices integrated pest management involving cultural (clipping of top leaves), mechanical (burnt soil dust application) and chemical (dichlorvos @ 0.1 %) practices showed greater reduction in larval population than the same measures applied individually. Statistically there was no significant difference between integrated measures to chemical control measures (T4 and T3). The order of treatments for their effectiveness in reducing the larval population was T4 > T1 > T3 > T2 > T5.

Fifteen days after the application of treatments all the plots recorded more larval population than control. No significant differences were found among the treatments. (Table 9)

Table 9. Effect of management practices on the larval population in monsoon season

Treatment	July,2004			August- September,2004		
	0DAT	7DAT	15DAT	0DAT	7DAT	15DAT
T1	13.87	11.1[bc]	15.87[a]	21.31	18.17[b]	25.73[b]
T2	14.9	14.52[ab]	19.52[a]	22.06	19.33[b]	26.97[ab]
T3	17.54	12.11[bc]	20.83[a]	23.84	19.38[b]	30.94[a]
T4	16.69	9.924[c]	17.66[a]	20.33	10.37[c]	20.4[c]
T5	17.56	17.1[a]	15.87[a]	24.37	25.9[a]	30.21[a]
		C.D3.95	C.D5.6		C.D4.44	C.D 4.26

DAT = Days After Treatment

Alphabets with same letter didn't differ significantly at P(0.05)

T1 = Clipping of the top leaves

T2 = Pre- heated soil dust application

T3 = Dichlorsos @ 0.1%

T4 = Trt 1+2+3

T5 = Control

The numbers denote the mean larval population per ten plant

Table 10. Effect of management practices on the larval population in post-monsoon season

S.No	Treatment	November,2004			December-January,2005			March – April,2005		
		0DAT	7 DAT	15DAT	0DAT	7DAT	15DAT	0DAT	7DAT	15 DAT
1	T1	33.38	28.9[b]	36.6[b]	35.83	34.41[b]	41.8[ab]	24.21	26.65[ab]	20.28[ab]
2	T2	30.08	30.69[ab]	38.99[ab]	43.2	39.43[ab]	45.52[a]	29.52	30.02[a]	22.69[a]
3	T3	30.51	28.54[b]	44.17[a]	46.85	36.15[ab]	45.63[a]	29.6	29.08[a]	24.71[a]
4	T4	34.32	19.58[c]	19.31[c]	40.52	29.86[b]	37.17[b]	21.49	22.37[ab]	20.59[ab]
5	T5	31.38	36.79[a]	43.18[ab]	42.54	45.15[a]	44.63[a]	27.9	17.89[b]	13.23[bc]
			C.D7.02	C.D 6.35		C.D9.79	C.D 5.38		CD8.38	CD 7.11

Alphabets with same letter didn't differ significantly at P(0.05)

Numbers are the mean larval population per ten plants

The effect of management practices on larval population in August – September, 2004 were as follows. Seven days after the treatment the integrated plot, T4 (10.37) had shown greater reduction in larval population than other management practices. The T4 and T 3 had no significant variations in the number of larvae. Hence the treatments were on par with each other.

The effect of treatments at 15 DAT showed significant reduction in larval population. The best treatment was T 4 and T1. The dust application and cultural treatment(T2 and T3) had shown no reduction of larval population over control. T3 had no effect at 15 days after treatment. Among the five treatments, T4 remained effective at 7 and 15DAT, followed by T1 and T2.(Table 9)

4.5.1.1.2 Post monsoon season

The effect of management practices on larval population in the month of November, 2004 were as follows. At the 7DAT the most effective plot was found to be plot 4 (19.58). It was followed by T3, T1 and T2. All the treatments had shown reduction in the larval population than control (T5).

At 15 DAT, T4 had remained the best one with the least larval population of 19.31. The T3 had shown more larval population than control (T5). T4 and T1 remained effective at 7 and 15 DAT. (Table 10)

The effect of management practices on larval population in the month of December- January, 2005

Table 11. Effect of management practices on the pupal population in monsoon season

Treatment	July,2004			August –September,2004		
	0DAT	7 DAT	15DAT	0DAT	7 DAT	15 DAT
T1	6.02	4.495[a]	3.336[a]	1.8	1.64[a]	1.22[a]
T2	5.95	5.098[a]	4.018[a]	1.71	1.53[a]	1.36[a]
T3	4.77	1.143[b]	1.655[b]	2.14	0.055[b]	1.02[a]
T4	5.13	1.722[b]	1.768[b]	2.00	1.64[a]	1.03[a]
T5	4.12	3.291[ab]	4.223[a]	1.76	1.874[a]	1.06[a]
		CD 2.93	CD 2.3		CD1.01	CD 0.42

Alphabets with same letter didn't differ significantly at P(0.05)

The numbers denote the mean pupal population per ten plant

Were as follows. At, 7DAT, T4 showed greater reduction in larval population than other treatments. T4 was followed by T1, T3, T2 and T5.

At the 15th DAT T4 still showed significant reduction of larval population over other treatments. There was no variation among T2 and T3 to T5. Hence they were on par with each other.

The effect of management practices on larval population in March- April, 2005 were as follows. At 7 DAT no treatment recorded any reduction in larval population. The larval population was less in control than the other treatments.(Table 10)

At 15 DAT there existed no reduction in larval number over control. Here too the control had recorded the minimum larval population than other treatments. (Table 10)

4.5.1.2 Effect of management practices on the pupal count

4.5.1.2.1 Monsoon season

Larvae were observed to pupate both in fallen leaves and at the bottom leaves of the plant.

The effects of management practices in July 2004 were given below. At 7DAT, T3, T4 had shown less pupal count over other treatments. T1, T2 had recorded more pupal count than control. At 15 DAT T3, T4 remained the best by recording less number of pupae. T3, T4 had shown some effect on both 7 and 15 DAT. (Table 11)

Table 12. Effect of management practices on the pupal population in post monsoon season

S.No	Treatment	November			December-January			March - April		
		0DAT	7 DAT	15 DAT	0DAT	7 DAT	15 DAT	0DAT	7 DAT	15 DAT
1	T1	6.27	4.49[a]	3.33[a]	2.79	2.055[a]	1.53[a]	1.01	1.019[a]	1.221[a]
2	T2	5.00	5.09[a]	4.01[a]	2.55	1.874[ab]	1.067[ab]	1.00	1.519[a]	1.2[a]
3	T3	4.27	1.14[b]	1.655[b]	3.14	0.917[b]	0.955[b]	1.00	1.019[a]	0.97[a]
4	T4	4.38	1.72[b]	1.768[b]	2.84	1.336[ab]	0.992[b]	1.32	1.971[a]	1.043[a]
5	T5	4.22	5.29[a]	4.223[a]	2.01	1.917[ab]	1.205[ab]	0.99	0.97[a]	1.54[a]
			CD 2.9	CD2.89		CD 1.01	CD 0.45		CD 0.94	CD 0.83

Alphabets with same letter didn't differ significantly at P(0.05)

The numbers denote the mean pupal population per ten plans

The effect of management practices on pupal population in August-September, 2004 were as follows. At 7 DAT T3 had recorded minimum pupal count. All the other treatments recorded insignificant reduction in pupal population.

4.5.1.2.2 Post monsoon season

The effect of management practices on the pupal population in November, 2004 was as follows. At 7 DAT T3, T4 showed the minimum pupal population. The least population was recorded on T3. T1, T2 were on par with control (T5). At 15 DAT, T3, T4 had still recorded minimum population. T1, T2 were on par with T5. At 7 and 15 DAT both T3, T4 were the best treatments. The order of treatments at 7 DAT was T3> T4 >T1> T2 >T5. (Table 12)

The effect of management practices on the pupal population in December - January, 2005 was as follows. The pupal population before the treatment was almost similar. At 7 DAT, T3 recorded the least pupal count. T1 recorded more population than control (T5). At 15 DAT, T3 and T4 remained the best treatments. T1 recorded more pupal count than control (T5). The order of the treatments was T4 >T3 > T2 > T5> T1. (Table 12)

The effect of management practices was insignificant in March – April ,2005. At 7,15 DAT, no treatment recorded any effect on the pupal count.

