VARIETAL PREFERENCE AND BIOLOGY OF MULBERRY LEAF-WEBBER, *Diaphania pulverulentalis* (HAMPSON)

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AFFECTIONATELY

DEDICATED TO

MY BELOVED PARENTS,

BROTHERS, SISTERS AND SHRUTHI,

SPOORTHI AND CHITRASHREE

DEPARTMENT OF SERICULTURE
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CERTIFICATE

This is to certify that the thesis entitled **"VARIETAL PREFERENCE AND BIOLOGY OF MULBERRY LEAF-WEBBER, *Diaphania pulverulentalis* (HAMPSON)"** submitted by **Mr. SOMASHEKAR, K.S., ID No. PAK-5244** in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **SERICULTURE** is a record of research work carried out by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

BANGALORE
JANUARY, 2009

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ABSTRACT

Studies on the air layering and softwood grafting in Jamun was carried out at the Division of Horticulture, Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bangalore, to standardize air layering and soft wood grafting in Jamun.

Air layers prepared during June and July months with 7500 ppm IBA as well as July and August months with 10000 ppm IBA recorded maximum rooting (100%). Layers treated with 10000 ppm IBA during September month layering recorded highest number of adventitious roots.

The softwood grafting in Jamun plants carried out on two species of rootstocks (*Syzygium cumini* and *S. operculatum)* from June to October. The grafting success was maximum in the month of June in both *S. cumini* (94%) and *S. operculatum* (92%) root stock. The cured scion shows 96 per cent of success during month of June in *S. cumini* and 92 per cent in *S. operculatum.* Length of sprouts and number of sprouts found maximum in *S. cumini* during the month of July in cured and uncured scions (0.27 and 0.24 cm respectively). The number of sprouts in *S. cumini* found maximum in cured scions (3.38) used grafts.

The days taken for sprouting was minimum during the month of June in cured and uncured scions (11.50 and 12.14 days, respectively) in *S. cumini* rootstock used grafts. Significantly minimum number of days taken for scion sprouting in cured (12.28 days) as well as uncured (12.30 days) scion grafted on *S. operculatum.*

Signature of the Student Signature of the Major Advisor

CONTENTS

LISTS OF TABLES

LISTS OF FIGURES

LIST OF PLATES

INTRODUCTION

I INTRODUCTION

Mulberry (*Morus* sp.) is regarded as native of Himalayas and it's culture spread to India from China through Tibet during 140 BC. It is now being cultivated in over 32 countries all over the tropical, temperate and subtropical regions of the world. Mulberry leaves serve as the sole food for silkworm, *Bombyx mori* L. Its production on the scientific lines is essential for practicing sericulture on the sound economic lines. From the economic point of view, moriculture coupled with silkworm rearing remains as a highly labour intensive activity providing vast scope for employment. Hence, it is essential to harvest better quality leaves through integrated nutrient management (INM) and integrated pest management (IPM) systems. Due to its evergreen, perennial, luxuriant foliage, mulberry provides food and shelter to a variety of insects and non-insect pests. A large number of insect pests have been reported on mulberry from different countries. Maki (1918) listed 87 insect and 6 non-insect pests on mulberry in Farmosa, whereas 118 insects were reported on the mulberry in Korea (Umeya and Omi, 1935). In China and Japan, more than 126 and 200 insect species cause damage to mulberry, respectively (Chu and Chi, 1936; Kukuchi, 1976). In India, more than 70 insect and non-insects species belonging to Lepidoptera, Hemiptera, Coleoptera, Thysanoptera, Orthoptera, Isoptera and Tetranychidae are known to feed on mulberry (Biradar, 1989; Naik, 1997).

In India, the area under mulberry has substantially increased from 10,485 hectares during 1971 – 72 to 91,434 hectares during 2008 (Bhaskar, 2008). Poor yield of mulberry has been reported due to attack by several pests. Leaf roller, Bihar hairy caterpillar, wingless grasshopper, mealy bug, thrips, weevils, root grubs, *etc.,* occur in serious proportions causing loss of leaf which in turn affects the

production of silk (Rangaswami *et al.*, 1976; Kotikal, 1982; Reddy and Kotikal, 1988; Biradar, 1989; Singh and Sarath chandra, 2002).

The insect pests of mulberry are classified as sap suckers, defoliators, stem borers and root feeders. Among defoliators, the mulberry leaf -webber, *Diaphania pulverulentalis* (Hampson) (Lepidoptera: Pyralidae) has been causing extensive damage to mulberry in south India in recent years (Siddegowda *et al.,* 1995).

The early stage larvae inhabit the apical part of mulberry shoot and feed on the tender leaves. The infested leaves are brought together and bound through a silky web formed by the larvae some times a single leaf is rolled by the web with the larvae inside and hence, the name leaf roller/ leaf webber. The infested plants show stunted growth (Narayanaswamy *et al.*, 2003). Though it occurs throughout the year, its incidence is severe from October to January.

Bajwa and Ashiq (1999) screened five exotic mulberry varieties *viz.,* Kanmasi and *Morus latifolia* (Japanese), Garyansuban and Qumji (Korean) and Husang (Chinese) and local variety (PFI - 1) for relative resistance against the leaf – roller. The local variety was relatively more resistant with infestation of 25.90 per cent, while Husang (35.50%) and Kanmasi (42.50%) were classified as moderately resistant ones. In Karnataka the rate of infestation of *D.pulverulentalis* was maximum on V_1 (89.40%) followed by M_5 (87.60%) and S_{36} (86.59%), and it was lowest (40.31%) on Mysore Local variety of mulberry (Srinivasa Gowda, 2000).

Among screened varieties against leaf- roller, Kanva-2 had registered maximum leaf damage (88.83%) and leaf yield reduction (66.14%) followed by MR_2 (83.05% and 64.87%), V_1 (61.78% and 51.57%) and S_{54} (40.81 and 31.41%), Palladuam (24.19% and 13.56%) (Seelan, 1999).

The life cycle of the leaf roller is completed in 17-24 days. Female moths lay eggs (100 – 250 eggs) along the midrib of the mulberry leaf guarded by the leaf trichomes. Incubation period lasts for 2-3 days. The larval development is completed within 8-12 days, with a pupal period of 7-9 days (Rajadurai *et al*. 1999).

The available information on the mulberry varietal preference by the leaf – webber and the development of this insect on different mulberry varieties is meager. In view of this the present investigation was undertaken in order to find out the tolerance of mulberry varieties against *D. pulverulentalis* with the following objectives.

1. To study the mulberry varietal preference by leaf-webber, *Diaphania pulverulentalis* (Hampson).

2. To study the biology of mulberry leaf-webber on most tolerant and most susceptible varieties of mulberry.

Review of literature

II REVIEW OF LITERATURE

The Leaf-webber, *Diaphania pulverulentalis* (Hampson) (Lepidoptera: Pyralidae) is a major pest of mulberry with an incidence up to 100 per cent in sericultural belt of south India. Though it occurs through out the year, its incidence is severe during winter months. The literature related to this study is presented in the following paragraphs under appropriate headings.

2.1 Varietal preference of mulberry Leaf- webber

2.1.1 Host preference

The host plant preference varies with different genera. *Glypodes pyloalis* feeds on *Eugenia jambulina* and *Metanastria hyrtaca* (Cram.) (Pillai, 1921). The larva of G. *pyloalis* feeds on the fig (*Ficus* sp.) (Nair, 1970; Ramakrishna Ayyar, 1963).

Butani (1979) also reported that *Glyphodes* sp. was a serious pest on Jack in Assam (India). In Uttar Pradesh, the forest trees were defoliated by *G. pyloalis* (Mathur, 1980). Geethabai *et al.,* (1997) reported that the larva of *D. pulverulentalis* feeds on *Sonchus orachyotis,* a Compositae weed growing around the mulberry gardens.

2.1.2 Seasonal incidence

The occurrence of *Glyphodes pyloalis* moths was more during spring season at Farmosa in Japan (Maki, 1918). Yokoyama (1925) reported *Glyphodes pyloalis* to be a serious pest on mulberry and usually appearing at the later half of May, the second generation adults appear in the middle of July, the third generation in middle of August whereas the fourth generation adults appear at the end of August and beginning of September in Japan.

The *Margaronia pyloalis* has five generations in a year. The adult activity is seen from April to November in Japan (Kuwana *et al*. 1993). The activity of *M. (G). pryeri* begins at mid May and continues upto late October in Japan with four generations per year (Kiyoku, 1941). Rangaswami *et al*. (1976) reported that the activity of *Glyphodes pyloalis* starts in late autumn in Japan.

Mathur (1980) reported that the appearance of the adults of *Glyphodes pyloalis* depends on various environmental conditions, but commences from late April and continues upto November in Dehradun (India). The highest incidence of *Glyphodes pyloalis* on mulberry was observed during the humid seasons in North India (Mathur and Singh, 1983).

Sengupta *et al*. (1990) reported that the mulberry pyralid, *Glyphodes pyloalis* appears in summer season and continues to cause damage upto autumn season in Burma, Indonesia, Japan, Korea and Vietnam. However, its activity starts at summer and autumn season in China and February to September in Malayasia.

Aruga (1994) reported the activity of *Glyphodes pyloalis* to drastically increase during July-September months in Japan.

In Karnataka, Siddegowda *et al*. (1995) reported that the incidence of *Diaphania* sp. on mulberry was ranged from 0 to 100 per cent, and it's incidence was severe during winter months (October-February) in Koppa, Mandya, Mysore and Kanakapura taluks of Karnataka. But the incidence ranged from 0 to 30 per cent during summer months (March-June) in the above places.

In Jammu and Kashmir, the maximum damage (71.26 per cent) due to *Glyphodes pylaolis* on mulberry was observed during October and

minimum damage of 2.23 per cent during July (Anonymous, 1996b). The results of survey revealed that the leaf roller, *D. pulverulentalis* occurred on mulberry during June to February months. However, initially the incidence was 22 per cent during June which reached up to 85 per cent during September and 100 per cent during December. The Infestation declined below 50 per cent when the ambient temperature increased during the month of January, further decline in infestation was noticed to the level of 25 per cent in February and 14 per cent in March (Geethabai *et al.* 1997; Anonymous, 1998; Geethabai and Marimadaiah, 2002).

The incidence of leaf roller occurs during June and persists upto February, the disappearance of this pest was from March to May with average incidence of 27.85 per cent in Karnataka, 20.98 per cent in Andhra Pradesh and 16.48 per cent Tamil Nadu (Rajadurai *et al.*, 1999).

Seelan (1999) studied the influence of larval density on leaf damage by releasing the larvae @ 1,2,3,4 and 5 per plant on mulberry variety Kanva-2 under green house condition at TNAU, Coimbatore. The leaf damage was maximum (100%) when five larvae per plant were introduced, followed by four larvae per plant (99.6%), whereas it was 92.09, 76.78 and 56.58 per cent with three, two larvae and one larvae per plant, respectively. The per cent leaf reduction was maximum (84.39%) at a population density of five larvae per plant while minimum reduction (43.03) was in the case of one larva per plant.

The rate of infestation of *D.pulverulentalis* was maximum on R-1 (89.40%) followed by M-5 (87.60%) and S-36 (86.59%), while it was lowest (40.31%) on Mysore Local variety of mulberry. Srinivasa Gowda, (2000).

Srinivasa Gowda *et al.* (2001) studied the seasonal incidence of the mulberry leaf-webber *D. pulverulentalis* in Bangalore rural district. The pest appeared on mulberry during July and remained active until February. The peak incidence was observed during January (91.25%). The pest was not observed during summer i.e. from March to June. The incidence of leaf roller was positively correlated with the relative humidity (r=0.429) and negatively correlated with maximum and minimum temperatures and sun shine hours (r = - 0.54, r = - 0.70 and r = - 0.46, respectively).

Velavan (2001) studied the damage potential of *G. pulverulentalis*. The highest damage was observed during December (77.40%) followed by January (74.70%). The lowest damage was observed during March (6.34%). Weekly observations on shoot damage indicated a damage level of 2.5 to 95.20 %. However, maximum shoot damage was recorded during January second week.

Zeya *et al.* (2003) recorded *G. pyloalis* in Jammu and Kashmir during May to October with a damage level of 20 to 25 per cent by defoliating the mulberry plants. The characteristic feeding pattern is that the larvae web the leaves together feeding midrib and skeletonizing the leaves. The larvae soil the leaves with litter.

Manjunath Gowda *et al.* (2005) reported that the leaf roller *D. pulverulentalis* causes extensive damage to mulberry. The severity of the pest is during winter months with the damage reaching 100 per cent

2.2 Bio–chemical composition of infested mulberry leaf

Lipke and Fraenkel (1956) studied that many constituents of leaves whose function is unknown serve as repellant of proportion would account for the irregular distribution of proportion of the curious glycosides, tannins, saponins, alkaloids and essential oils whose

occurrence is unexplained by plant physiologist. It is contended that early in their evolution plant development the means by which they become unpalatable to the rising multitude of insects.

The unpalatability was in turn accomplished by the production of the vast array of chemical compounds which now characterized specific taxonomic groups of plants. In fact, the appearance of flowering plants in the early cretaceous coincides with the development of the various morphological and physiological adaptations in insects which characterized the interdependence of insects and the flowering plants.

The biochemical analysis of healthy and tukra infeted leaves of the six mulberry varieties revealed that there was a significant increase in the moisture, total minerals, crude fibre and total free amino acids contents in tukra affected leaves compared to the healthy leaves in all the six mulberry varieties. On the other hand there was a significant reduction in non-reducing sugars, total sugars, starch, water soluble proteins and crude protein contents in tukra affected leaves compared to the healthy leaves in the all the six varieties.

A maximum increase in the moisture, crude fibre and total free amino acids was observed in the local variety (5.78%, 172.88% and 18.18%, respectively) and minimum increase was observed in S_{36}, S_{54}, and S_{41} varieties (0.14%, 15.19% and 2.27%) in the case of total minerals and reducing sugars, the maximum increase was observed in S_{36} and S_{54} varieties (22.22% and 18.64%) and the minimum increase was observed in local and S_{41} varieties (1.02% and 4.84%). This increase of moisture, total minerals, crude fibre and reducing sugars and total free amino acids contents in the tukra infested mulberry leaves may be attributed to diversion of the above mentioned constituents to the site of infestation and by stimulus activity (Sadashivan and Subramanian, 1960) and / or

these constituents were synthesized at a faster rate at the site of infestation and are more stable (Shaw, 1963).

On the other hand, the maximum loss in reducing sugars, total sugars and total carbohydrates was observed in S_{54} variety (15.31%, 11.43% and 9.47%, respectively) and the minimum was in S_{41} variety (2.73%, 1.64% and 4.44%, respectively). In the case of starch, water soluble proteins and crude protein, the maximum reduction was observed in Mysore Local, S_{54} and S_{30} varieties (10.31% and 18.03% and 16.12%, respectively). whereas the minimum reduction was recorded in $S_{36,}$ S_{30} and S_{54} varieties (4.00%, 4.78% and 0.91%, respectively), This loss of non reducing, total sugars, starch, total carbohydrates and water soluble proteins and crude protein in tukra affected mulberry leaves may be attributed to the disruption of the leaf tissue due to the growth of pathogen insects (Subramanian and Saraswathidevi, 1959).