Table 13. Effect of management practices on the leaf damage in monsoon season

S.No	Treatment	July,2004			August- September,2004		
		0DAT	7 DAT	15 DAT	0DAT	7 DAT	15 DAT
1	T1	17.87	13.42[b]	19.5[b]	33.1	26.58[b]	31.66[b]
2	T2	21.3	21.55[a]	28.22[a]	33.1	26.46[b]	35.98[b]
3	T3	19.89	14.75[b]	19.49[b]	25.47	23.06[b]	32.53[b]
4	T4	19.72	14.27[b]	18.77[b]	27.26	25.19[b]	29.85[b]
5	T5	18.47	22.27[a]	25.52[a]	35.06	33.46[a]	43.73[a]
			CD 7.11	CD 4.26		CD 6.82	CD 7.37

Alphabets with same letter didn't differ significantly at P(0.05)

The numbers denote the per cent leaf damage per ten plants

Table 14. Effect of management practices on the leaf damage in post monsoon season

Treatment	November,2004			December-January,2005			March – April,2005		
	0DAT	7 DAT	15DAT	0DAT	7DAT	15DAT	0DAT	7 DAT	15DAT
T1	56.12	51.74^{a}	59.1^{ab}	64.58	69.44^{a}	65.02^{a}	32.54	39.59^{a}	29.11^{a}
T2	52.63	50.39^{ab}	62.21^{a}	62.26	49.76^{b}	47.65^{a}	34.62	30.87^{abc}	30.73^{a}
T3	52.01	43.67^{b}	45.46^{c}	61.14	54.4^{b}	57.84^{a}	34.93	27.07^{bc}	17.57^{b}
T4	51.07	43.1^{b}	$51.1b^{c}$	62.66	56.06^{b}	54.91^{a}	33.11	23.08^{c}	17.65^{b}
T5	53.5	57.1^{a}	63.14^{a}	69.02	73.84^{a}	54.95^{a}	37.12	35.15^{ab}	25.43^{ab}
		C.D7.46	C.D9.0		CD11.1	C.D20.6		CD8.61	C12.16

Alphabets with same letter didn't differ significantly at P(0.05)

The numbers denote the per cent leaf damage per ten plants

4.5.1.3 Effect of management practices on the leaf damage

4.5.1.3.1 Monsoon season

The effect of management practices on the leaf damage in the month of July, 2004 was as follows. At 7 DAT, the least leaf damage was found in plot number 4. T4, T3 and T1 were most effective over control. Treatment 2 was on par with the control(T5).

At 15 DAT, T4 remained the best followed by T3 and T1. T2 and T 5 did not vary significantly. (Table 13)

The effect of management practices on the leaf damage in the month of August- September, 2004 was as follows. Seven days after the treatments all the treatments recorded less leaf damage than control. But there was no significant difference among the 4 treatments.

At 15 DAT all the 4 treatments recorded less leaf damage than control. But there was no significant difference among the 4 treatments.(Table 13).

4.5.1.3.2 Post monsoon season

The effect of management practices on the leaf damage in the month of November, 2004 were as follows. At the 7 DAT T4, T3 had shown greater reduction in the leaf damage than other treatments. T1 and T5 were on par with each other. At 15 DAT the best treatment was the T 3 followed by T4, T1, T 2 and T5. T2 and T5 were on par with each other. (Table 14)

The effect of management practices on the leaf damage in the month of December-January, 2005 were as follows.

Table 15. Effect of management practices on the larval population in monsoon season

S.No	Treatment	July,2004			August – September,2004		
		0DAT	7 DAT	15 DAT	0DAT	7 DAT	15 DAT
1	T1	18.42	11.02^{b}	13.5^{bc}	18.11	19.03^{b}	24.02^{abc}
2	T2	14.52	12.47^{b}	14.9^{b}	29.2	21.27^{ab}	24.28^{ab}
3	T3	16.22	10.69^{b}	11.94^{cd}	22.17	18.51^{b}	22.62^{bc}
4	T4	14.27	7.74^{c}	10.8^{d}	24.22	11.97^{c}	19.85^{c}
5	T5	17.24	16.82^{a}	20.86^{a}	22.12	24.23^{a}	27.47^{a}
			CD2.68	CD 2.17		CD 4.77	CD 4.105

Alphabets with same letter didn't differ significantly at P(0.05)

The numbers in denote the mean larval population per ten plants

At the 7 DAT, T2, T3 and T4 showed significant reduction in the leaf damage than T1 and T5. At 15 DAT, control (T5) was on par with other treatments.

The effect of management practices on the leaf damage in the month of March – April, 2005 were as follows. At 7DAT, T4 recorded the least leaf damage. The leaf damage was more in T1 than T5(Control). T 3 and T 2 were not statistically different.

At 15 DAT, T3 and T4 remained the best treatments with less leaf damage. T 1 recorded more leaf damage than control (T5). (Table 14)

4.5.2 Results of Field Experimentation and Management in Intercropped Cultivation System

4.5.2.1 Effect of management practices on the larval population

4.5.2.1.1 Monsoon season

The effect of management practices on the larval population in July, 2004 were as follows. At 7 DAT, there was a significant reduction in larval population. T4 had recorded the least larval population (7.743). There was no difference among T1, T2 and T3..

At 15 DAT,T4 still remained the best treatment, with the larval population mean of 10.8. The difference between T2 and T3 was not statistically significant. (Table 15) T4 recorded the least larval population at 7 and 15 DAT. All the other treatments too recorded the less larval population than control.

Table 16. Effect of management practices on the larval population in post monsoon season

S.No	Treatment	November,2004			December- January,2005			March – April,2005		
		0DAT	*7 DAT*	*15 DAT*	*0DAT*	*7 DAT*	*15DAT*	*0DAT*	*7 DAT*	*15DAT*
1	T1	33.96	30.07[a]	34.31[a]	32.12	35.98[a]	40.04[a]	19.27	17.29[a]	12.47[a]
2	T2	30.69	30.33[a]	33.29[a]	34.14	37.18[a]	39.7[a]	21.22	16.31[a]	15.45[a]
3	T3	32.72	29.27[a]	30.94[a]	35.62	32.37[a]	31.08[b]	20.24	16.39[a]	12.14[a]
4	T4	30.43	20.66[a]	29.08[a]	30.33	21.72[b]	24.82[c]	18.66	12.7[a]	9.486[a]
5	T5	30.32	32.66[a]	35.38[a]	39.41	42.11[a]	42.11[a]	18.42	12.56[a]	10.45[a]
			CD5.32	CD10.47		CD8.09	CD3.81		CD5.49	CD7.1

Alphabets with same letter didn't differ significantly at P(0.05)

The numbers denote the mean larval population per ten plants

The effect of management practices on the larval population in the month of August- September, 2004 was as follows. At 7 DAT the most effective treatment was T4. All the treatments had shown less larval population than control. But the difference between T 1 and T 3 was not statistically significant.

At 15 DAT, T4 recorded the least larval population over other treatments. The T1, T2 and T3 did not differed significantly. All the treatments had shown reduction in larval population than control (T5). Among the treatments T4 had recorded the least larval population at both 7 and 15DAT. All the treatments had recorded some degree of reduction in larval population. (Table 15)

4.5.2.1.2 ***Post monsoon season***

The effect of management practices on the larval population in November were as follows. At 7 DAT, T4 had shown the least number of larvae. All the other treatments did not show any significant reduction in larval population.