The variety S_{1635} recorded significantly highest value of leaf sugar content (12.44%) followed by S_{34} (11.60%) and differed significantly from the rest of the varieties (9.98 to 11.13%). The S_{1635} variety (26.91%) exhibited highly significant differences compared to all other varieties under study (20.91% - 24.96%). The S_{34} variety recorded second highest values of protein content (24.96%) followed by Viswa variety (24.26%) and did not show significant differences between themselves. The lowest values of protein content were recorded with Mysore Local (20.91%) and S_1 variety (22.38%) (Krishnaswamy *et al.,* 1971).

The constituents are degraded or utilized by the pathogen / insects at a faster rate (Samborski *et al.*, 1958). The reduction in total soluble sugars due to the activity of invertase (Michell, 1982). The decrease in the amount of starch is obviously due to the decrease rate of net photosynthesis (Ahmed *et al.*, 1987). The reduction of total soluble

proteins in the diseased leaves may be attributed to their break down by the proteolytic enzymes secreted by the pathogen (Agrawal *et al.,* 1989)

The leaf nitrogen ranged from 2.98 to 3.53 per cent with variety S_{36} recording the least values. TR_{10} recorded maximum values of leaf phosphorus content, followed by K_2 which differed non significantly from the rest of the varieties (0.26 to 0.3%). Mysore Local recorded significantly less values of potassium content (1.807%) than the other varieties (1.922 to 2.265%). Similarly, magnesium, calcium, iron, zinc and copper contents in leaves varied distinctly in the range of 0.8-1.627 per cent, 1.027 per cent, 56.683-76.767 ppm, 68.183-11.50 ppm and 18.363 – 36.667 ppm, respectively (Singvi *et al.,* 2000).

2.3 Morphological features of mulberry

2.3.1 Density of Trichomes

Raju *et al.* (1981) conflicting reports are available on the association of leaf hair with resistance to thrips attack. According to some authors, dense pubescence interfered with the biological activity of thrips favorably while a group of workers found it otherwise. A few studies revealed that hairyness in some plants remain impartial so as far as resistance to thrips is concerned. The presence or absence of shelter for insect has some times been of importance in resistance (Jones *et al.*, 1934).

Katsumata (1974) studied that the axil of the leaf on the under surface of the leaves in *Morus australis* leaf base is lancealate and truncate *in M.australis* whereas leaf is multilobed and base is broad chordate in case of *M. kagayamae.*

The number of trichomes on the lower midrib of the uninfested 4th leaf of MR_2, RFS_{175} and Mysore Local varieties were counted under steriozoom microscope (Rajagopalan Raju *et al.*, 1980).

The trichom index study did not reveal any phylogenetic relationship among the varieties. The succulent varieties namely Kosen and S_{30} had more number of trichomes per square millimeter area in adaxial surface in contrast to the less succulent varieties. (Raju *et al.*, 1981).

The trichomes are mostly dense in both indigenous (58.2%) and exotic (64.91%) accessions (Anonymous, 2000a).

Manjunath (2001) reported that the trichomes were thin and longer on susceptible MR_2 and intermediate in RFS_{175} whereas thick and shorted trichomes were recorded in the tolerant Mysore Local. However, the number of trichomes exist on lower midribs were maximum on Mysore Local (98.6 per cm) followed by RFS_{175} (90.6 per cm) and MR_2 (82.40 per cm).

Ananda Rao *et al.* (2002) reported that the leaf trichomes are the epidermal hairs, which increase succulence and protected the stomatal openings in the stress condition. It is probable that attractants like glycosides, saponins, tannins, alkaloids, essential oils and organic acids which attract silkworms are produced in glandular and eglandular trichomes, Rajagopalan Raju *et al.,* (1980) observed that considerable number of mulberry accessions and both in the indigenous and exotics have dense trichomes.

Tikader *et al.* (2004) reported that higher trichome density was noticed in indigenous mulberry accessions compared to the exotic accession.

2.3.2 Bud size:

Fotedar *et al.* (2003) reported that, genotype S_{146} recorded 0.7 cm of bud length compared to that of Chakmajra (0.5 cm) Katsumata (1974) studied the presence of white stiff hairs on both the sides of the midrib, especially at the axil of the leaf on the under surface of the leaves in *Morus australis* leaf base is lanceolate and truncate in *Morus austarlis* whereas leaf as multilobed and base, which is broad cordate in case of *M. kagayamae*.

2.3.3 Leaf lobation pattern

Katsumata (1974) studied that, the axil of the leaf on the under surface of the leaves in *Morus australis* leaf base is lanceolate and truncate in *M.australis* whereas leaf is multilobed and base is broad chordate in case of *M. kagayamae*.

Wide range of variability was observed in different strains of mulberry in various leaf yield attributing characters like leaf shape and size, plant height, internodal distance, number of primary and secondary shoots (Rangaswami *et al.,* 1976).

Tojyo (1980) reported that hexaploids were characterized by the irregular leaf shape, malformed leaf tip, margin and base, twisted and asymmetric leaf tip margin and base, twisted and asymmetric leaf veins and irregular phyllotaxy.

Gray and Gray (1987) reported that, the leaf lobation patterns in mulberry shrubs and tree. The number of divisions (sinuses) were counted to a maximum of five per leaf for tree, entire leaves were most frequent and single division leaves were second most frequent for shrubs, entire leaves with four or five divisions occurred at equal frequencies.

The leaf is unlobed and coriaceous both in indigenous (55.97% and 53.30%) and exotic (59.64% and 70.18%) accessions. The leaf shape is mostly ovate followed by wide orate (broad leaves) in both indigenous (63.37% and 22.63%) and exotic (50.88 %and 43.85%) accessions respectively (Anonymous 2000b).

Anand Rao *et al.* (2002) reported that majority of the indigenous and exotic accessions have homophylious unlobed leaves and the leaf texture is mostly chartoceous (thin) in indigenous while exotic ones have more number of cariaceous (thick) leaves. There is a wide variation in the leaf lobation number ranging form one to multilobation. The leaf shape is predominantly ovate but the broad ovate, smooth glossy leaves with larger leaf area in the exotic may be utilized for higher leaf production.

Fotedar *et al.* (2003) reported that twenty six characters for studying the morphology have been used to characterize, the genotype and a difference in distinct way could be seen in the shoot length branching behaviour leaf base, leaf glossiness leaf-angle, lamina length, lamina width, leaf shape and petiole length these parameters can help in identification of genotype.

Tikader *et al.* (2004) reported that, the morphology traits of different mulberry verities where high leaf lobation was noticed in Indigenous variety compared to the exotic varieties.

Tikader and Roy (2006) studied the Kandall and Spearman ranking correlation both for rank vs. rank and rank vs. numeric data and revealed of common groups, which were positively significant with each other the characters are like leaf lobation, leaf colour, leaf surface, leaf thickness, leaf appearance, axillary bud colour, branch number total biomass weight and leaf yield, besides this, other group of combination of character is also associated in kendall methods compared to spearman

method. So morphological parameters may not show direct association with leaf yield but indirectly play a vital role for contribution towards yield.

2.4 Life- cycle of *D.pulverulentalis*.

2.4.1 Egg

The adults of mulberry pyralid lay eggs on the lower surface of the leaves of mulberry which hatch in 5-6 days (Yokoyama, 1925).

Kiyoku (1941) reported the adult of *Margaroni pryeri* deposited approximately 150 eggs on the leaves with incubation period of 3.5 to 9.0 days.

The eggs of mulberry pyralid, *Glypodes pyloalis* are green, flat, oval and measure 0.7 mm in width and the incubation period last for 5.6 days (Rangaswami *et al.*, 1976).

Mathur (1980) reported that the adults of *Glyphodes pyloalis* deposited eggs singly on the under surface of the leaf along the mid rib or veins. The eggs are oval or circular, transparent, pale green with slightly convex surface and the bottom is always securely glued onto the leaf. The incubation lasts for 2 to 3 days.

Harado and Kikuchi (1982) observed that the eggs were laid by the female moths of *G. pyloalis* singly on the tender shoots, with an average fecundity of 250 eggs. Eggs were deposited along the leaf vein on the surface of the leaves (Sengupta *et al.*, 1990).

The leaf roller, *M. pulverulentalis* laid gelatinous eggs on the young leaves near the terminal buds of mulberry (Sengupta *et al.,* 1990). The adults of the leaf tier, *D. pyloalis* laid creamy eggs on the under surface of the leaves (Sengupta *et al.,* 1990).

The eggs of *G. pyloalis* measured 0.7 mm and semitransparent and were laid singly along the leaf vein on ventral side of the mulberry leaf and the fecundity ranged from 100 – 400 eggs (Govindan *et al.*, 1995; Aruga, 1994).

The eggs of *Diaphania sp.* are flat and pink in colour and hatch in 5-7 days (Siddegowda *et al.*, 1995).

The adults of *D. pulverulentalis* lay eggs singly on tender leaves of the apical region of plants, within the leaf buds or on the ventral surface of the tender leaves. Freshly laid eggs are slightly elongated and round at both ends and pink in colour. They measure 0.18 to 0.19 mm in length and 0.13 to 0.14 mm in breadth. The incubation period lasts for four to five days (Anonymous., 1996c; Geethabai *et al.,* 1997).

The moths of *D. pulverulentalis* lay about 100 – 250 eggs singly along the mid rib of the mulberry leaf guarded by the leaf trichomes and the incubation period lasts for 2-3 days (Rajadurai *et al.,* 1999).

Manjunath Gowda *et al.* (2005) reported that each female of leaf roller, *D. pulverulentalis* each female lays around 400 eggs with 2-3 days of incubation period.

2.4.2 Larva

Yokoyama (1925) reported that the larval period of *G.pyloalis* to ranged from 13 to 19 days in first three generations, whereas it was 247-271 days for the hibernating generations.

The fully grown larva of *M. pyloalis* is bluish green and rarely an inch in length. Hibernation occurs during cold weather from mid December to February (Beeson, 1941). Kiyoko (1941) reported the fully grown larva of *M. (=G) pryeri* to hibernate in late October at a

temperature of 18^0C or below. However, the larva did not complete its development or unable to survive in winter.

The larva of mulberry pyralid, *G. pyloalis* is green in colour, has 4-5 moults and the mature larva measures 18 mm in length. In September, the larvae crawl to the surface and make irregular shaped of cocoons where they hibernate in the larval stage. The hibernation varies with warm and cold zones of Japan (Rangaswami *et al.,* 1976).

The youngest larva is about 2 mm long, cylindrical and colourless except brownish head and mouth parts. The fully grown larva measures about 22 mm in length and 3 mm in width. The larva is apple green to bluish green having black tuberculated areas, each surrounded by whitish line. The head is pale yellow to light brown and each tuberculated bears one slender pale hair, the prothorasic segment bears small scattered air arranged dorsolaterally; the meso and metathoracic and anal segments possess three tubercles in a line near the anterior border of each segment and on either side of the middle line. The abdominal segments possess two anterior and one posterior tuberculated areas on each segment. A faint white strip runs on either side of the mid dorsal line and one each on lateral side (Mathur, 1980).

Siddegowda *et al.* (1995) reported that the larvae of leaf webber *D. pulverulentalis* on hatching move to apical portion of shoot and starts feeding on the unopened leaves. The larval duration lasted for 16 days.

Manjunath Gowda *et al.* (2005) reported that the larval duration lasted for 13-19 days in leaf roller D. *pulverulentalis*.

2.4.3 Pupa

As per Sengupta *et al.* (1990) that the pupa of mulberry pyralid, *G. pyloalis* is brown. The leaf roller, *M. pulverulentalis* pupates in soil.

Whereas the leaf tier, *D. pyloalis* pupates within the folded and tied leaves or in crevices, which is generally protected by faint films of silk secreted by the mature caterpillar.

The pupal period of leaf roller, *Diaphania* sp. Lasts for 10 to 12 days (Siddegowda *et al.*, 1995). The pupa of leaf roller *D. pulverulentalis* is deep brown and measures about 1- 1.5 cm in length and pupal period lasts for 9-10 days (Anonymous, 1996a: Geethabai *et al.*, 1997).

Rajadurai *et al.* (1999) reported that the pupa of mulberry leaf roller, *D. pulverulentalis* occurs in fallen dry leaves and debris or in the loose soil at the base of the plant. Sometimes it pupates on the branches. The pupal period lasts for 7 to 9 days.

Manjunath Gowda *et al.* (2005) observed the pupal stage to last for 4-11 days.

2.4.4 Adult

The adult of leaf roller, *G. pulverulentalis* possesses oblique lateral stripes on the abdomen. The anal portion of the adult moth has a tuft of black hairs with brown middle. The forewings have marking abscured by many number of spots and striae. The antimedial, medial and post medial bands are broader and less irregular. The first dentate was found inward on vein two, while in the second vein without discocellular spot, three had a series of pale specks on the outer edge form the vein four to the inner margin. The dentate sub marginal line replaced by a series of diffused black patches in the interspaces. Hind wings were thickly irrorated and striated with oblique black heded brown spot medial and submarginal bands almost meeting at a point near the angle, cilia of both wings fuscous, with falvous and brown lines at base (Hampson, 1896).

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 fore wing was pale in colour with fulvous. The inner margin of the wing was white in colour with fulvous. The inner margin of the wing was pale white in color, the base fuscous. The inner margin of the wing was white in colour, the base fuscous contained ante medical oblique white line followed by a black edged flavous band, band with discocellular lunule, a ring like spot was present on the vein two, possessing a sub marginal black heded with white line expanding into a dentate mark below the costa. Hindi wing was hyaline white and contained a broad marginal pale fulvous band with black inner edge. The inner margin was white with a fine black line (Hampson, 1896).

According to Rangaswami *et al.* (1976) the adults of the mulberry pyralid are dark brown in colour and measures about 2 cm at wing expanse, the wings are dark brown in colour and measures about 2 cm at wing expanse, The wings carry dark brown stripes on light yellow whitish background.

Mathur (1980) reported that moths of *G. phyloalis* are vary widely in size, females being bigger in size. But, the moths emerge during the dry period were very small, nearly half the size of the largest moth emerging during favourable season.

The adult of *G. pyloalis* is small, light silvery cream in colour (Sharma and Tara, 1985). Seol *et al.* (1986) reported that the life- cycle of mulberry pyralis *D. pyralid* lasts for 29 – 32 days.

The adults of mulberry pyralid, *M. pyloalis* are greyish white in colour body measuring 1 cm in length. The wings are folded behind the body at rest, fore wings are triangular and grayish white whereas hind wings are semi-circular and white (Sengupta *et al.,* 1990).

The adults of mulberry leaf- roller, *M. pulverulentalis* are greyish with black colour with black brown stripes on the forewing and measure about 10 mm in body length (Sengupta *et al.*, 1990). Siddegowda *et al.* (1995) observed that the life cycle of mulberry leaf roller lasted for 35 days, with two or more generations per year.

The moths are greyish white measures about 1.0 cm in length and possesses of the same colour on the wings

Manjunath Gowda *et al.* (2005) reported that the longevity of males and females of *D.pulverulentalis* varied from 9 to 14 days and 7 to 12 days, respectively.

Material and Methods

III MATERIAL AND METHODS

The studies on the varietal preference and biology of mulberry leaf–webber, *Diaphania pulverulentalis* were undertaken during 2006-2007 at KSSR&DI, Thalaghattapura and in Department of Sericulture, University of Agriculture Sciences, GKVK, Bangalore. The techniques adopted and materials used are mentioned hereunder.

3.1 Survey on the incidence of leaf- webber, *Diaphania pulverulentalis*

The survey work was conducted from November, 2006 to February, 2007 to record the incidence of leaf - webber on different accessions/ varieties of mulberry viz., S_1, DD, 240, 248, S_{13}, RFS_{135} MR_2, Mysore Local, Thalaghattapur, S_{1635}, 249, S_{34}, 238, 250 and M_5 maintained at mulberry Germplasm Bank, KSSRDI, Thalaghattapura, Bangalore. For each accession / variety, ten plant were selected randomly and the observations on total number of shoots per plant, number of caterpillars per plant were recorded. Then the rate of infestation was worked out and the mulberry accessions / varieties were categorized as most susceptible, moderately susceptible and most tolerant ones (Annexure-1).

3.2 Varietal preference of mulberry leaf webber

The study was carried out in respect of S_1, DD, 240, 248, S_{13}, RFS_{135} MR_2, Mysore Local, Thalagattapur, S_{1635}, 249, S_{34}, 238, 250 and M_5 varieties of mulberry maintained at mulberry Germplasm Bank, KSSRDI, Thalagattapura, Bangalore (Plate 1). Where in the leaf harvest was the common practice. The spacing adopted was 90X 90cm.

During the period of study, 300 plants (Three plots with 100 plants/variety) were selected and pest infestation (Plate 2.)

Plate 1. A view of experimental plot to study the varietal preference of mulberry leaf webber

Plate 2. Apical portion of mulberry shoots damaged by *D*. *pulverulentalis*

Based on the leaf webber count on 15 mulberry varieties, they were classifield as susceptible (TG) maderately susceptible (248) and resistant variety (DD). From these varieties, 3, 4 and 5 leaves were selected for the estimation of biochemical parameter, morphological features and biology.

3.3 Biochemical analysis

To find out variation in the biochemical constituents of the apical buds of mulberry, where the pests starts feeding, the apical leaves were analysed for biochemical constituents in respect of mulberry varieties viz., S_1 DD, 240, 248, S_{13}, RFS_{135} MR_2, Mysore Local, Thalagattapur, S_{1635}, 249, S_{34}, 238, 250 and M_5. The apical buds including the first unfolded leaf were drawn randomly from 20 plants of the selected varieties at an interval of 30 days and biochemical analysis was carried out.

3.4 Collection of leaf samples

The apical bud including the first unfolded leaf of mulberry varieties and also top, middle and bottom leaves were collected in paper bags at 30 days interval. Composite leaf samples were made and leaves were shade dried for three days and then dried in hot air oven at 70^0C until constant weight was obtained. The dried leaf samples were ground into fine powder and preserved in butter paper bags for chemical analysis. Each sample had three replications.

3.4.1 Estimation of leaf moisture

Moisture content of the leaves of all the mulberry varieties was estimated separately, through gravimetric method by taking the difference between fresh and dry weights and expressed as percentage on fresh weight basis (Thimmaiah, 1994).

$$\text{Leaf moisture (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.4.2 Estimation of total carbohydrates

The total carbohydrate contents of the leaves of selected mulberry varieties was estimated separately, according to the procedure of Dubios *et al.* (1956) and expressed as of percentage on oven dry weight basis.

3.4.3 Estimation of soluble proteins

Crude protein content of the different varieties of mulberry was estimated separately by determining total nitrogen content in 0.5 g sample by Micro–Kjeldhal, digetion-distilation method. The crude protein was calculated by multiplying the per cent nitrogen of the sample with factor 6.25 (Thimmaiah, 1994).

3.4.4 Estimation of total soluble sugars

The total amount of soluble sugars was estimated by using anthrone reagent test calorimetrically. Carbohydrates are the important components of storage and structural materials in the plants. They exist as free sugars and polysaccharides. The basic units of carbhohydrates are monosaccharides which cannot be split by hydrolysis in to more simple sugars.

The carbohydrates content was measured by hydrolyzing the polysacchardides in to simple sugars by acid hydrolysis and estimating the resulting simple sugars by acid hydrolysis and estimating resultant monosaccharides. The mulberry leaf samples were analysed for total soluble sugars by following anthrone method (Sadasivam and Manickam, 1992).

3.5 Morphological traits of mulberry varieties

3.5.1 Trichome density (cm^2)

The number of trichomes per cm^2 area on the lower midrib of the uninfested 4^{th} leaf of the M_5, TG, DD, Mysore Local, S_1, S_{135}, S_{13}, and RFS_{175} varieties were counted under Stereozoom binocular microscope (1 cm^2 area of leaf).

3.5.2 Unopened terminal bud size (cm)

The length of the randomly selected terminal buds in different varieties of mulberry was measured by using a centimeter scale and mean values were recorded.

Lobation pattern: The mulberry varieties were categorized as lobed and unlobed ones and if lobed, they were subgruped as regular and irregularly lobed varieties. (Plate 3).

3.6 Biology of mulberry leaf webber, *D. pulverulentalis*

The biology of *D. pulverulentalis* was studied on the most susceptible, moderately susceptible and most tolerant mulberry varieties at Department of Sericulture, UAS, GKVK, and Bangalore.

The ovipositional preference was studied by using most susceptible, moderately susceptible and most tolerant mulberry varieties by choice test. The observations on durations of egg, larva, pupa and adult (male and female), grown up larval weight, pupal weight and fecundity were recorded in the case of individuals developed / resulted from most susceptible, moderately susceptible and most tolerant varieties. For each varietiy, three replications of fifty individuals were maintained. During this period, maximum and minimum temperature and relative humidity were recorded.

S_1 RFS_{135} 250 ML 238 S_{1635}

249 240 TG

S_{13} DD 248 M_5 MR $_2$ S_{34}

Plate 3. Morphology of different varieties of Mulberry

A pair of freshly emerged adults (male and female) were released into blow up pin holed transparent polyethylene covers (20 x 20 cm) for ovipositon and provided with 10 per cent honey (plate 3). The freshly harvested apical shoots of all the selected mulberry varieties were kept upwards in the covers individually (Plate 4). The shoots were replaced daily to record fecundity. The eggs were collected every day and incubated at room temperature. On hatching, caterpillars were transferred on to fresh, tender mulberry shoots kept in petri plates (10 cm diameter). The freshness of the shoots was maintained by providing water as and when required One hundred such sets with larvae per petriplate were maintained for every mulberry variety.

3.6.1 Egg

A pair of freshly emerged moths were released into the blown up, pin holed polyethylene cover and provided with 10 per cent honey. Another set of male and female was enclosed in holed polyethylene covers was maintained as control. For both the sets, freshly harvested mulberry shoots of different varieties were provided (Plate 4)

3.6.2. Larval development

Observations were made at every six hours interval on larval growth and development. The observations such as instar duration, size (length x width) of larva at the end of each instar and weight of fifth instar mature larvae were recorded variety wise.

3.6.3 Pre- pupa

The pre-pupa is characterized by the shrunken body segments with pinkish translucent skin which later changes to parrot green after shedding the last larval skin. The duration between the stage of pinkish colour formation to greenish colour change was considered as pre-pupal duration.

Plate 4. Blown up polythene covers for oviposition of *D. pulverulentalis*

3.6.4 Pupa

The duration between the green colour formation of pupa to the adult eclosion was considered as pupal duration.

3.6.5 Adult

Adult longevity: The duration between adult emergence and death was recorded as adult longevity sexwise.

Pre-oviposition period: The period between the time of female emergence and depositing of the first egg was recorded as pre-ovipositon period.

Oviposition period: The period between the day of first egg laying and the day on which it stopped egg laying was recorded as oviposition period.

Post-oviposition period:

The period between the day on which it stopped eggs laying till the death of the female adult was considered as post oviposition period

3.6.6 Fecundity

The mulberry shoots were daily replaced and the number of eggs laid on that particular variety as recorded daily and the fecundity was arrived. Observations were also made on the number of eggs deposited on both ventral and dorsal sides of the leaf, on mid-rib and petiole.

3.6.7 Incubation

The eggs of leaf-roller along with mulberry leaf were collected and incubated at room temperature. The duration between the day of oviposition to the day of egg hatching was recorded as incubation period (Annexure-1).

3.6.8 Statistical analysis

The data on different parameters were subjected to simple CRD analysis. Data on incidence of leaf webber was correlated with morphological and biochemical parameters of mulberry varieties accessions (Panse and Sukatme, 1957).

Experimental Results

IV EXPERIMENTAL RESULTS

The fortnightly survey was conducted in mulberry gardens at KSSR&DI, Thalaghattapura, Bangalore from November 2006 to February 2007 to know the incidence of mulberry leaf-webber, *Diaphania pulverulentalis*.

4.1 Varietals preferences of *D. pulverulentalis*

4.1.1 The population of leaf-webber, *D. pulverulentalis* on different mulberry varieties

The highest mean number of leaf- webber per plant was recorded on TG (59.60%) followed by M_5 (52.55%), 250 (50.06%), 249 (47.29%), S_{34} (44.69%), 238 (43.47%), Mysore Local (42.47%), S_{1635} (40.76%), 240 (40.28%), 248 (39.70%), S_{13} (37.60%), MR_2 (36.82%), RFS_{135} (35.29%) and S_{13} (4.79%) in decreasing order however, the lowest leaf- webber population was observed on DD (33.36%).

The results as shown in (Table 1) and (Fig 1) indicated that the mulberry variety DD was most tolerant to leaf-webber infestation when compared to TG, which was highly susceptible variety.

4.1.2 Per cent incidence of *Diaphania pulverulentalis*

The percent incidence of leaf-webber, *D.* pulverulentalis in the mulberry garden was significantly higher during the first fortnight of January, 2007 (47.79%) followed by second fortnight on January 2007 (46.55%), second fortnight of December 2006 (42.74%), first fortnight of December 2007 (42.23%) and the second fortnight of November 2006 (41.09%) the incidence was minimum during First fortnight on November 2006 (39.03%) where as no incidence recorded during first and second fortnights on February, 2007 as shown in (Table 2).

Table 1. Fortnightly incidence of leaf-webber, *Diaphania pulverulentalis* on different mulberry varieties

Fortnight	Mulberry varieties														
	S_1	RFS_{135}	250	ML	238	S_{1635}	249	240	TG	S_{13}	DD	248	M_5	MR_2	S_{34}
FFN-06	23.27	32.68	30.92	38.86	46.78	40.77	38.21	29.28	37.16	30.00	28.92	32.25	40.65	31.44	36.45
SFN-06	32.22	42.79	53.34	38.06	39.97	34.75	41.34	42.31	41.94	34.04	38.56	37.33	56.20	34.94	48.68
FFD-06	34.88	33.26	52.18	40.72	40.78	33.26	48.18	39.61	65.94	41.10	30.36	40.00	52.34	37.00	43.87
SFD-06	36.26	35.16	53.64	42.61	38.81	37.80	48.18	39.61	65.94	36.61	33.47	39.89	52.34	37.00	43.87
FFJ-07	41.86	33.16	54.47	46.52	46.58	43.40	52.94	45.16	72.18	41.33	33.85	43.11	56.24	39.82	47.65
SFJ-07	40.27	34.72	55.83	48.09	47.92	46.75	54.91	45.75	74.48	42.54	35.05	45.66	57.45	39.82	47.65
FFB-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SFB-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MEAN	34.79	35.29	50.06	42.47	43.47	40.76	47.29	40.28	59.60	37.60	33.36	39.70	52.53	36.82	44.69
SE m ±	2.72	1.55	3.86	1.67	1.65	1.71	2.64	2.45	6.52	2.02	1.40	1.90	2.53	1.30	1.85
F test	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
CD at 5%	6.98	3.99	9.92	4.29	4.24	4.40	6.79	6.29	16.76	5.18	3.60	4.89	6.52	3.33	4.76

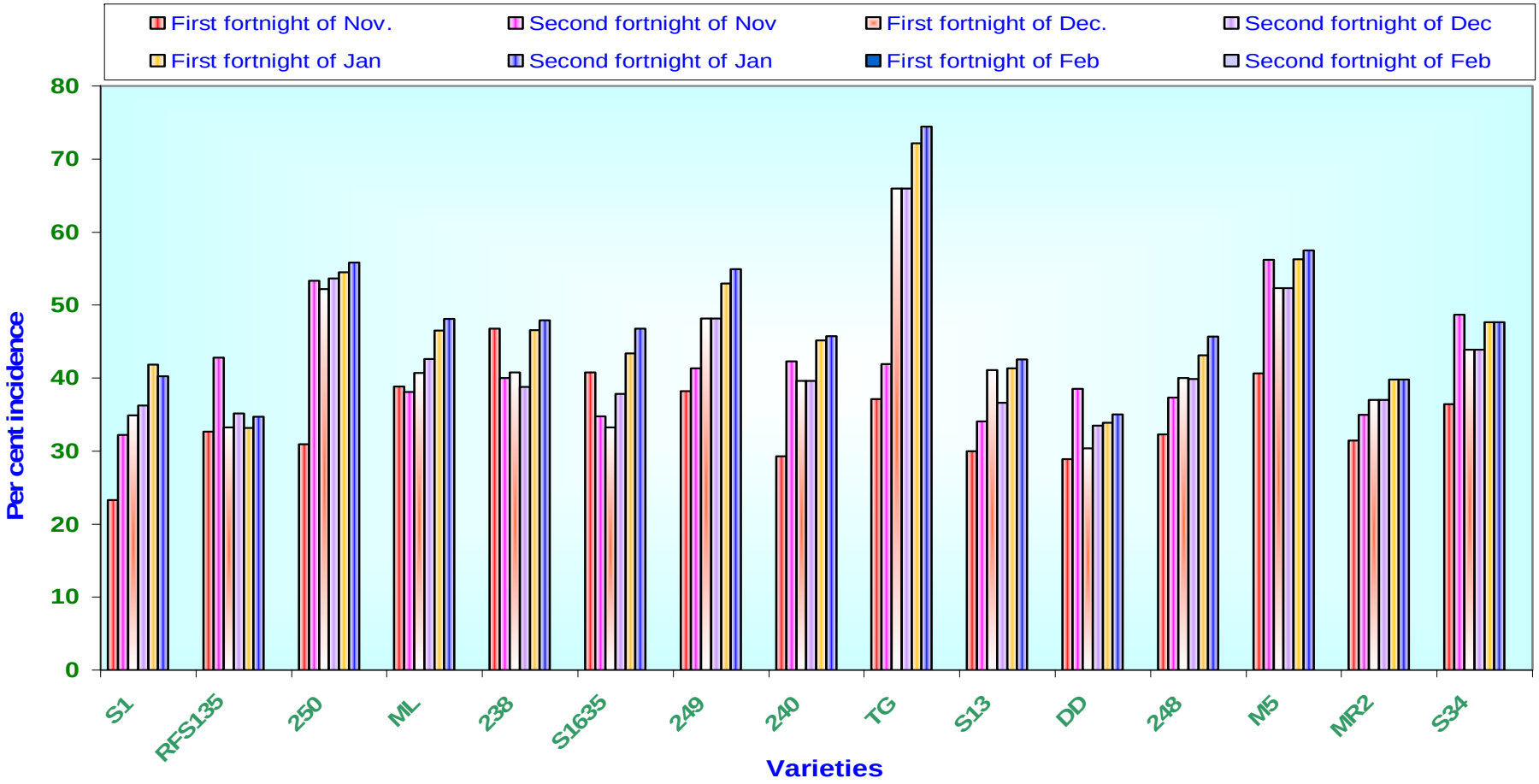

Fig 1: Per cent infestation by the mulberry leaf webber, *Diaphania pulverulentalis* on mulberry during different months

Table 2. Rate of infestation of leaf –webber on mulberry From Nov-2006 to Feb- 2007

Fortnight	Infestation (%)
First fortnight of November 2006	39.03
Second fortnight of November 2006	41.09
First fortnight of December 2006	42.23
Second fortnight of December 2006	42.74
First fortnight of January 2007	46.55
Second fortnight of January 2007	47.79
First fortnight of February 2007	0.0
Second fortnight of February 2007	0.0

N= 150 plants / observation

4.1.3 Seasonal incidence and per cent infestation of leaf-webber.

The field survey on the seasonal incidence of leaf-webber, *D. pulverulentalis* indicated that the pest appeared on mulberry from November, 2006 to February 2007, with a peak during January 2007 (47.17%) followed by December, 2006 (42.48%) and November 2006 (40.60%), whereas the leaf-webber was not observed during the month of February, 2007. As shown in (Table 3) (Fig 2).