At 15 days after the application no management practices had got any effect on larval population. Though T4 had recorded the least larval number it was not statistically significant to other treatments.

Among the treatments, T 4 had shown some reduction in larval population after 7 days. All other treatments did not show any effect on larval population at 7, 15 days interval. (Table 16)

The effect of management practices on larval population in January,2005 were as follows. Among the 5 treatments, T4 had shown considerable reduction I

larval population over other practices. All the other management practices *i.e* T1, T2 andT 3 were on par with control (T5) and did not differ significantly.

At 15 days after the treatments T4 remained the best by showing the least larval population. But T3 had also shown less larval population than control. T 4 and T3 differed significantly for the larval population. T 1 and T2 were on par with control (T5). (Table 16)

At 7,15 days after the treatment application, T4 had shown the best results by recording least larval count. Chemical treatment (T3) too showed less larval population at 15 day after the treatment.

The effect of management practices on larval population in March- April, 2005 were as follows. There was no significant variation in larval population among treatments at 7, 15 days after the treatment. (Table 16)

4.5.2.2 The effect of management practices on pupal population

4.5.2.2.1 Monsoon season

In July, 2004 at 7 DAT, the most effective treatment was T3 and T4. T1 also recorded some reduction in pupal count. At 15 DAT, T1 recorded the best results. In August – September, 2004 the most effective treatment was T3. T4 closely followed T3. T1 too showed less pupal count than T5. (Table 17)

Table 17. Effect of management practices on the pupal population in monsoon season

Treatment	July,2004			August - September,2004		
	0DAT	7 DAT	15 DAT	0DAT	7 DAT	15 DAT
T1	3.24	2.43^{ab}	2.28^{ab}	3.14	2.44^{ab}	2.15^{a}
T2	3.22	3.68^{a}	3.78^{a}	2.99	3.557^{a}	2.4^{a}
T3	2.97	1.2^{b}	0.92^{b}	2.78	1.236^{b}	3.11^{a}
T4	3.42	1.62^{b}	1.81^{ab}	3.21	1.66^{b}	1.91^{a}
T5	4.01	3.8^{a}	3.442^{a}	3.24	3.84^{a}	3.52^{a}
		CD1.33	CD 2.01		CD1.37	CD 2.18

Alphabets with same letter didn't differ significantly at P(0.05)

The numbers denote the mean pupal population per ten plants

Table 18. Effect of management practices on the pupal population in post monsoon season

Treatment	November,2004			December-January,2005			March – April,2005		
	0DAT	7 DAT	15 DAT	0DAT	7 DAT	15 DAT	0DAT	7 DAT	15 DAT
T1	2.91	2.24[a]	4.05[a]	1.94	1.57[b]	1.584[a]	1.94	1.42[a]	1.69[a]
T2	3.42	3.27[a]	1.78[b]	2.11	1.51[b]	1.768[a]	2.47	2.17[a]	1.44[a]
T3	3.12	1.23[b]	1.121[b]	2.43	1.06[b]	1.565[a]	2.22	0.92[a]	1.52[a]
T4	2.67	1.5[b]	1.66[b]	2.68	1.66[b]	1.907[a]	3.15	1.55[a]	1.22[a]
T5	2.14	2.23[a]	3.87[a]	3.48	3.67[a]	2.426[a]	3.11	0.92[a]	1.97[a]
		CD1.02	CD 1.56		CD 1.332	CD 1.1		CD 1.43	CD 0.94

Alphabets with same letter didn't differ significantly at P(0.05)

The numbers denote the mean pupal population per ten plants

4.5.2.2.2 Post monsoon season

In November at 7 DAT the best treatment was T3 and T4. The least pupal count was recorded on T3. T 1 and T2 were on par with T5. At 15 DATthe best treatments were T2, T3 and T4. T 1 and T5 were on par with each other. At 7 and 15 days after the treatment application T3, T4 remained the best treatments.

In December-January, 2005 at 7 DAT the best treatments were T1, T2, T3, and T4. T3 recorded the least pupal count. But at 15 days no treatment got any effect on pupal population. All the treatments showed affect only upto first 7 days.

The effect of management practices on the pupal population in March – April, 2005 were insignificant. No treatment recorded any significant reduction in pupal population. (Table 18)

4.5.2.3. The effect of Management practices on leaf damage.

4.5.2.3.1 Monsoon season

The effect of management practices in July, 2004 were as follows. At 7 DAT, T4 leaf damage. It was followed by T1 and T3. There was not much difference in leaf damage in T3 and T5. T2 had recorded more damage than control.

At 15 DAT, T4 remained the best by recording the least number of damaged leaves. It was closely followed by T1. T1 and T5 were on par with each other. The T2, T3 had recorded more leaf damage than control. At 7, 15 DAT, the T4 showed greater effect than others. T 2 had recorded more damage than control. (Tab

Table 19. Effect of management practices on the number of damaged leaves in monsoon season

Treatment	July,2004			August- September,2004		
	0DAT	7 DAT	15 DAT	0DAT	7 DAT	15 DAT
T1	24.26	16.85[b]	20.6[ab]	20.22	24.62[b]	29.34[c]
T2	25.22	20.35[a]	24.85[a]	28.26	32.2[a]	40.07[b]
T3	29.67	18.93[ab]	25.32[a]	24.8	33.11[a]	44.36[a]
T4	19.22	12.92[c]	18.57[b]	20.18	24.72[b]	33.12[c]
T5	19.00	18.95[ab]	21.41[ab]	28.28	29.6a[b]	31.11[c]
		CD2.68	CD4.88		CD5.58	CD4.11

Alphabets with same letter didn't differ significantly at P(0.05)

The numbers denote the per cent leaf damage per ten plants

Table 20. Effect of management practices on the leaf damage in post- monsoon season

Treatment	November,2004			December-January,2005			March – April,2005		
	0DAT	7 DAT	15 DAT	0DAT	7 DAT	15 DAT	0DAT	7 DAT	15 DAT
T1	50.26	44.81^{b}	51.4^{ab}	61.2	57.63^{ab}	60.86^{a}	29.99	29.68^{ab}	19.2^{b}
T2	53.24	41.24^{bc}	52.58^{ab}	58.77	52.3^{b}	61.49^{a}	38.23	34.74^{a}	21.86^{ab}
T3	58.22	43.65^{b}	48.01^{b}	64.42	51.7^{b}	53.35^{b}	34.24	31.21^{ab}	19.02^{b}
T4	56.47	34.65^{c}	41.47^{c}	59.47	42.98^{c}	54.81^{b}	37.27	19.65^{b}	18.85^{b}
T5	50.21	52.9^{a}	54.29^{a}	60.31	63.55^{a}	57.74^{ab}	38.88	35.22^{a}	28.07^{a}
		CD7.02	CD 5.6		CD 6.64	CD5.74		CD 12.2	CD6.92

Alphabets with same letter didn't differ significantly at P(0.05)

The numbers denote the per cent leaf damage per ten plants

The effect of management practices in August-September, 2004 were as follows. At 7 DAT, T1 and T4 had recorded the less leaf damage. T 1 and T4 did not differ significantly from each other. T 2 and T 3 had recorded more leaf damage than control.

At 15 DAT, T1, T5 and T4 recorded less leaf damage. T1 and T4 did not vary significantly. T2 andT 3 had recorded more leaf damage than control (T5). At 7 and 15DAT, T1 remained the best and recorded the less number of damaged leaves. (Table 19)

4.5.2.3.2 Post monsoon season

The effect of management practices on the leaf damage in November, 2004 were as follows. At 7 DAT, T4 had shown the minimum leaf damage. T 1 and T3 were on par with each other, showed significant reduction in leaf damage but far above than T4.