4.1.4 Evaluation of infestation level of *D. pulverulentalis* on selected varieties of mulberry

The data on the study of incidence of *D.pulverulentalis* on different mulberry varieties during first fortnight inter of November 2006 to second fortnight of February, 2007 are presented in Table 1.The Mean result and percent incidence in mulberry variety T.G (57.60%) showed maximum infestation in susceptible variety followed by M_5 (52.53%).

The resistant variety D.D (33.36%) has showed least percent incidence was recorded. But in moderately susceptible variety 248 has show (39.70%) incidence. The pest population was nil during first and second fortnight of February 2007 (Table 4 and Fig 3).

4.2 Bio-chemical analysis of leaf of different mulberry varieties

4.2.1 Influence of biochemical parameters on the larval population of *D. pulverulentalis*

The data on biochemical parameters are presented in Table 5 and Fig 4, 5.

4.2.2 Moisture content (%)

The highest leaf moisture content was recorded in TG, variety of mulberry (73.20%) followed by M_5 (72.87%) and the moisture content

Table:3. Incidence of leaf-webber during different months

Month	Infestation (%)
November 2006	40.06
December 2006	42.48
January 2007	47.17
February 2007	0.0

N= 150 plants / observation

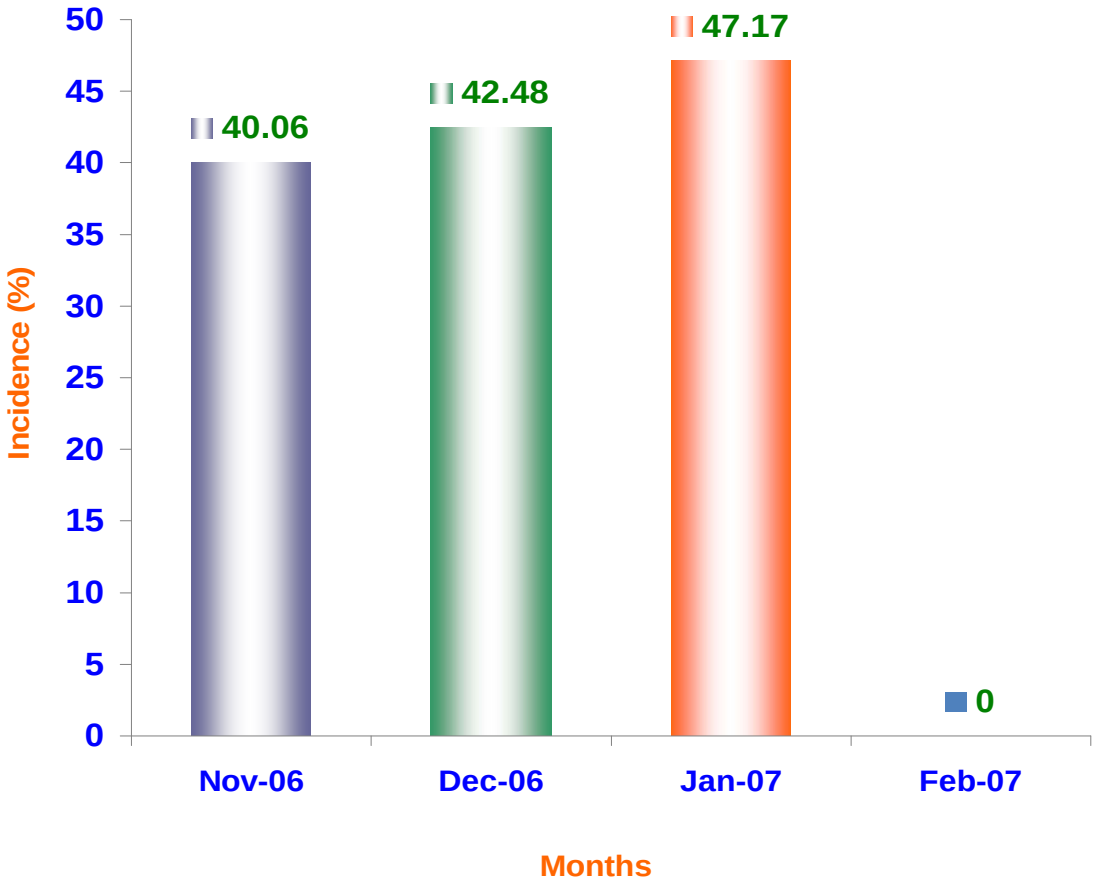

Fig 2: Incidence of leaf webber during different months

Table 4: Rate of infestation of leaf –webber on different mulberry varieties

Varieties	Per cent infestation
D.D	**33.36** (Resistents)
S_1	34.79
RFS_{135}	35.29
MR_2	36.82
S_{13}	37.60
248	**39.70** (Moderatly resistents)
240	40.28
S_{1635}	40.76
Mysore Local	42.47
238	43.47
S_{34}	44.69
249	47.29
250	50.06
M_5	52.53
TG	**59.60** (Susceptible)

D.D =Dehradun
T.G=Thalaghattapura

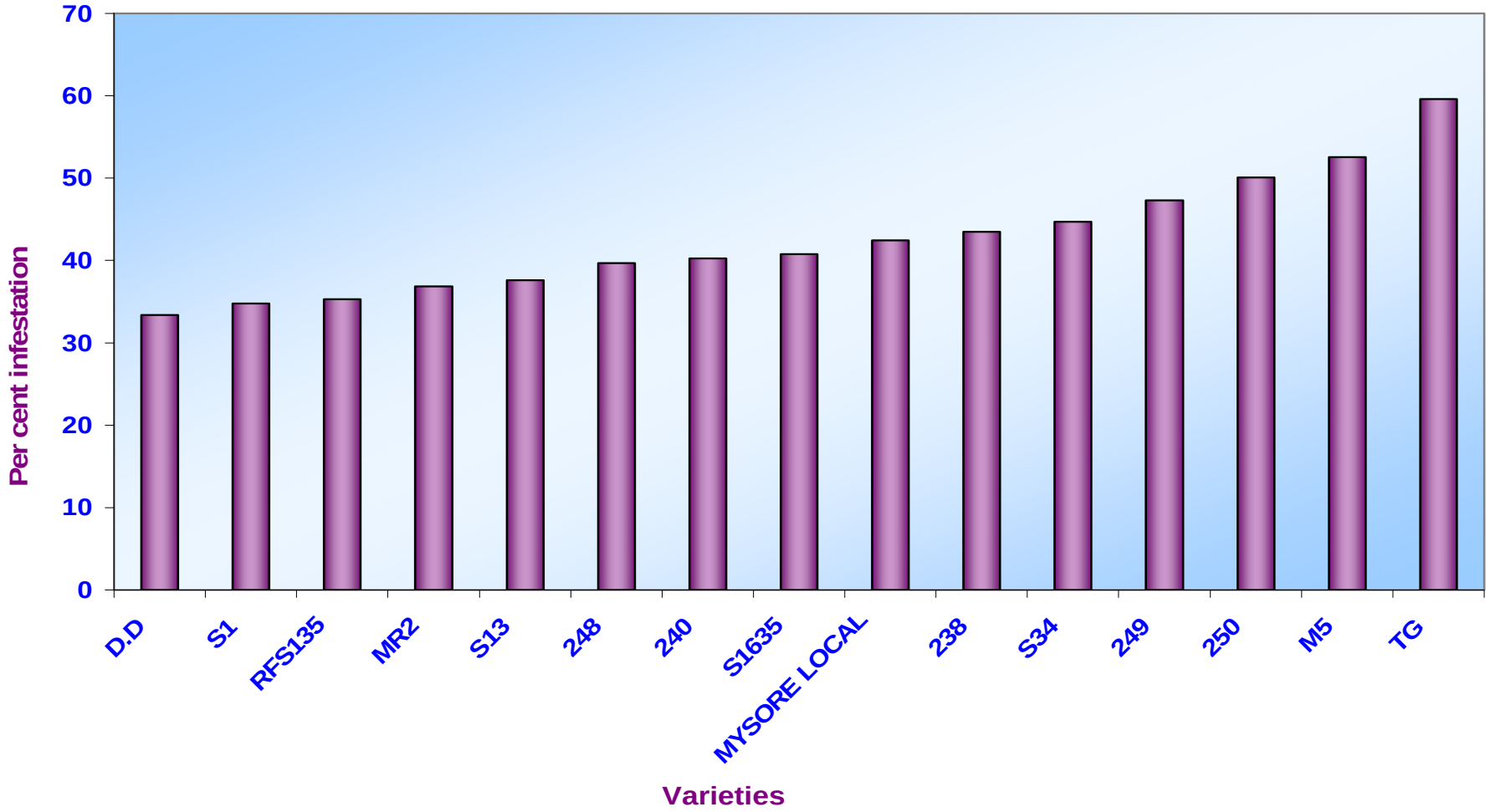

Fig 3 : Per cent infestation of *Diaphania pulverulentalis* on different mulberry varieties

Table 5. Bio-chemical composition of mulberry leaf among different varieties infested by leaf-webber.

Bio-chemical parameter	Varieties														
	TG	DD	240	S_1	RFS135	S_{13}	M_5	250	249	S34	238	S_{1635}	ML	MR_2	248
Soluble Sugars	13.0	9.35	11.02	11.38	11.96	10.55	9.78	10.36	8.55	7.76	8.03	10.90	9.78	8.4	11.78
Proteins	29.1	20.9	21.71	23.84	23.51	25.06	23.87	23.19	23.06	24.73	22.11	24.34	20.79	21.96	22.32
Phenols	7.19	8.29	7.66	7.76	6.99	7.98	7.69	7.74	8.12	8.14	8.33	7.70	8.27	7.38	9.02
Tannins	24.6	29.3	28.48	26.50	26.01	25.04	26.22	24.49	28.45	30.88	24.31	25.59	27.73	27.41	29.33
Carbohydrates	31.0	28.4	23.77	24.92	23.64	22.31	20.29	24.82	24.67	29.36	25.52	28.46	25.01	27.11	27.31
Iron	78.2	63.0	65.11	66.77	65.99	70.01	67.24	69.35	70.22	66.97	64.18	69.11	78.51	67.25	69.43
Manganese	46.6	36.3	43.77	42.24	34.21	34.17	30.02	34.93	39.90	42.67	41.53	38.91	39.26	37.48	36.20
Zinc	90.4	89.4	89.81	79.28	94.02	88.28	91.45	96.07	86.64	88.44	86.92	83.92	94.23	86.02	93.04
Copper	30.2	31.7	38.58	32.26	31.45	24.44	28.41	28.53	28.35	29.87	27.79	30.80	31.64	36.21	34.75
Moisture	73.2	68.0	73.25	74.57	72.47	69.55	72.87	75.34	72.38	73.35	73.5	76.27	76.17	74.40	72.60
SE m ±	9.08	8.41	8.72	8.19	9.04	8.80	9.09	9.47	8.77	8.67	8.71	8.59	9.69	8.67	8.90
F. test	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
CD at 5%	20.5	19.0	19.73	18.52	20.45	19.92	20.58	21.43	19.84	19.63	19.63	19.44	21.92	19.62	20.13

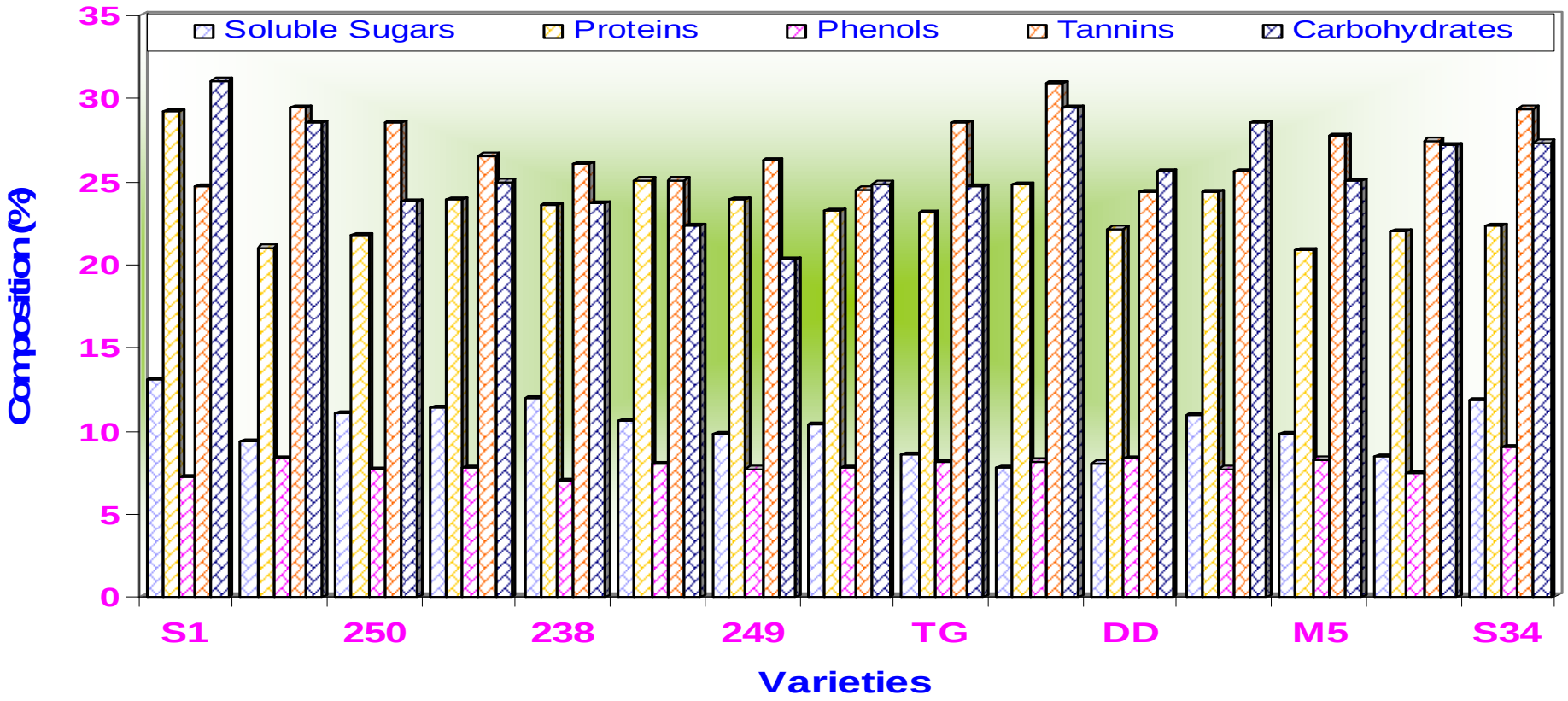

Fig. 4: Biochemical composition of different mulberry varieties infested by leaf webber