At 15 DAT,the best treatment was T 4, recorded the least damage. It was followed by T 3,T1 and T2. All the other treatments showed reduction in leaf damage than control. (Table 20)

T4 had shown the least damage at both 7, 15 days after treatment. Chemical management too had shown reduction in damage but not as much as T4. All the treatments recorded the reduction in damage over control.

The effect of management practices on number of damage leaves in December- January, 2005 were as follows. At 7 DAT, the best treatment was T4. It was followed by T3 and T2. At 15 DAT, the best treatment wasT 3 and T4. The reduction in damage in T4 and T3 were on par with each other. The T1 and T2 had shown core damage than control(T5).

T4 and T3 had shown their effect at 7,15 days after treatment. But T1 and T 2 had some effect at 7 days after treatment but not at 15 days after the treatment. (Table 27)

The effects of management practices on the number of damage leaves in March- April, 2005 were as follows. At 7 DAT, T4 had recorded the least number of damaged leaves. T 1 and T3 were on par with each other, showed next best results to T4. At 15 DAT, T4 remained the best treatment by recording the least damage. It was closely followed by T3, T1 andT 2. (Table 20)

T4 showed some reduction in damage at both 7,15 days after the treatment. But the T4 had shown overall reduction in damaged leaves.

4.6 OVICIDAL ACTION OF DICHLORVOS ON LEAF ROLLER

Two days old eggs were subjected to the bioassay for the ovicidal action of dochlorvos as in 3.5.3. The concentration of 0.5 per cent DDVP had shown the most lethal to eggs, recorded the maximum mortality and resulted in least hatching of eggs(6.67). The increase in concentrations increased the mortality rate of leaf webber. The field recommended doses of dichlorvos @ 0.1, 0.2 percent showed 43.33, 16.67 per cent mortality respectively. The results were presented in table 21.

Table21 Ovicidal action of dichorvos on *D. pulverulentalis*

S.No	Dichlorvos Concentration	Percentage hatchability	
		Mean	Range
1	0.01	83.25	71.25-93.5
2	0.05	62.25	54.5 – 59.55
3	0.1	43.33	32.07 – 59.5
4	0.15	20.0	15.45 –29.77
5	0.2	16.67	12.42 –23.15
6	0.5	6.67	4.25 – 12.45
7	Control*	91.45	84.45 –96.75

** = Treated with water*

S.No	No of larvae used	LC50/LT50 value	Fiducial levels		Regression equation	Heterogenity
			Upper level	Lower level		
1	30	1.73 mg/l	2.055	1.305	Y = 5.92 + 0.992x	0.925
2	30	17.12 h	20.686	13.654	Y = 6.42 + 0.72x	1.223

Table 22 Efficacy of dichlorvos on the larva of *D. pulverulentalis*

4.7 BIOEFFICACY OF DICHLORVOS ON *D. PULVERULENTALIS*

The probit analysis for dose mortality response of dichlorvos at different concentrations showed that the dose of 1.73 mg/l as the optimal 50 per cent lethal concentration (LC_{50}). The probit analysis for time mortality response showed that 17.12 h after the treatment were the 50 per cent lethal time (LT_{50}).(Table 22)

4.8 FOOD CONSUMPTION AND UTILIZATION INDICES

The approximate digestibility (AD) ,efficiency of conversion of ingested food to body tissue (ECI) and efficiency of conversion of digested food to body matter (ECD) of *D.pulverulentalis* was calculated on fresh weight basis of the digestible portion of food and weight of ingested food by the test larvae as per 3.8

The AD, ECI and ECD value were calculated to be 55.3 per cent (32.3 – 74.3), 37.34 (12.42 –54.32) and 25.23 (17.9 –38.47). The results were presented in the table 23.

Table 23 Food consumption and utilization indices of *D. pulverulentalis*

S.No	Variable	Range (%)	Mean (%)
1	Approximate digestibility (AD)	32.2 –74.3	55.3
2	Efficiency of digested food to body weight (ECD)	12.42 – 54.32	37.34
3	Efficiency of ingested food to body tissue (ECI)	17.9 – 38.47	25.23

5. DISCUSSION

The leaf roller, *Diaphania pulverulentalis* (Hampson) was widely prevalent in the Sericultural farms of Kerala. The present study was undertaken to assess the seasonal trends in larval population, extent of shoot damage and the leaf damage in the sericultural farms of Chalakkudy area of Thrissur district. The study included the biological aspects of the pest in relation to weather parameters to find out the suitable means to manage the pest with an emphasis on ecofriendly management practices.

5.1 SEASONAL INCIDENCE AND DAMAGE POTENTIAL

The studies have established the varying relationship between the weather parameters and the population of the leaf roller. The multiple regression equation for weather parameters and the pest incidence was found to be as

$Y = 60.2 + 0.63x_1 + 1.35x_2 - 0.57x_3 - 0.31x_4 + 0.98x_5 - 0.17x_6$

The multiple regression equation explained the variability in pest incidence due to weather parameters up to 56.6 per cent.

The variability due to weather can be explained as follows. A significant negative correlation was recorded in open system of cultivation between larval population and relative humidity at morning (-0.709) and relative humidity at evening (-0.645). The effect of photo phase on larval population is significantly positive (0.5). An insignificant, negative correlation was observed between the larval population and maximum temperature (-0.082) and minimum temperature (-0.261). Precipitation showed a positive but insignificant correlation (0.0511).

In intercropping system a significant negative correlation was recorded between larval population and relative humidity at morning (-0.75), relative humidity at evening (-0.57). Precipitation was negatively correlated with larval population (-0.539). The effect of photo phase on the larval population is positive and significant

(0.55). The effect of maximum temperature (0.232) and minimum temperature (-0.3) was insignificant on larval population.

The multiple regression equation fitted with weather parameters and the larval population in the intercropped system was

$Y = 52.27 + 0.99x_1 + 0.67x_2 - 0.48x_3 + 0.21x_4 + 0.76x_5 - 0.076x_6$

The multiple regression equation explained 52 per cent variability in larval infestation due to weather parameters.

The larval infestation is negatively correlated with relative humidity at morning and at evening. So the increase in larval population can be predicted by relative humidity and the management can be planned accordingly. Photo phase recorded positive correlation with the larval population and shoot damage. As the months of October to December receive maximum sunlight comparing to preceding monsoon season the larval population increased to the maximum. The relative humidity is a hindrance for the perpetual of larval population from January to May as recorded by the decline in the larval population and shoot damage.

The multiple regression equation for the weather parameters and the leaf damage in open system is as follows

$Y = 48.2 + 1.47x_1 - 1.26x_2 - 0.747x_3 + 0.665x_4 + 5.841x_5 + 0.349x_6$

The multiple regression equation explained 48 per cent variability in damaged leaves due to weather parameters.

A significant, negative correlation is observed between leaf damage and relative humidity at evening (-0.649). The effect maximum temperature on the damage is negative (-0.5). The effect of minimum temperature (0.139), relative humidity at morning (0.368) and precipitation (0.3) was insignificant but positive.