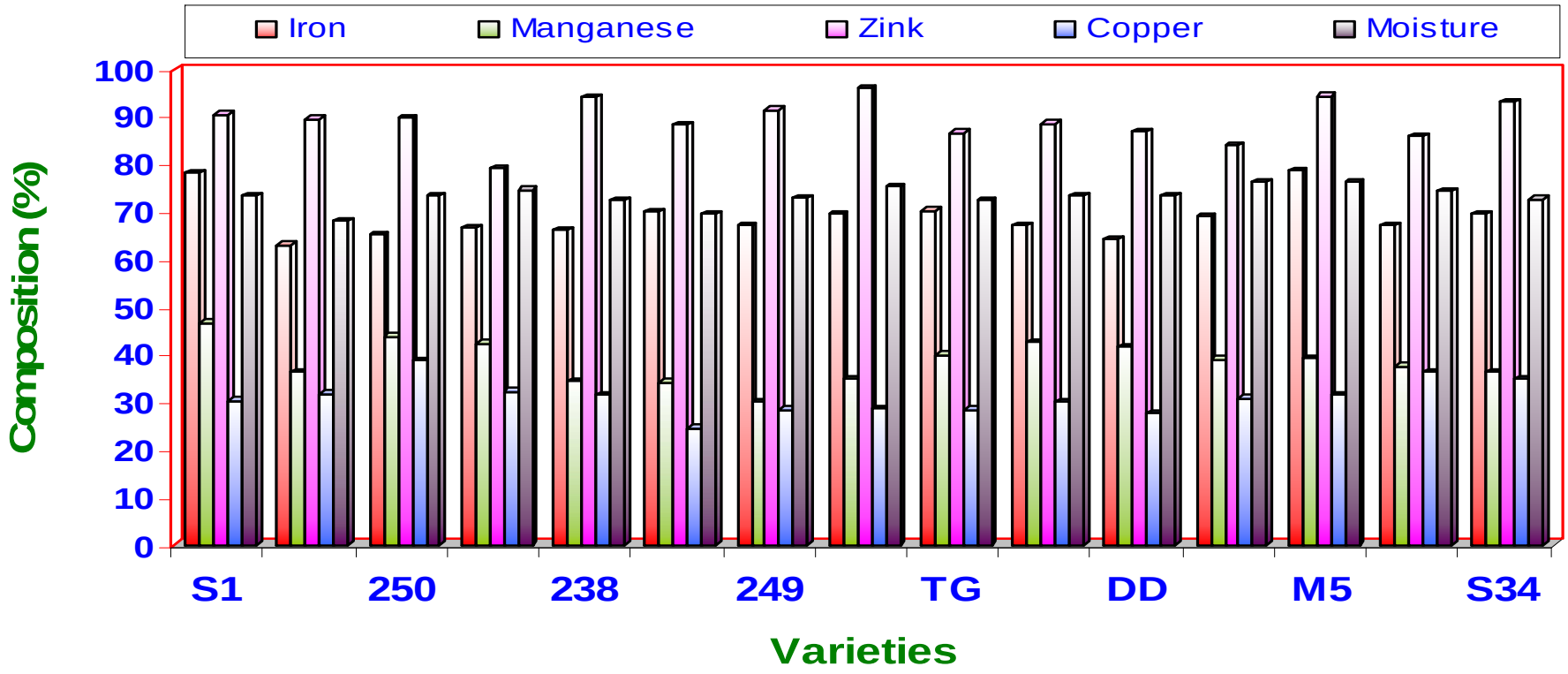

Fig. 5: Biochemical composition of different mulberry varieties infested by leaf webber

was less recorded in DD (68.04%). But moderately susceptible variety 248 (72.60%) had the moisture content in between the above two varieties.

4.2.3 Soluble sugar content (%)

The highest soluble sugar content of different mulberry varieties recorded (13.05%) in T.G as susceptible variety, followed by M_5 (9.78%) and least soluble sugar content was recorded in D.D (9.35%) as resistant variety. But in moderately susceptible variety, 248 (11.78%) has show the soluble sugar content on middle of both.

4.2.4 Carbohydrates content (%)

The carbohydrates content of different mulberry variety recorded (31.03%) in T.G as susceptible variety, followed by M_5 (20.29%) and the carbohydrates content was less seen in D.D (28.47%) as resistant variety. But in the moderately susceptible variety in 248 (27.31%) show that carbohydrate content in between the two variety.

4.2.5 Protein content (%)

The protein content of different mulberry leaves was highest in the varieties TG (29.16%) a susceptible variety, followed by M_5 (23.87%) and the protein content less was seen in DD (20.99%) as resistant variety. But in moderately susceptible variety, 248 has recorded (23.23%) of protein content in between the two variety.

4.2.6 Phenols content (%)

The phenols content of different mulberry varieties recorded was highest in 248 (9.02%) as moderately susceptible variety, followed by 240 (7.66%) and phenols content less was seen in TG (7.19%) as susceptible variety. But in resistant variety DD has recorded (8.29%) of phenols.

4.2.7 Tannins content (%)

The tannin content of different mulberry varieties recorded was highest in (29.38%) in DD as resistant variety, followed by S_1 (26.50%) and tannins content less was seen in TG (24.68%) as susceptible variety. But in the moderately susceptible variety 248 (29.33%) of tannins content in between two variety.

4.2.8 Iron content (%)

The Iron content of different mulberry varieties recorded (78.26%) in TG on susceptible variety, followed by M_5 (67.24%) and less was seen in DD (63.05%) on resistant variety. But in moderately susceptible variety 248 (69.43%) of iron content.

4.2.9 Zinc content (%)

The zinc content of different mulberry varieties recorded (93.04%) in 248 on moderately susceptible variety, followed by 240 (89.81%) and less was seen in DD (89.47%) on resistant variety. But in susceptible variety TG (90.49%) of zinc content were recorded.

4.5.10 Copper content: (%)

The copper content of different mulberry varieties recorded (34.75%) in 248 on moderately susceptible variety, followed by S_{1635} (30.80%) and was less seen in TG (30.25%) on susceptible variety. But in the resistant variety DD (31.74%) of copper content were less recorded.

4.2.11 Manganese content: (%)

The manganese content of different mulberry varieties recorded (46.67%) in TG on susceptible variety, followed by M_5 (30.02%) and was less seen in DD (36.30%) on resistant variety. But in moderately

susceptible variety 248 has show (36.20%) of manganese content were recorded.

4.3 Morphological features of mulberry varieties

4.3.1 Trichomes density (per cm^2)

Trichomes are the microscopic, unicellular hairs distributed on the ventral side of the leaves**.** They are basically broad and pointed at the distal end as shown in (Table 6 and Fig 6).

The highest mean trichome number per cm^2 of leaf was recorded in TG (182/cm^2), followed by M_5 (177/cm^2), 250 (174/cm^2), 249 (172/cm^2), S_{34}(168/cm^2), 238 (165/cm^2), ML (163/cm^2), S_{1635}(162/cm^2), 240 (157/ cm^2), 248 (156/cm^2), S_{13} (154/cm^2), MR_2(153/cm^2), RFS_{135} (150/cm^2) and S_1(147/cm^2) in decreasing order however, the lowest number of trichome was observed on D.D (145/cm^2) in different varieties.

The trichome number of different mulberry varieties recorded (182/ cm^2) in TG on susceptible variety, followed by M_5 (177/cm^2) and the trichome number less was seen in DD (145/cm^2) as resistant variety. But in the moderately susceptible variety 248 showed that trichome number (156/cm^2),

4.3.2 Size of the unopened terminal bud (cm)

The highest mean terminal bud length in mulberry variety was recorded in TG (1.4 cm) followed by $S1_{635}$(1.3 cm), MR_2(1.3 cm), M_5 (1.3 cm), S_{34} (1.3 cm), 248 (1.2 cm), M.L (1.2 cm), 249 (1.2 cm), S_{13} (1.1 cm), 240 (0.9 cm), D.D (0.8 cm), S_1(0.8 cm), 238 (0.7 cm) and 250 (0.6 cm) in decreasing order however, the lowest bud length among different varieties observed in RFS_{135} (0.6 cm). As shown in (Table7 and Fig 7)

Table 6: Density of trichomes in different mulberry varieties (per cm^2)

Varieties	Trichome density (No./cm^2)
TG	182
DD	145
240	157
S_1	147
RFS $_{135}$	150
S_{13}	154
M_5	177
250	174
249	172
S34	168
238	165
S_{1635}	162
Mysore Local	163
MR_2	153
248	156
F test	*
S Em$\pm$	1.35
CD at 5%	3.91

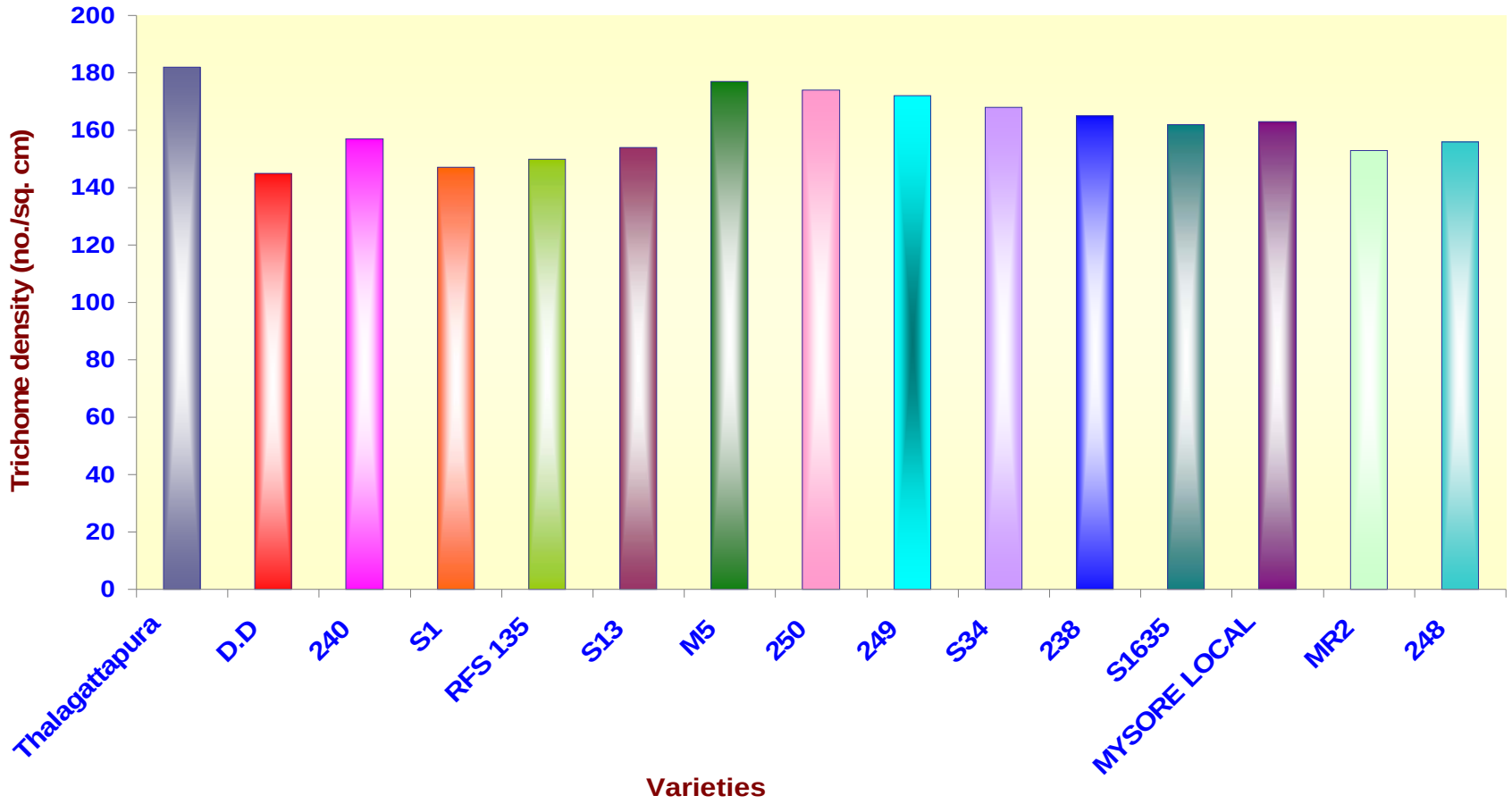

Fig 6: Trichome density in mulberry varieties

Table 7: Size of the unopened terminal bud in different varieties of mulberry (cm)

Varieties	Unopend terminal bud size (cm)
TG	1.4
DD	0.8
240	0.9
S_1	0.8
RFS $_{135}$	0.6
S_{13}	1.1
M_5	1.3
250	0.6
249	1.2
S34	1.3
238	0.7
S_{1635}	1.3
Mysore Local	1.2
MR_2	1.3
248	1.2
F test	*
S Em$\pm$	0.06
CD at 5%	0.19