In intercropping system the larval population was negatively correlated with relative humidity at morning (-0.63), relative humidity in the evening (-0.63). An insignificant positive correlation was observed between leaf damage and photo phase (0.311) and rainfall (0.064). There was an insignificant negative correlation between leaf damage to maximum temperature (-0.17) and minimum temperature (-0.1178)

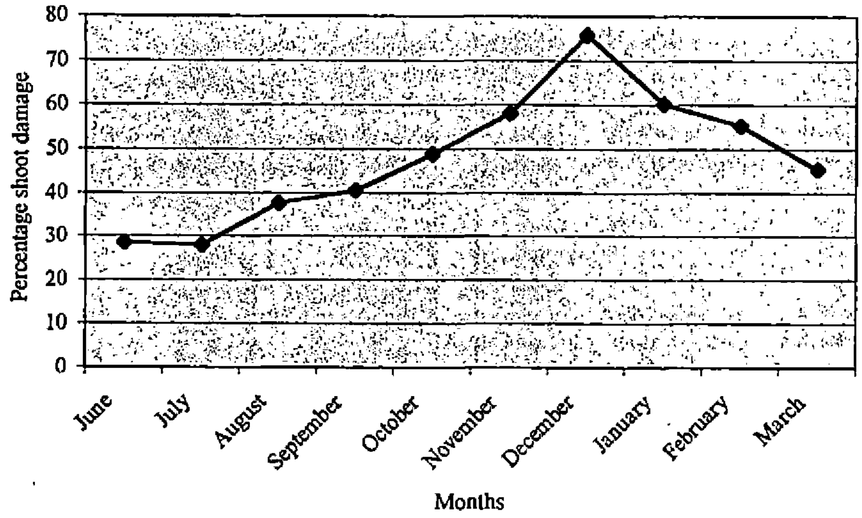

Fig. 1 Seasonal variations in shoot damage in open system

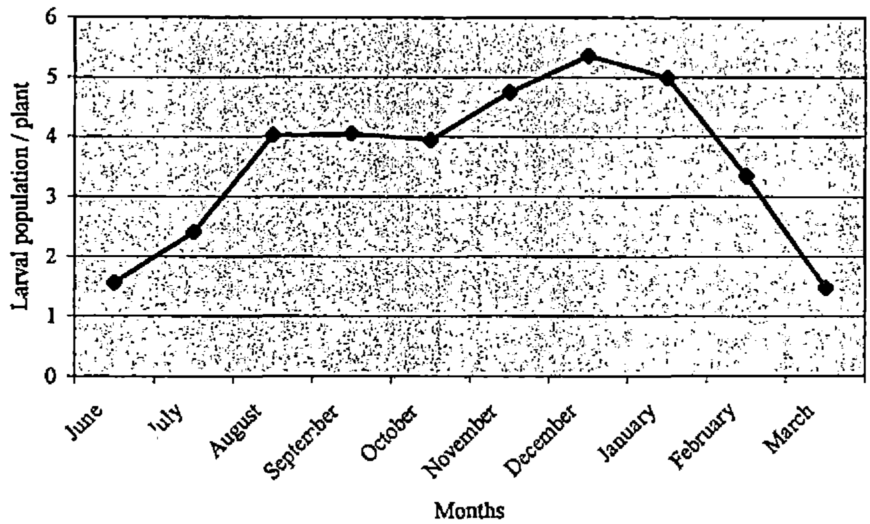

Fig. 2. Seasonal variations in larval population in open system

with the leaf roller infestation. The multiple regression equation for the weather parameters and the leaf damage was

$Y = 39.4 + 0.818x_1 + 1.105x_2 - 1.01x_3 + 0.82x_4 + 3.65x_5 + 0.27x_6$

The regression equation established 39.4 per cent variation in leaf damage due to weather parameters. From the above results it can be concluded that larval population increased with corresponding decrease in relative humidity at morning, evening and precipitation.

Such negative association of relative humidity with damage of sesamum by shoot webber, *Antigastra catalaunalis* Dup. has been reported by Philip (1990). Siddegowda *et al.* (1995) reported that the incidence of mulberry leaf webber maximum in winter months (October to February).

In both the systems of cultivation the shoot damage was very less in summer season (January to May). The shoot damage varied from 28.5 in June to 75.83 in December. It came down to 45.46 per cent by the following March in open system of cultivation (Figure 1). The number of larvae per plant was 1.56 in June and it ascended to 5.37 by December. The population came down to 1.47 by the following March in open system of cultivation (Figure 2).

Shoot damage in intercropping system of cultivation was the lowest in June (37.13), reached the maximum in December (72.83). It came down to 36.96 by the following March (Figure 3) In the intercropping system of cultivation the larval population was recorded to be minimum in June (1.94) and ascended to 7.26 by December. It recorded 2.25 larvae per plant in the following March (Figure 4).

This shows that the shoot damage and larval population were maximum in post monsoon season (October to December) and they came down by next February to March.

The results were in coincidence with Philip (1990) who reported that the damage by *A. catalaunalis* was maximum during November to December months.

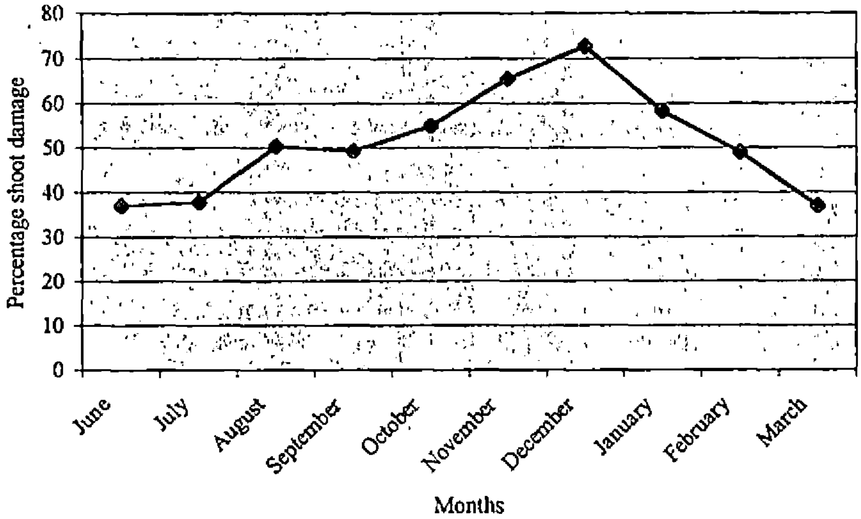

Fig. 3. Seasonal variations in shoot damage in intercropped system

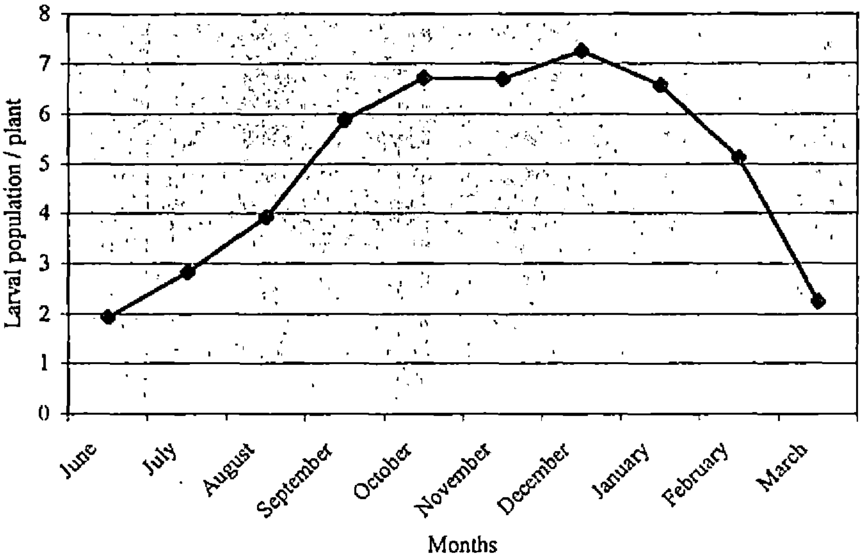

Fig. 4. Seasonal variations in larval population in intercropped system

Natarajan (1990) observed that higher population density of larvae caused the maximum shoot damage when compared to the low population density on cotton against *Helicoverpa armigera.*

Siddegowda *et al.* (1995) made a detailed survey in the mulberry gardens at Annedoddi, Pannidoddi, Thorshettihalli, Sunnadekere and Malavlli of Karnataka state. They reported that the infestation due to *Diaphania* sp. on Kanva-2 ranged from 50 -80 per cent during October to December months.