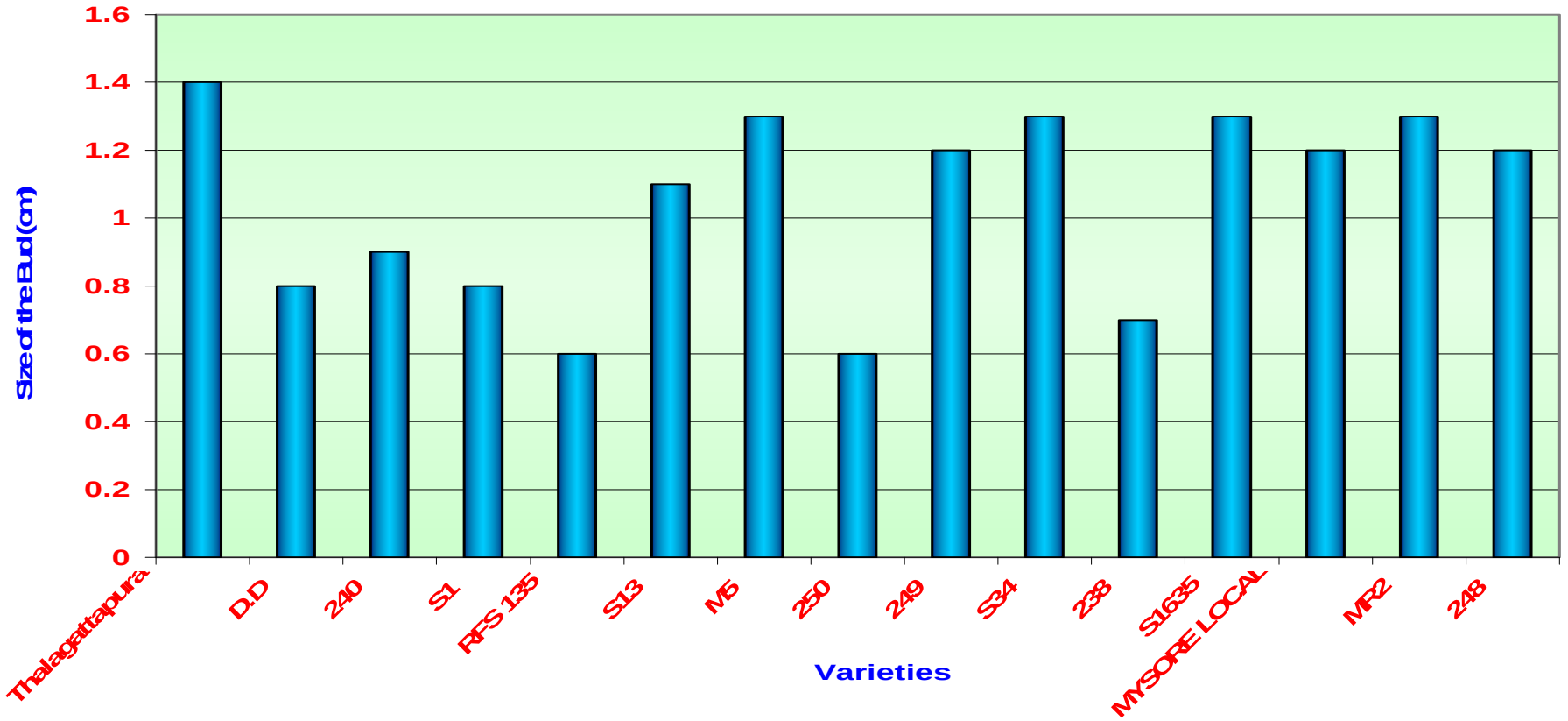

Fig 7: Size of the unopened terminal bud among the mulberry varieties

The highest bud length in different mulberry varieties recorded (1.4 cm) In TG on susceptible variety, followed by M_5 (1.3 cm) and the less bud size was seen in D.D (0.8 cm) as resistant variety. But in the moderately susceptible variety 248 show the bud length was 1.2 cm.

4.3.3 Leaf lobation pattern in mulberry varieties:-

Lobation: mulberry is unique in possessing both lobed and unlobed leaves it could be seen that leaves are irregular and unlobed in susceptible variety, as shown in (Plate 10) whereas the resistant variety DD has unlobed leaves and moderately susceptible variety has 248 having lobed leaf. The varieties 250, Mysore Local, 238 and 249 had lobed leaves as shown in (Table 8 and Plate 4).

4.3.4 Relation ship between rate of infestation of *D.pulverulentalis.* with biochemical composition of mulberry variety

Total 10 parameters were analysed as soluble sugars (-2.80), Protein content (3.69), phenols (4.60), tannins (-0.89), carbohydrates (-0.80), iron, (0.16), manganese (0.22), zinc (0.84), and copper (0.61), above parameters were correlated with per cent of pest incidence. it shows that among 10 parameters were total soluble sugars , tannins and carbohydrates were negatively correlated with pest incidence (Table 9).

4.3.5 Relation ship between rate of infestation of *D. pulverulentalis.* with morphological features of mulberry variety

Apart from the biochemical parameter two morphological parameters like bud size and trichome density, were correlated with pest incidence and it shows that these two parameters were positively correlated with pest incidence (Table 10).

Table 8: Lobation pattern of mulberry varieties

Varieties	Lobation pattren
TG	UNLOBED
DD	UNLOBED
240	UNLOBED
S_1	UNLOBED
RFS $_{135}$	UNLOBED
S_{13}	UNLOBED
M_5	UNLOBED
250	LOBED
249	LOBED
S34	UNLOBED
238	LOBED
S_{1635}	UNLOBED
Mysore local	LOBED
MR_2	UNLOBED
248	LOBED

Table 9: Relationship between rate of infestation of *D.pulverulentalis.* with biochemical composition of mulberry varieties.

Biochemical Composition	Correlation co-efficient	Regression Co-efficient	S.E	T	R^2
Soluble Sugars	0.0592*	-2.8076	1.9317	-1.45	0.7621
Proteins	0.5452*	3.6904	1.8070	2.04	
Phenols	-0.1437*	4.6075	5.1073	0.90	
Tannins	-0.2969*	-0.8788	1.4582	-0.60	
Carbohydrates	0.0449*	-0.8056	0.8482	-0.94	
Iron	0.5115*	0.1677	0.5682	0.29	
Manganese	0.1551*	0.2273	0.5899	0.38	
Zinc	0.3242*	0.8478	0.4818	1.75	
Copper	0.3469*	0.7195	1.0995	0.65	
Moisture	0.2786*	0.6048	1.0394	0.58	

Table 10: Relationship between rate of infestation of *D.pulverulentalis.* with morphological features of mulberry varieties.

Morphological factors	Correlation co-efficient	Regression Co-efficient	SE	T	R^2
Bud size	0.3980*	10.1670	6.617	1.53	0.15
Trichome density	0.9757*	0.6345	0.0395	16.04	0.95

4.4 Biology of *D. Pulverulentalis* on selected mulberry varieties:

The biology of leaf webber was studied from August 2007 to December 2007 with a temperature and relative humidity 27.84^{0}C and 92.78 per cent respectively on most susceptible resistant varieties and moderately susceptible variety on TG, DD, 240, S_1, RFS_{135}, S_{13}, M_5, 250, 249, S_{34}, 238, S_{1635}, ML, MR_2 and 248. As shown in (Table 11).

4.4.1 Egg

The eggs were laid singly on leaf veins on both sides of the mulberry leaves. The eggs were oval, soft and translucent on the day of ovipositon. The dorsal surface was convex and had rough and irregular crimps on lines.

The freshly laid eggs were greenish yellow with gel-like appearance. The egg turned to pinkish red on the third day of ovipositon. The microscopic observation on third day showed a brown head and light brownish slender body through chorion. Prior to hatching, the eggs were dull whitish to cream coloured. When observed under microscope, fully grown 'C' shaped embryo with black head was clearly visible through the chorion, the egg duration was four days in all the mulberry varieties. As shown in (Plate 5)

4.4.2 Larva

The pest has five larval instars and the total larval period in different varieties ranged from 9.85 days to 12.24 days, as shown in (Table 11 and Plate 6).

First instar

The first instar larva has light yellow colored transparent body with minute black spots on lateral, upper lateral, lower lateral, ventral and dorsal regions of each segment with single seta on each spot. The head is

Plate 5. Eggs of leaf webber

Plat 6.First and second instars of leaf webber

Plate 7. Third and forth instars leaf webber

Plat 8.Fifth larval instars of leaf webber

dark brown with a prominent head capsule followed by a light brownish prothorasic segment. The newly emerged larva starts feeding by scraping the green matter and the larva remained within the silken web throughout the instar, pre-moulting symptoms.

The longer first instar larval duration of (2.80days) was recorded on DD, a resistant variety, followed by S_1 and the instar period has shortest on TG (2.33days) a susceptible variety. The moderately susceptible varieties (248) were recorded 2.60days.

Second instar

The feeding behavior and webbing nature was similar to that of first instar, whereas the expansion of area of black spot with slender setae, dull yellow coloured body with translucent skin, the later stage of the instar showed light greenish colour with scarce white mid-dorsal line.

The second instar period recorded in DD (1.20days) on resistant variety, followed by S_1 (1.13days) and less larval duration was recorded in TG (1.06 days) a susceptible variety. But in the moderately susceptible variety 248 the larval duration was (1.13days).

Third instar

The larva turned light green with prominent black spot on the body with the brown coloured setae on each spot towards lateral and sub-lateral region. The prothorasic segment is fully covered with the brown band. The larvae started feeding on whole leaf by biting hole, leaving the large veins and mid-rib

Under natural condition the larvae secreted a thin silken filament to bind the leaf margins and roll inside. The fully grown third instar larva turned to green colour.

The larval duration recorded was (2.53 days) in DD a resistant variety, followed by S_1 (2.20days) and the larval duration recorded less was in TG (2.26days). But in the moderately susceptible variety 248 the larval duration was (2.13days).

Fourth instar

The feeding behavior and presence of black spots on larvae were similar to that of third instar, except the division of brown band on the prothorasic segment.

Under the microscope brown colored claspers were seen at the top of the true legs, with five minute setae around the caudal legs and pro legs were dark brown in the colour.

The fully grown larva was light greenish with discontinuous white mid-dorsal line the longest larval body. The larval duration were recorded was (2.26days) in DD a resistant variety followed by S_1 (2.26 days) and the larval duration was less in T.G (2.20days) as susceptible variety, but in the moderately susceptible variety 248 the larval duration was (2.20days).

Fifth instar

The head capsule at the fourth moult was dark brown highly sclerotized and hard. The larva was dark green in colour at the beginning of the fifth instar, later it turned to pinkish. The black spots became prominent and increased the area discontinuous white mid dorsal line was clearly seen, which started from second thoracic segment to last abdominal segment. The larvae fed on the whole leaf leaving the mid-rib and on the whole leaf leaving the mid-rib and leaf veins and began to feed within the fold.

The fifth instar larval duration was maximum in D.D (2.93days) on resistant variety followed by S_1 (2.13days) and larval duration was recorded in T.G (2.40) days on susceptible variety. But in the moderately susceptible variety 248 the value recorded was (2.20days).

Total larval period:-

The total larval duration recorded was longest in resistant D.D (12.24 days) variety followed by S_1 (10.12days) and the larval duration recorded less in the T.G (10.24days) on susceptible variety, but in the moderately susceptible variety 248 it was 10.06days.

The weight of the ten mature larvae was recorded maximum in T.G (4.85g) on susceptible variety followed by M_5 (4.22g) and the less larval weight was recorded in D.D (4.06g) on resistant variety, but in moderately Susceptible variety 248 the value recorded was 4.25g.

4.4.3 Pre-pupa

The fully grown fifth instar larva stopped feeding and rested in a thin silken cocoon with in the leaf. The pupa turned pinkish green on the first day with reduction in length. It turned to lighting green on the second day with hard body and then it transformed into pupa on the third day casting out the larval skin.

The pre- pupal period was maximum in D.D (3.20days) on the resistant variety followed by S_1 (3.20days) and the less pre-pupal period was recorded in T.G (3.0days) but in the moderately susceptible variety 248 variety value recorded was (3.06days).

Pupal period

The freshly formed pupa was soft and light brownish. As the age advanced it turned to dark brown with more sclerotization. The eyes were

4.4.4 Adult

Adult were medium sized, straw colored thickly irrorated and striated abdomen with oblique lateral stripes. The anal tuft is black with brown middle, fore wing with all the markings obscured by the spots and setae, the ante medial and the post- medial bands were broad and less irregular, the first dentate inwords on vein 2, the second without disc cellular spot on it. The third with series of pale specks on its outer edge from vein 4 to inner margin the dentate sub marginal line replaced by a series of diffused black patches in the inter spaces hind wing was thickly irrorated and striated, oblique black edged brown post medial and sub marginal bands almost meeting at a point near anal angle, cilia of both wings fuscous, with fulvous and brown lines at base, as shown in (Plate 10).

Adult male

Males were more active than females. The antenna was brown, the anal tuft on the last abdominal segment were few with light brownish. The abdomen was slightly narrow than females.

The adult male had more longevity of (8.92days) on DD a resistant variety, followed by S_1 (7.20 days) and the adult duration recorded was (8.86days) in TG a susceptible variety. But in the moderately susceptible variety were less recorded in 248 (8.66days) when fed with food (10% honey)

The same as recorded in DD (6.13days) a resistant variety followed by S_1 and in TG (5.33days) a susceptible one. But in moderately susceptible variety 248 it was 5.33days respectively when fed with no food.