5.2 STUDIES ON THE BIOLOGY OF LEAF ROLLER, D. PULVERULENTALIS

The investigations on the biology and bionomics of leaf roller *D. pulverrulentalis* was carried out in the insectary of department of Entomology of College of Horticulture, Vellanikkara.

The fecundity of the leaf roller was found to be 157 eggs with a range of 117 to 211 eggs per adult female. The incubation period of the eggs varied from 2.5 to 5.5 days with an average of 4 days depending upon the season. The eggs were flat or oval or spherical in shape and semitransparent to yellow in colour. Siddegowda *et al.*(1995) observed that the eggs of *Diaphania* sp. was flat, spherical, semi-transparent and the egg period varied from 5 to 7 days. In case of *G. pyloalis* the eggs were pale green, flat and egg period varied from 5 to 7 days (CSR&TI, 1996).

The larval period of leaf roller in peak season varied from 12.5 to 17.5 days. The larval period is less in lean season. (9.75 to 15 days). The larval period of *Glyphodes* sp. is 15.54 days on the variety S 54, 18.46 days on Palladam local (Sathyaseelan, 1999).

The shortened larval duration during January to March may be due to the prevailing high temperatures and relative humidity in the region. The temperature starts increasing in January. So the maximum temperatures were recorded before the onset of premonsoon showers. The increase in temperature shortens the period required for a particular growth period.

The prolonged larval duration of *G. pulverulentalis* on Palladam Local was observed by Satyaseelan (1999). The poor nutrient quality of palladam local was stated as the reason for the prolonged larval period. Similar results were reported on corn borer, *H. zea* by Beland and Hatchett (1976). The prolonged larval period of fruit borer *H. armigera* on resistant cultivar Paiyur 1 of tomato was reported by Sivaprakasam (1988).

The growth index varied from 2.93 to 4.83 with a mean value of 4.2. The total development period was 28.01 days. The percentage adult emergence was 67.7 per cent. The difference in growth index and total development period was due to seasonal variations.

The results were in conformation with Satyaseelan (1999). He reported that the growth index was maximum on Kanva-2 (4.83) and minimum on Palladam local (2.79). The total development period was 32.7 days. The per cent adult emergence was 85 per cent on Victory-1. Seol *et al.*, 1987 reported that the percentage pupation of *G.pyloalis* was less (47%) in autumn and more (70.0%) in spring season on mulberry.

The adult longevity of male was 8.2 to 12.5 days with a mean of 9.7 days in peak season, 7.5 to 9.5 days with an average of 8.15 days in lean season. The adult female life span varied from 10.4 to 15.15days with a mean value of 11.5 days in peak season, 8.91 to 13.45 days with and average value of 10.225 days in lean season. The reduction in duration in lean season mat be due to prevailing high temperature in February – March. The quantum of heat required to complete a growth stage is Heat Requirement (HR) for the species. Life stage is completed if the heat requirement is met. (Ananthakrishnan and Viswanathan, 1982). This may be the reason for the shortened duration of life cycle and adult moth period.

5.3 NATURAL ENEMIES

Biololgical control forms an important strategy in IPM practices for its feasibility and eco- friendliness. A survey on the mulberry gardens revealed that a number of parasitoids and predators were associated with different larval and pupal stages of *D. pulverulentalis.* Hymenopteran parasitoids, *Bracon hebetor*, *Chelonus* sp., *Apantales* sp. were observed to parasitize on the larvae of leaf roller. *Bracon* sp. attacked the late larval instars, where as *Chelonus* sp. attacked the early larval instars. A long mermithid nematode is also observed from early instars of leaf roller. A pupal parasitoid, *Tetrastichus howardi* was also recorded from the pupae of leaf roller.

Two spiders *viz,. Tetragnatha* sp. and *Philidromus* sp. were observed predating on the larvae of leaf roller.

The results were in conformation with the research findings of KSSR&DI (1998). They recorded two braconid parasitoid viz., *Apanteles bisulcata* and *A. agilis*, which were abundant during December and January months. The percentage parasitisation of the above parasitoids on *D. pulverulentalis* was 11.1 and 10.5 respectively. The percent parasitism by *A. bisulcata* on *D. pulveulintalis* was 9.4, 67.8, 33.0 and 10 during July, August, September and February respectively. In Karnataka a reduvid predator *Isyndus herus* (Fab.) (Hemiptera: Reduviidae) and an unidentified wasp were recorded on *D. pulverulentalis* (KSSR&DI, 1998).

Bai and Marimadaiah (2000) reported a solitary larval endoparasitoid, *Apantales agilis* on *D. pulverulentalis.* Marimadaiah and Bai (2000) observed the emergence of a gregarious larval endoparasitoid *Apantales bisulcata* from mulberry leaf roller *D. pulverulentalis.* The endoparasitoids spun cocoons on the dead larvae found pupating on the mulberry leaves. Marimadaiah and Bai (2001) reported a solitary egg- larval endoparasitoid, *Phanerotema noyesi* on *D. pulverulentalis.*

Sathyaseelan and Chandramohan (2002) reported that there were five natural enemies on leaf webber *D. pulveruentalis. Bracon hebetor, Apantales* sp., *Goniozus* sp. were the parasitoids and *Tetragnatha sp., Philodromus* sp. were the spiders.

A few natural enemies of spider fauna were reported to predate on mulberry leaf roller. *Tetragnatha* and *Philodromus* spp. were the spiders found to prey upon mulberry leaf roller. The experiments conducted in Tamil Nadu have shown that the above-mentioned spiders could be effectively utilized in the biocontrol of mulberry leaf roller (Subramanian, 2002).

The egg parasitoid *Trichogramma chilonis* Ishii is highly effective against *D. pulverulentalis*. Field release of this parasitoid @ 50,000/ha at 10 days interval is recommended. A pupal parasitoid *Tetrastichus howardi* Olliff has also been reported to parasitise the pupae of the leaf roller (Govindan *et al.*, 2003).

5.4 COLLATERAL HOSTS OF MULBERRY LEAF ROLLER

During the study period leaf roller was not found to feed on any plants other than mulberry. A no-choice experiment with cucurbits, hibiscus, jack leaves indicated that leaf roller cannot sustain on these plants.

5.5 FIELD MANAGEMENT STUDIES OF LEAF ROLLER

The field management studies were conducted from April, 2004 to March, 2005 were divided into two seasons *i.e.* monsoon season and post monsoon season.

A comparison of the treatments in open system of cultivation in monsoon season showed that integrated treatment (T4) has pronounced effect in reducing the larval population. Dichlorvos spray (T3), clipping(T1)have closely followed integrated treatment . At 7 and 15 DAT, integrated treatment showed less number of larval populations per 10 plants.

A critical look into the biology of the leaf roller reveals that adult female lays eggs on ventral side of the top leaves. Upon hatching, larvae move upwards, enter just opened leaves of mature buds and starts scraping epidermis. With the help of silken threads, larvae roll the leaf and feed within.

Cultural approach emphasises on clipping of just opened leaves and the top leaves, so as to provide no food for the early instars larvae. Regeneration of buds takes place 5 -10 days depending upon nutrient status of the crop and season. Activated soil, when dusted on the leaves, causes abrasive action in the crawling larvae. Thereby larvae stop moving and feeding. Chemical control with dichlorvos kills both the eggs on tender leaves and the remaining larvae. The safe period of dicholrvos is 10 -11 days (Raghupathy *et al.*, 2003).

The reason for the integrated treatment to remain effective for 15 days is that there is a clear gap of 15 days between the two consecutive life cycles of the larva. The regeneration of flushes takes 5 – 10 days. The effect of dichlorvos remains for 10 -11 days. The egg period is 4 days. This affords protection against the pest for a minimum of 15 days.

A comparison of the treatments in the intercropping system showed that integrated treatment recorded the least number of larvae per 10 plants both at 7 and 15 DAT. Dichlorvos spray, clipping and burnt soil dust applications have closely followed integrated treatment. The effect of dichlorvos, clipping and soil dust was more apparent at 7 DAT but not at 15 DAT.

Monsoon season in open cultivation system points out that the best treatment is integrated treatment . Clipping showed less larval population than dichorvos spray. Integrated treatment remained effective both at 7 and 15 DAT. But in the months of March – April, 2005 there was no significant difference among the treatments, because the population itself was on decline. So the control is on par with the other treatments.

In intercropping system no treatment showed reduction in larval population in monsoon season. Though, integrated treatment, dichlorvos spray and clipping showed some control against larvae .it was not statistically significant. The population trend came down by the following March – April.

In open system of cultivation both monsoon, post monsoon season pupal population showed that dichlorvos spray and integrated treatment recorded reduction in pupal count. Clipping and soil dust did not showe any ffect on pupal count. In March – April, 2005 no treatment showed specific effect because the pupal population itself was on decline. So the treatments were on par with each other. In intercropping system dichlorvos spray showed greater reduction in pupal count than integrated treatment . Clipping and soil dust pplication were on par with control. In March – April, 2005 all the treatments recorded the same level of reduction in pupal count.

The reason behind dichlorvos and integrated treatment to be the effective treatments was that dichlorvos application on the canopy destroys the pupae on the bottom of leaves. As dichlorvos has fumigant action it acts on the target despite of no physical contact. In March- April the population trend was decreasing as evidenced in the 4.1.1. The larval population and shoot damage were on decline after January.

The integrated and dichlorvos spray were the best treatments in the monsoon season in Open system of cultivation and recorded the least leaf damage. Clipping closely followed dichlorvos spray. The effect of integrated treatment and dichlorvos spray was felt even at 15 DAT. T1 remained effective only up to 7 DAT but its effect got weakened by 15 DAT.

In post monsoon season too integrated treatment and dichlorvos spray remained the best treatments. In March – April, 2005 the effect of dichorvos spray and integrated treatment was felt up to the first 7 days only. Their effect was not pronounced at 15 DAT. All the treatments were effective than control.

In intercropping system the monsoon management practices revealed that integrated treatment was the best one. It was followed by clipping and dichlorvos spray. Integrated treatment showed reduction in leaf damage both at 7 and 15 DAT. Burnt soil dust also showed some reduction in leaf damage.

In post monsoon season integrated treatment emerged as the best treatment closely followed by dichlorvas spray, burnt soil dusting and clipping. All the treatments are effective than control. In March – April, though the population trend was on decline integrated treatment and dichlorvos spray showed greater reduction in leaf damage than control.

From the above it can be concurred that among all the treatments integrated practices were the best one. Though dichlorvos spray followed integrated treatment closely, considering environment safety concerns integrated treatment was the best approach to manage the leaf roller. The effect of cultural practice (clipping) is more pronounced when the larval population was at its peak (October – December). Burnt soil dusting too showed some effect in reducing the damage, but its effect was not much apparent.

The results of chemical treatment were in line with the findings of CSR&TI (1996). The results showed that monocrotophos at 0.05 and 0.1 per cent concentration caused mortality of larvae of *G. pyloais* by 93 and 95 per cent, while dichlorvos at 0.04 and 0.02 per cent concentration significantly reduced the larval population by 90 and 75 per cent respectively.

Siddegowda *et al.* (1995) reported that foliar spray of dichlorvos (0.2%) with 0.5 per cent soap solution significantly reduced the larval population of *Diaphania* sp. with a safe waiting period of 17 days for feeding to silkworm, *B.mori*. Raghupathy *et al.* (2003) mentioned that the safe waiting period of dichlorvos was 10-11 days. He has also mentioned that application of dichlorvos 1ml/ lt at 30 days after pruning controls the leaf webber on mulberry.

Foliar spray of dichlorvos 0.076 per cent was found effective against mulberry leaf webber with a safe waiting period of 10 days after the last spray. A second spray is recommended after 10 days of first spray if the infestation exceeded 20 per cent (KSSR&DI, 1999).

5.6 OVICIDAL ACTION OF DICHORVOS ON LEAF ROLLER

Dichlorvos showed greater reduction in the hatchability at the concentrations above 0.1 per cent. The hatchability percentages for 0.1, 0.2 per cent(field recommended doses) of dichlorvos showed 43.33 and 16.67 per cent hatchability respectively.

5.7 EFFICACY OF DICHORVOS ON LARVAL POPULATION OF LEAF ROLLER

The probit analysis for the dose mortality response of dichorvos at different concentrations showed that the dose of 1.73 mg/l as the optimal LC_{50} value. The probit analysis for the time mortality response showed that 17.12 hours was the optimal LT_{50} value.

The results were in agreement with Satyaseelan (1999) who stated that the LT_{50} value for the dicholrvos at 0.15 per cent concentration was 17.5 hours.

5.8 FOOD CONSUMPTION AND UTILIZATION INDICES

The approximate digestibility (AD), efficiency of conversion of ingested food into body tissue (ECI), efficiency of conversion of digested food to body matter (ECD) of D. pulverulentalis is 53.3, 37.34 and 25.23 per cent respectively.

These indices showed that out of every 100g of leaf tissue consumed by the larvae, only 53.3g were digested. Out of the 53.3 g digested food the efficiency of conversion of ingested food to body tissue was 37.34 per cent and the conversion of digested food to body tissue was 25.23 per cent only.

6. SUMMARY

The present study on mulberry leaf roller, *Diaphania pulverulentalis* (Hampson) was undertaken in the Kottat village of Chalakkudy area to investigate upon the extent of shoot damage, leaf damage per shoot and the seasonal trends in larval population. The study included bioecological aspects of pest in relation to weather parameters and seasons to find out the suitable and affordable means to manage the pest with an emphasis on ecofriendly management practices.

The studies have established the relationship between the weather parameters and the population of leaf roller. Relative humidity at morning(-0.709) and at evening (-0. 45) exhibited a significant negative correlation on the larval population in the open system of cultivation. Photo phase showed a significant positive relationship with the larval population(0.5).In intercropping system, relative humidity at morning (-0.75) and evening (-0.57) showed a negative correlation on the larval population. Photo phase was positively correlated to larval population (0.55), where as precipitation was negatively correlated (-0.539) to larval population in intercropping system of cultivation.

Two out of six weather parameters namely relative humidity at evening (-0.649) and the maximum temperature (-0.5) had recorded negative correlations with leaf damage in open system of cultivation. Relative humidity at morning (-0.75) and at evening (-0.57) and also precipitation (-0.539) exhibited a negative correlation on the shoot damage in intercropped system of cultivation.

The number of larvae per plant was 1.56 in June and it ascended to 5.37 by December. The population came down to 1.47 by the following March in open system of cultivation. The shoot damage varied from 28.5 in June to 75.83 in December. It came down to 45.46 per cent by the following March in open system of cultivation.In the intercropping system of cultivation the larval population was recorded to be minimum in June (1.94) and ascended by December (7.26). It recorded 2.25 larvae per plant in the following March.Shoot damage in intercropping

system of cultivation was the lowest in June (37.13), reached the maximum in December(72.83). It came down to 36.96 by following March.