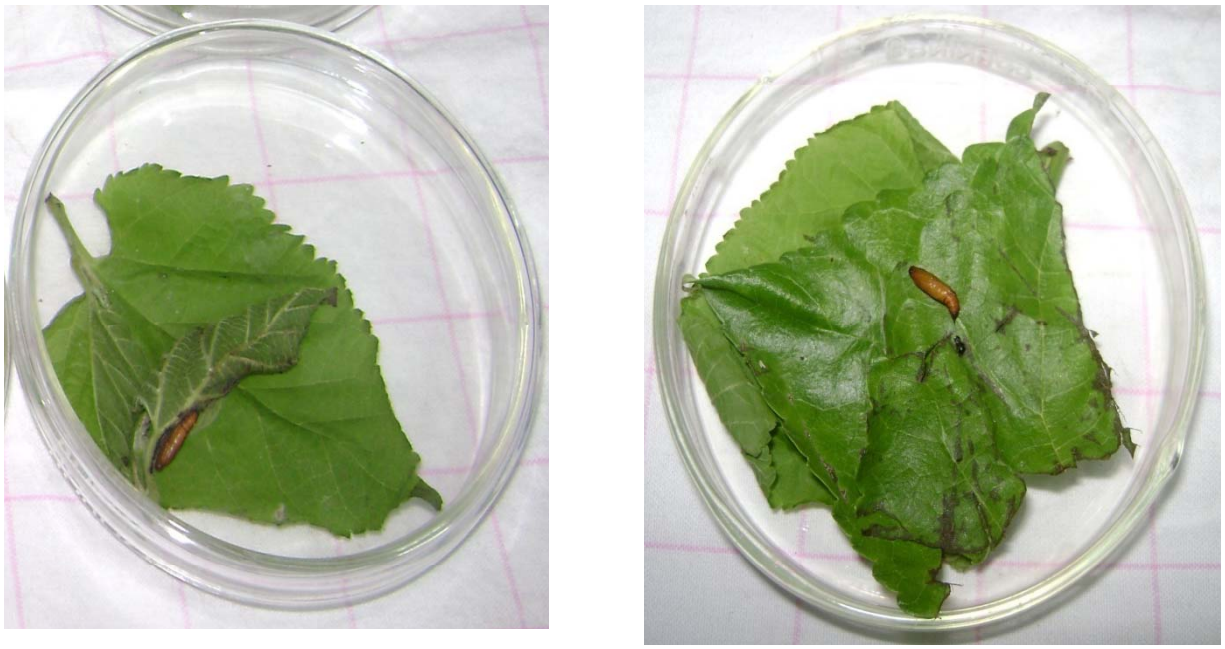

Plate 9. Female and male pupa of leaf webber of *D. pulverulentalis*

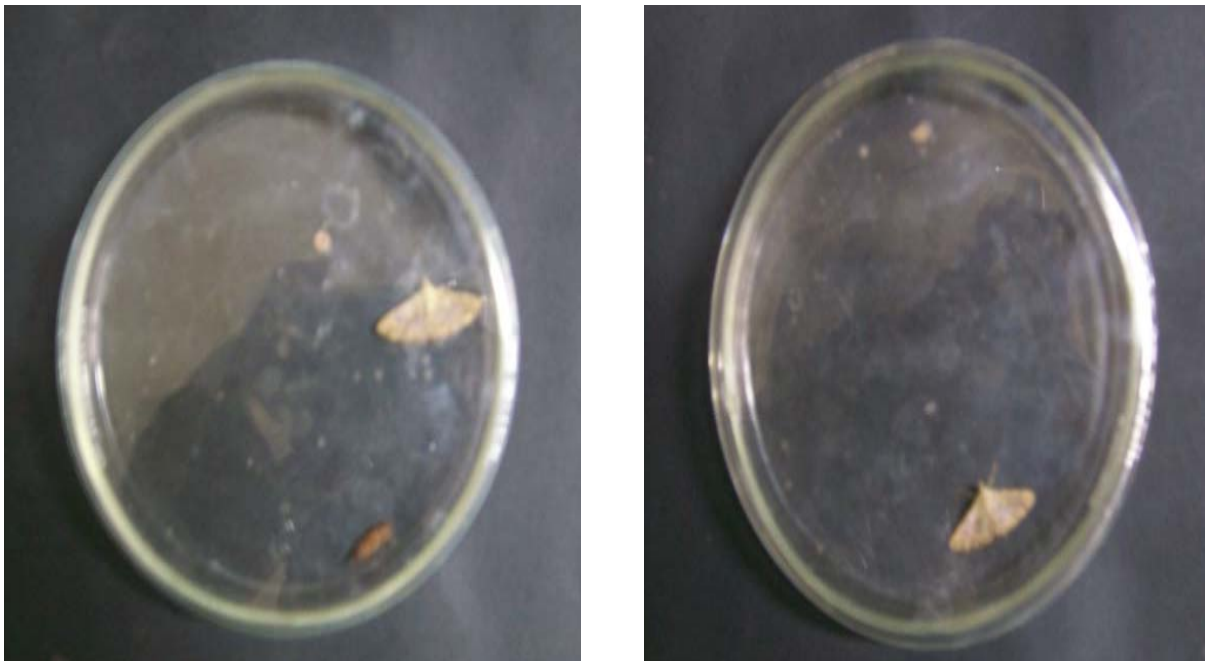

Plate 10. Female and male adult of leaf webber of *D. pulverulentalis*

prominent. The body was broader towards anterior and narrow towards posterior end. The female pupa was more boarder at the middle portion than the male. As shown in (Plate 9)

The pupal period was recorded maximum in DD (7.66days) on the resistant variety followed by S_1 (7.26days) and the less pupal duration was recorded in TG (7.20days) on susceptible variety but in the moderately susceptible variety 248 the pupal duration recorded was (7.26days).

The total pupal period was longer in D.D (10.86days) on resistant variety followed by S_1 (10.43days) and the total pupal duration was shorter in TG (7.20days). The susceptible variety 248 recorded was (10.32days).

The weight of 10 male pupa was maximum in DD (3.33g) on resistant variety, followed by S_1 (3.22g) and lowest pupal weight recorded in TG (3.20g) on susceptible variety. But in the moderately susceptible variety 248 (3.27) was recorded the pupal weight.

Weight of 10 female pupa was maximum in DD (3.58g) in resistant variety and the lowest weight was recorded in TG (3.51g) a susceptible variety, but in the moderately susceptible variety 248 the weight was (3.41g).

The pupal diapause duration was maximum in TG (146.66days) as the susceptible variety, and the pupal diapause duration was lowest (101.4days) in DD as resistant variety. But in moderatively susceptible variety, 248 (120.40days).

Adult female

Female moths were less active than males, the antennae over dark brown the anal tuft on the last abdominal segment were dense and dark brown.

The pre-oviposition period recorded was more in DD (4.93) on resistant variety in case of TG (4.26) on susceptible variety but in moderately susceptible variety 248 the pre-oviposition period was 4.80 days, of pre-ovipositor period. When fed with 10% honey.

Whereas pre-oviposion period was more in DD (4.40 days) on resistant variety but was less recorded in TG (4.00days) on susceptible variety. But in moderately susceptible variety 248 it was 2.20 days, when the female were unfed.

The oviposion period was 3.00 days in all the varieties when feed with 10% honey solution and it was 2.00 days when they were unfed.

The maximum female longevity was recorded in DD (12.39days) on resistant variety followed by S_1 (11.46days) and the adult longevity in TG (11.39days) on susceptible variety but in the moderately susceptible variety 248 it was 12.13days, when fed on 10% honey solution. The longevity was recorded in 248 it was 8.93days, followed by 8.59days in variety 240. But in susceptible variety DD it was 8.53days.

4.4.5 Fecundity

The number of eggs laid by individual female was found maximum in TG (253.40eggs/adult female) on susceptible variety followed by M_5(200.13) and it was lowest in DD (176.76) resistant variety, but in moderately susceptible variety 248 the fecundity was in between the value was 235.00 when fed with 10% honey as food.

Table 11: Biology of mulberry leaf-webber *D. pulverulentalis* on different mulberry varieties.

Stage	**Mulberry varieties**																
	T.G	**D. D**	**240**	**S_1**	**RFS_{135}**	**S_{13}**	**M_5**	**250**	**249**	**S_{34}**	**238**	**S_{1635}**	**ML**	**MR_2**	**248**	**SEm±**	**C.D at 5 %**
1 instar (days)	2.33	2.80	2.40	2.60	2.33	2.13	2.33	2.40	2.33	2.20	2.20	2.26	2.26	2.26	2.60	0.08	0.24
2 instar(days)	1.06	1.26	1.20	1.13	1.13	1.13	1.20	1.20	1.13	1.13	1.06	1.13	1.13	1.13	1.13	0.02	0.08
3 instar(days)	2.26	2.53	2.20	2.20	2.26	2.13	2.20	2.20	2.13	2.20	2.20	2.13	2.26	2.26	2.13	0.02	0.08
4 instar(days)	2.20	2.26	2.20	2.26	2.26	2.13	2.20	2.33	2.20	2.26	2.26	2.13	2.26	2.20	2.20	0.02	0.07
5 instar(days)	2.40	2.93	2.33	2.13	2.20	2.33	2.13	2.13	2.13	2.26	2.40	2.26	2.33	2.33	2.20	0.08	0.24
Total larval duration(days)	10.24	12.24	10.19	10.12	10.18	9.85	9.99	10.52	9.92	10.05	10.12	10.18	10.58	10.18	10.06		
Weight of 10 mature larvae (gm)	4.85	4.06	3.92	4.25	4.20	4.23	4.22	4.25	4.24	4.32	4.19	4.18	4.20	4.23	4.25		
Pupal period Pre pupal period (days)	3.00	3.20	3.13	3.20	3.20	3.20	3.20	3.13	3.13	3.26	3.20	3.00	3.00	3.20	3.06		
Pual period (days)	7.20	7.66	7.46	7.13	7.26	7.26	7.13	7.20	7.13	7.20	7.20	7.06	7.53	7.33	7.26		
total pupal	10.20	10.86	10.59	10.43	10.46	10.46	10.33	10.43	10.26	10.46	10.40	10.06	10.53	10.53	10.32		
Weight of 10 male pupe (gm)	3.20	3.33	3.17	3.22	3.17	3.24	3.17	3.24	3.21	3.18	3.15	3.18	3.17	3.22	3.27		
Weight of 10 female pupae (gm)	3.51	3.58	3.74	3.73	3.51	3.69	3.48	3.58	3.50	3.57	3.45	3.35	3.27	3.38	3.41		
Pupal diapause duration (days)	146.6	101.4	107.8	103.4	116.4	126.9	121.8	116.3	117.8	115.06	116.6	118.6	118.5	120.4	120.4		

contd……

Adult longevity female (days) Male, with food (10 % honey)	8.86	8.92	8.20	7.20	7.20	7.06	7.93	8.66	7.00	7.73	7.80	7.66	8.40	8.40	8.66
Pre oviposition period (days)	4.26	4.63	4.33	4.20	4.26	4.33	4.66	4.46	4.53	4.26	4.93	4.60	4.73	4.73	4.80
Oviposition period (days)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3.0
Post – oviposition period (days)	4.13	4.46	4.33	4.26	4.33	4.33	4.26	4.46	4.46	4.33	4.26	4.20	4.53	4.40	4.33
Total no oviposition period (days)	11.39	12.39	11.66	11.46	11.69	11.66	11.92	11.92	11.96	11.56	12.16	11.80	12.26	11.13	12.13
female Male, with food (10 % honey)	5.33	6.13	5.86	5.86	5.86	5.60	5.60	5.53	5.53	5.06	5.20	5.13	5.26	5.20	5.33
Pre oviposition period (days)	4.00	4.40	4.26	4.26	4.40	4.26	4.26	4.33	4.26	4.33	4.13	4.26	4.20	4.16	4.20
Oviposition period (days)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Post oviposion period (days)	2.66	2.13	2.33	2.40	2.40	2.26	2.40	2.66	2.46	2.43	2.33	2.46	2.46	2.66	2.73
Total oviposition period (days)	8.66	8.53	8.59	8.66	8.80	8.52	8.66	8.99	8.72	8.76	8.46	8.72	8.66	8.82	8.93
Fecundity no.Without food	128.1	99.46	115.13	130.66	134.53	126.73	127.66	127.40	102.46	111.6	117.00	124.8	111.60	100.86	124.93
With food	253.4	176.76	195.66	235.86	226.53	241.46	200.10	219.26	232.33	239.2	230.13	234.0	237.46	235.40	235.0
Egg duration (days)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00

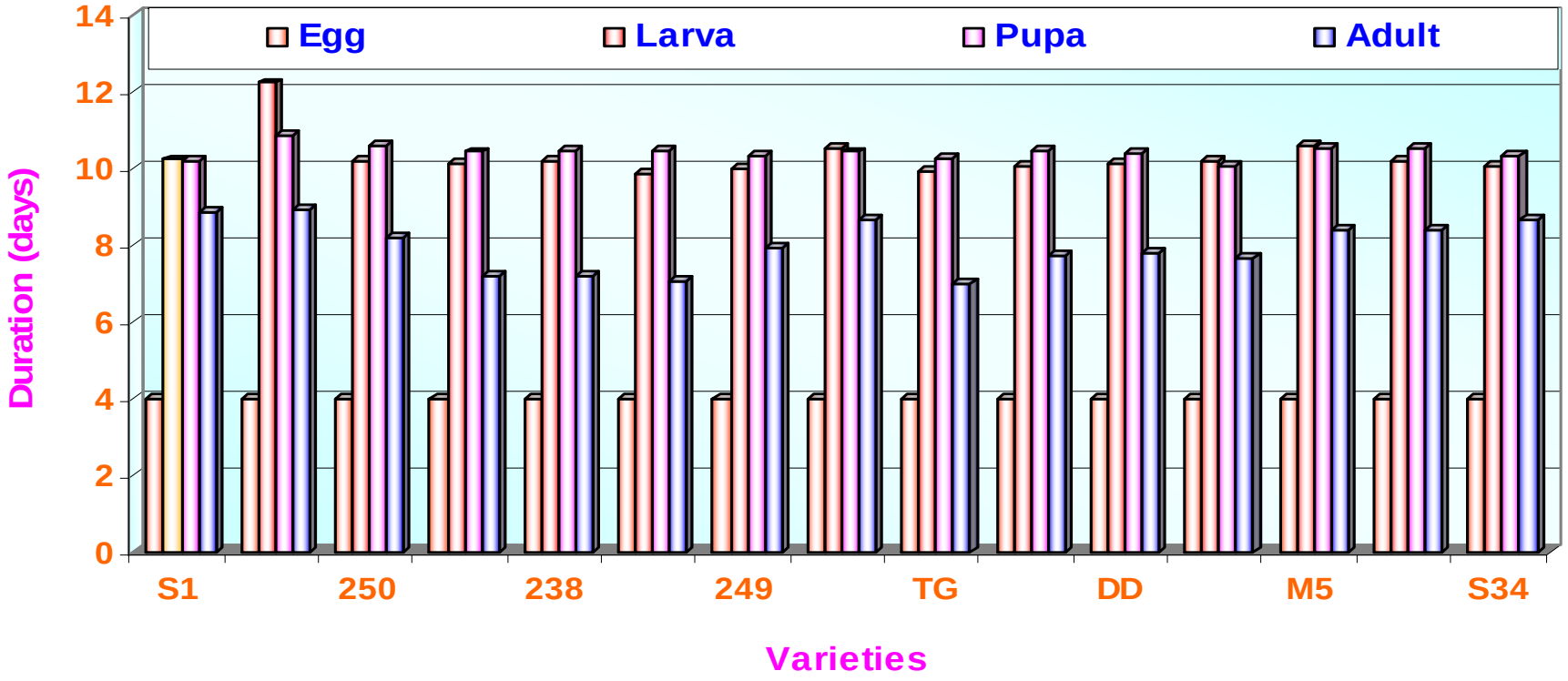

Fig. 8: Biology of mulberry leaf-webber *Diaphania pulverulentalis* on different mulberry varieties

Whereas the fecundity recorded was maximum in TG (128.13) on susceptible variety and it was lowest in DD (99.46). But in moderately susceptible variety 248 it was 124.93 when the adult females were fed.

Discussion

V DISCUSSION

The present study was undertaken to assess the seasonal incidence and rate infestation in mulberry gardens of KSSR&DI, Thalaghattapura, Bangalore district, Karnataka and to study the biology of leaf-roller.

5.1 Varietal preference of *Diaphania pulverulentalis*

5.1.1 Seasonal incidence of *D. pulverulentalis* on different mulberry varieties

The field survey on the seasonal incidence of leaf-webber, *D. pulverulentalis* indicated that the pest appeared on mulberry from November, 2006 to February 2007, with a peak incidence during January 2007 (47.17%) followed by December, 2006 (42.48%) and November 2006 (40.60%), whereas the leaf webber was not observed during the month of February, 2007. These observations are comparable with the observations of Siddegowda *et al.* (1995), who recorded the maximum incidence during March – June (0 to 30%) and October – February (0 to 100%) (Anonymous (1996a) July (2.23%) to October (71.26%) June to February (1997). Geethabai and Marimadaiah (2002) reported that, the rate of infestation ranged from 0 to 100 percent being maximum during winter months (October to February) at Koppa, Mandya, Mysore and Kanakapura taluks of Karnataka state, while it was 0 to 30 per cent during summer months (March to June). The results are in agreement with the findings of Sengupta *et al.* (1990), according to them maximum activity of *D. pulverulentalis* was observed from February to September. Rajadurai *et al.* (1999) observed maximum infestation during June – February, while Geethabhai and Marimadaiah (2002) reported maximum infestation of *D. pulverulentalis* between June to April.