The biological studies on leaf roller showed that there is a variation in life periods of individual stages *Viz.*, egg, larval instars, pupae and adult moths. The fecundity of leaf roller was found to be 157 eggs with a range of 117 to 211 eggs per adult female.Biological studies in peak season (October to December) recorded an incubation period of 4 days with a range of 2.5 to 5.5 days.The individual larval periods were 1.714, 2.5, 3.214, and 3.28 and 3.92 days for the I, II, III, IV and V instar larvae respectively.

The pupal period was 8.0 to 10.5 days, adult male lived for 8.2 to 12.15 days, where as adult female moth longevity was 10.4 to 15.15 days.The studies in lean season (February to Mach) recorded an incubation period of 3.3 days with a range of 2.75 to 4.25 days. The individual instar larval period was 1.516, 2.009, 2.471, 2.52 and 3.51 days for I, II, III, IV and V instar larvae respectively.The pupal period ranged from 6.275 to 9.79 days with a mean of 7.95 days. The adult male lived for 8.15 days with a range of 7.5 to 9.5 days, where as female moth lived for 10.225 days with a range of 8.91 to 13.45 days respectively.The total development period was 23.25 days in lean season and 28.01 days in peak season.

The leaf roller was attacked by many parasitoids and predators. Hymenopterans like *Bracon hebetor*, *Chelonus* sp. attack the larval stages. *Tetrastichus howardi* was found to parasitize on the pupae of leaf roller. A long mermithid nematode attacks the larvae. The spiders *Tetragnatha* sp., *Philodromus* sp. were found to predate on the leaf roller.

The leaf roller was not found to feed on the weed flora adjacent to mulberry garden. The captive feeding experiment with the leaves of Cucurbits, Hibiscus and Jack leaves indicated that leaf roller couldn't sustain on these leaves.

The field management studies involving clipping of tender leaves and unopened buds, inert sterilised soil application, dichlorvos application @ 0.1 per cent and the integrated treatment with the combination of the above three practices showed reduction in the larval, pupal population and leaf damage.The integrated treatment showed the least larval population in the monsoon season (June –September) and in the non-monsoon season in both the systems of cultivation.

A critical look into the pupal count revealed that the chemical treatment was effective in controlling the pupal population in both monsoon and post-monsoon seasons in open and intercropping systems of cultivation.The integrated treatment showed the least leaf damage in the monsoon as well as post-monsoon seasons in both the systems of cultivation.The effect of the treatments were insignificant in summer (January to April) as the larval, pupal populations and leaf damage was in declining trend.

Dichlorvos exhibited greater ovicidal action (43.33, 16.67 per cent) at the concentrations of 0.1 and 0.2 per cent.The probit analysis of dose mortality response of dichlorvos t different concentrations showed that the dose of 1.73 per cent as the LC_{50} value. The time mortality response of dichlorvos at 0.1 per cent showed 17.12 hours as the LT_{50} value.

The experiments on food consumption and utilization indices recorded that the approximate digestibility (AD), efficiency of conversion of ingested food into body tissue (ECI) and the efficiency of digested fool into body matter (ECD) were 53.3, 37.34 and 25.23 per cent respectively.

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* originals not seen.

Source of Journal abbreviations

http//:WOS17.isiknowledge.com/help/D_abrvjt.html

APPENDIX I

Details of the survey

Name of the Farmer:

Name of the village:

Cropping system: Open/ intercropped

Stage of the crop:

Plant no	Total no of shoots	No of infested shoots	No of larvae	Natural enemies observed
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

BIOECOLOGY AND MANAGEMENT OF MULBERRY LEAF ROLLER *Diaphania pulverulentalis* (HAMPSON) (LEPIDOPTERA : PYRALIDAE)

By

RAMALAKSHMAIAH. C.

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Entomology
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

2005

ABSTRACT

Investigations were carried out on the " Bioecology and management of mulberry leaf roller, *Diaphania pulverulentalis* (Hampson) (Pyralidae : Lepidoptera) simultaneously in the Department of Entomology, College of Horticulture, Vellanikkara and in Kottat village of Chalakkudy area of Thrissur district during April 2004 to March 2005. The objectives of the study were to find out the biological aspects of leaf roller namely, fecundity, duration of each life stage, number of larval instars as well as bioecological aspects like identification of collateral hosts, natural enemy complex and the correlation of weather parameters on leaf roller incidence and also the pest management issues like population counts at before and after treatments and per cent leaf damage per harvestable shoot.

Relative humidity at morning and evening was negatively correlated to larval population and shoot damage in both the open and intercropped system of cultivation. Photo phase showed significant positive relation on larval population in open and intercropped system of cultivation. Precipitation showed significant negative correlation on the larval population in the intercropping system of cultivation. The number of larvae per plant and shoot damage varied from month to month on mulberry. The number of larvae per plant was 1.56 in June, ascended to 5.37 by December. It came down to 1.47 in the following March in open system of cultivation. The number of larvae per plant was 1.94 in June, ascended to 7.26 by December. It came down to 2.25 per plant by the following March in intercropping system of cultivation. The shoot damage increased from 37.13 (June) to 72.83 (December). It came down to 36.96 by the following March in inter cropped system of cultivation. The shoot damage ascended from 28.5 (June) to 75.83 (December). It came down to 45.46 per cent by the following March in open system of cultivation.

The biological studies on the leaf roller revealed that the fecundity was 157 eggs with a range of 117 to 211eggs per female. The biological studies in peak season

(October to December) recorded the egg period as 4 days, individual larval periods as 1.714, 2.5, 3.214, 3.28 and 3.92 days for the I, II, III, IV and V instar larvae respectively. The pupal period was 7.95 days, the adult male longevity was 8.15 days and the adult female longevity as 10.225 days.

The biology in lean season (February – March) recorded the incubation period of egg as 3.3 days, individual larval periods as 1.516, 2.009, 2.471, 2.52 and 3.5 days for I, II, III, IV and V instar larvae respectively. The pupal period was 7.95 days. The adult male longevity was 8.15 days and female longevity was 10.225 days. The total development period varied from 23.25 days during the lean season to 28.01 days during peak season.

There are many natural enemies affecting different life stages of leaf roller. *Bracon hebetor*, *Chelonus* sp. and a mermithid nematode parasitizes the larvae. *Tetrastichus howardi* attacks the pupae. The spiders *Tetragnatha* sp. and *Philodromus* sp. predated on the leaf roller.

The experiments on the collateral hosts showed that the existing weed flora in and around mulberry garden, were not the hosts of leaf roller. The leaf roller did not feed on the leaves of related plant species to mulberry like Jack, Hibiscus and Cucurbits.

The evaluation of different management practices against leaf roller showed that the integration of the practices like clipping of top leaves, inert soil dust application and the application of dichlorvos 0.1 per cent as the best treatment than the individual treatments concerned for the reduction in larval population and shoot damage. The management practices were not pronounced in summer season (February to April). The results were almost similar in open, intercropped system of cultivation. The chemical treatment with dichlorvos at 0.1 per cent afforded greater reduction in pupal population than other treatments.

Dichlorvos exhibited greater ovicidal action by recording the hatchability of 43.33 and 16.67 per cent at 0.1 and 0.2 per cent concentrations respectively. The probit analysis if dose mortality response of dichlorvos at different concentrations showed that 1.73 per cent as the LC_{50} value. The time mortality response of dichlorvos at 0.1 per cent showed that 17.12 hours as the LT_{50} value. The experiments on food consumption and utilization indices recorded that the approximate digestibility (AD), efficiency of conversion of ingested food into body tissue (ECI) and the efficiency of digested fool into body matter (ECD) were 53.3, 37.34 and 25.23 per cent respectively.