5.1.2 Population of leaf-Webber on different mulberry varieties:

The highest population of leaf-webber was recorded on TG (59.60%), whereas it was lowest on DD (33.36%). The results clearly indicated that the variety TG was found highly susceptible to leaf-webber whereas DD was highly tolerant. However the degree of tolerance was intermediate in the other varieties screened namely S_1 and $RFS_{135,}$ which were on par, like wise MR_2, S_{13}, 248, and 240, were on par with each other. Similarly $S_{1635,}$ Mysore local, 249 S_{34}, 250 and M_5 were also on par with each other. The incidence of leaf-webber was on maximum in TG (57.60%) followed by M_5 (52.53%), and the less percent incidence was recorded on DD (33.63%). But in the moderately susceptible variety. 248 (40.28%) the incidence was nil during on February. The present results are in close conformity with the findings of Manjunath (2001) who reported that, Mysore Local was most tolerant to thrips when compared to MR_2 which was highly susceptible. The analysis of the data indicated that the variety TG having broad leaf was highly susceptible, while M_5 variety having thick leaves which was susceptible to leaf-webber. Almost uniform leaf morphology in DD, S_1, RFS_{135}, MR_2, S_{13}, 248, which had uniform levels of infestation which were on par with each other and also similar to 240, S_{1635}, Mysore local, 238, S_{34}, 249 (with the exception of 250, M_5) had uniform level of infestation. The unlobed and thickness leaf characteristic feature of DD could be attributed to its tolerance.

5.6 Biology of leaf- webber, *Diaphania pulverulentalis*

The eggs of *D. pulverulentalis* was oval soft and translucent convex top surface, having irregular crips (lines) with greenish yellow colour, gel like appearance turns to pinkish red on second day and pink on third day. The results are in conformity with those of Rangaswami *et al.* (1976) who reported the eggs of *G. pyloalis* were oval and flat. Mathur (1980) reported that the eggs are oval or circular, translucent, pale green with a

convex top. Sengupta *et al.* (1990) reported that the eggs are cremy eggs. Geethabhai *et al.* (1997) reported freshly laid eggs were slightly elongated and round at both ends with pinkish colour. The incubation period was four days in *D. pulverulentalis* which was supported by Yokayama (1925) (5 to 6 days), Kiyoku (1941) (3.5 to 9.0 days), Rangaswamy *et al.* (1976) (5-6 days), Mathur (1980) (2-3 days) in *G.pyloalish,* Siddegowda *et al.* (1995) (5-7 days) and Geethabhai *et al.* (1997) (4-5 days), Rajadurai *et al.* (1999) (2-3 days) and Manjunath Gowda *et al.* (2005) 2-3 days in *D. pulverulentalis*. The maximum number egg were found towards the ventral side of the midrib in TG , M_5 ,250, 249, S_{34} which may be attributed to presence of trichomes. The first instar larva was apple green to bluish green having a black tuberculated area each surrounded by whitish line. The head was pale yellow to light brown and each tubercle bore one slender pale hair, the prothorasic segment bore small scattered spots arranged dorsolaterally, the meso, metathoracic and anal segments possessed three tubercles in a line near, the anterior border of each segment and on either side of the middle line. The abdominal segments possessed two anterior and one posterior tuber related areas on each segment. A faint white stripe runs on either side of the dorsal middle line and one on each lateral side. The total larval duration was maximum in DD, (12-24 days) while it was in TG, (10-24 days) but in moderately susceptible variety 248, it was 10.06 days. The findings are in conformity with those of Rangaswamy *et al.,* (1976), who reported that the mature larva of *G. pyloalis* as green in colour. It has 4 to 5 months and the mature larvae measured 18 mm in length. Seol *et al.* (1987), Honda *et al.* (1990) and Sengupta *et al.* (1990) have reported that *D. pyloalis* larva had five larval instars and matured larva measured 2 cm in length. Siddegowda *et al.* (1995) and Geethabai *et al.* (1997) have reported that larval period of 16 days and mature larva measured 1.0 to 1.5 cm in length. Rajadurai *et al.* (1999) reported a larval duration of 8 to 12 days.

The larval period of *D. pulverulentalis* was shorter (15.54 days) on S_{54} and longer (18.46) on palladom local (Seelan, 1999). The prolonged larval duration in DD might be due to the poor nutrition. The present observations revealed that the *D. pulverulentalis* did not undergo diapause. However, contrary to this Siddegowda *et al.* (1995) reported a pupal diapause in *D. pulverulentalis*. The newly formed pupa was green in colour and gradually changed to dark brown. The fully formed pupa was lighter towards the anterior end. The compound eyes were large and prominent and the spiracles were small ovate but distinct. The appendages extended slightly beyond the fourth segment of the abdomen. The pupa tapered characteristically towards the posterior end where an "8" hooked cremester was located. The fifth and sixth abdominal segment bore one pit like depression on either side of the middle. The pupa was sparsely hairy and the circinate hairs were elongated in the web. The pupal size was variable, the total pupal period was maximum in DD, 10.86 days on resistant variety followed by $S_{1,}$ (10.43 days) and the pupal duration was less in moderately susceptible variety 248 (10.30 days) and pupal diapause lasted for 146.66 days on susceptible variety and the pupal diapouse duration was less in DD, 101.4 days on resistant variety but in moderately susceptible variety 248, 120.40 days. The present findings are agreeable with those of Siddegowda *et al.* (1995) and Geethabai *et al.* (1997), who stated that the pupal period lasted for 10-12 days and measured 1-1.5 cm in length. Rajadurai *et al.* (1999) observed a pupal duration of 7 to 9 days. the variation might be due to season and location of rearing site. Manjunath Gowda *et al.* (2005) observed the pupal stage last for 4-11 days depending on the season. The reason for lower pupal weight and longer pupal duration in Dehradun, a resistant variety, may be due to the poor uptake of nutritionally imbalanced food by the larvae *D. pulverulentalis*. The adults of leaf roller G. *pulverulentalis* possess oblique lateral stripes

on the abdomen. The anal portion of the adult has a luft of black hairs with brown markings observed by many number of spots and striae. The antimedial, the first dentate was found inwards on vein two. While in the second vein without disco cellar spot, three had a series of pale species on the outer edge from the vein four to inner margin the dentate sub marginal line replaced by a series of diffused black wings were thickly irregular and striated with oblique black edged brown post meddle and sub marginal bands almost meeting at a point near the anal angle cilia of both wings fuscous, with fulvous and brown lines at base. The adult male longevity of 8.92 days was recorded on DD, variety followed by S_1 (7.20 days) and the adult duration was 8.86 days on TG, but in the moderately susceptible variety were less recorded in (248) it was 8.66 days with food (10% Honey). The pre-oviposition period of *D. pulverulentalis* was more in DD 4.93 days and it was 4.80 days in moderately susceptible variety 248. The oviposition period was 3.00 days on all the varieties when fed with 10% honey solution and 2.00 days when they were unfed. Maximum longevity was recorded in DD (12.39 days), a resistant variety fallowed by TG (11.39 days), a susceptible variety, but in moderately susceptible variety 248, it was 11.13 days. The fecundity was highest in TG, variety followed by M_5 (200.13 eggs) and in DD (176.76 eggs), but in moderately susceptible variety 248, it was 235.00. This might be due to nutritional status of the variety. The results are in conformity with the findings of Kiyoka (1980), who have recorded 150 eggs per adults. Mathur (1980) recorded 100-200 eggs. Hardo and Kikuchi (1982) recorded 250 eggs. Aruga (1994) and Govindan *et al.* (1995) have recorded 100-400 eggs per adult female of *G. pyloalis*. Rajadurai *et al.* (1999) reported 100- 250 eggs / adult in *D. pulverulentalis*. Seelan (1999) stated that polladam local having poor nutritional level prolonged developmental stages of *D. pulverulentalis* and

stated that the order of varieties influencing growth and development was M5> S54>MR2>V1> Palladam local.

5.7 Biochemical parameters in mulberry varieties

5.7.1 Influence of biochemical parameters on the larval population of *D. pulverulentalis*

Moisture content (%)

The leaf moisture content was maximum (73.20%) in TG followed by M_5 (72.87%) and the moisture content was less in DD (68.04%). But in moderately susceptible variety, 248 had the moisture content of 72.60%. In the present study it was observed that the moisture was more in susceptible variety which leads to greater succulency and tenderness thus promoting higher degree of infestation.

Soluble sugars (%)

The highest soluble sugar content was recorded (13.05%) in TG, followed by M_5 (9.78%) and least soluble sugar content was recorded in DD (9.35%). But in moderately susceptible variety, 248 it was 11.78%.The present results are in conformity with those of Shaw (1963). There was statistically significant reduction in non-reducing sugars, total sugars, starch, water soluble protein and crude protein content in tukra affected leaves compared to healthy leaves. According to Michel (1982), the reduction in total soluble sugars may be due to the activity of invertase. Krishnaswamy *et al.*, (1971) observed that the S_{1635} recorded significantly highest leaf sugar content (12.44%) followed by S_{34} (11.06%) and differed significantly form the rest of the varieties (9.98% to 11.13%). The S_{1635} variety (26.91%) exhibited highly significant difference compared to all other varieties under study (20.19 % to 24.96%).

Protein content (%)

The protein content was highest in the variety TG (29.16%) followed by M_5 (23.87%) and the protein content was minimum in D.D (20.99%). But in moderately susceptible variety, 248 has recorded (23.23%) of protein content of 23.23%.

In plants, the cell protein serve as the sources of amino acids required for the development of pest. The present results are in confermity with those of Agarwal *et al.* (1989). The reduction of total soluble proteins in diseased leaves may be attributed to their breakdown by the proteolytic enzymes secreted by the pathogens.

According to Subramanian and Sarswathidevi (1959), the starch, water soluble protein and crude protein contents were significantly reduced in tukra affected leaves of Mysore Local, S_{34}, and S_{30} varieties, while such parameters were less affected in S_{36}, S_{30} and S_{54} varieties.

This loss of non-reducing sugars, total sugars total carbohydrates, water soluble protein and crude protein in tukra affected mulberry leaves may be attributed to the disruption of the leaf tissue due to the growth of pathogen/insect. Samborski *et al.* (1958) reported that the constituents are degraded or utilized by the pathogen / insect at a faster rate.

Carbohydrates content (%)

The carbohydrates content was maximum (31.03%) in TG, followed by M_5 (20.29%) and the carbohydrates content was less in DD (28.47%). But in the moderately susceptible variety, 248 the carbohydrate content was 27.31%. Carbohydrates contribute to the dry matter production in plants which were synthesized through the process of photosynthesis. Plants put their carbohydrate to many uses as components of special substances like nucleic acid, glycosides and structural material. When

the carbohydrates are more in plant system naturally that will be preferred by any pest. The current observations are comparable with the findings of Subramanian and Saraswathidevi (1960).

Iron content (%)

The Iron content was significantly maximum (78.26%) in TG followed by M_5 (67.24%) and minimum in DD (63.05%), a resistant variety. But it was 69.43% in moderately susceptible variety 248. The current observations are comparable with the findings of Sarkar and Absar (1995). The mean nutrients elements such as nitrogen and zinc contents of mulberry leaves decrease, while iron, boron and manganese contents in mulberry leaves increased significantly with the maturity of the leaves. According to Singhvi *et al.* (2000) magnesium, calcium, iron, zinc and copper contents in leaves varied distinctly.

Copper content (%)

The copper content was varied significantly, being maximum (34.75%) in 248, followed by S_{1635} (30.80%) and was less in TG (30.25%). But it was (31.74%) in the resistant variety. the current observations are comparable with the findings of Singhvi *et al.* (2000) who reported that magnesium, calcium, iron, zinc and copper contents in leaves varied distinctly in the range of 0.8 – 1.6 per cent, 56.68 – 76.76 ppm, 68.18 – 11.50 ppm and 18.36 – 36.66 ppm, respectively.

Manganese content (%)

The manganese content was significantly maximum in TG (46.67%) followed by M_5 (30.02%) and was minimum in DD (36.30%). But in moderately susceptible variety, the manganese content was 36.20%.

Zinc content (%)

The zinc content was estimated to be maximum mulberry (93.04%) in 248 followed by 240 (89.81%) and was minimum in DD (89.47%). But it was 90.49% in susceptible variety TG.

Phenols content (%)

The phenols content was highest in 248 (9.02%) followed by 240 (7.66%) and phenols content was less in TG (7.19%). But in resistant variety DD, the phenol content was more (8.29). In a number of diversified ways, these compounds influence the defensive system in plant against herbivorous animals. The mode of action of tannins in insects is stated to be involved with repellant activity reducing palatability (Lipke and Fraenkel, 1956). The lower population of thrips with increase in phenolic content in host are in accordance with high amount of total phenol and tannins present in the sap of resistant cotton genotypes which are inhibitory to the growth and development of sucking insects like jassids, aphids and thrips (Rhoades, 1979).

Tannin content (%)

The tannin content was highest (29.38%) in DD followed by S_1 (26.50%) and tannins content less in TG (24.68%). But in the moderately susceptible variety 248 the tannins content was 29.33%.

5.8 Morphological features

5.8.1 Density of Trichomes

The trichome density was maximum (182/ cm^2) in TG variety of mulberry followed by M_5 (177/cm^2), while it was minimum (145/cm^2) in DD. But in the moderately susceptible variety, 248 the trichome density was number 156/cm^2. Similar observations were made by Rajagopalan Raju *et al* (1980). The trichome index study did not reveal any

phylogenetic relationship among the varieties. The succulent varieties namely Kosen and S_{36} had more number of trichomes per square millimeter are in adaxial surface in contrast to the less succulent varieties. According to Rajagopalan Raju *et al.* (1980). The trichomes were presented in both indigenous and exotic varieties. Anand Rao (2002) studied that the leaf trichomes are the epidermal hairs, which increase trichomes are the epidermal hairs which increase succulence and protected the stomatal opening in the stress condition. It is probable that attractants like glycosides, saponins, tannins, alkalaloids, essential oils or organic acids which attract silkworm are produced in glandular and eglandular trichomes. Tikadar *et al.* (2004) observed mulberry accessions where higher trichome density was noticed in indigenous accession compared to the exotic accession.

5.8.2 Bud size

The large sized buds (1.4 cm) were observed in TG variety of mulberry followed by M_5 (1.3 cm) and the small buds were observed in DD (0.8 cm). But in the moderately susceptible variety, 248 had the buds of 1.2 cm. Similar observations were made by Fotedar *et al.* (2003), who observed that genotype S_{14} recorded 0.7 cm bud length compared to that of Chakmajra bud length of 0.5 cm.

5.8.3 Leaf lobation pattern in mulberry variety:

Mulberry is unique in possessing both lobed and unlobed leaves. It was observed that leaves were irregular and unlobed in susceptible variety, whereas the resistant variety (DD) had unlobed leaves and the moderately susceptible variety (248) possesed lobed leaf. The varieties 250, Mysore Local, 238 and 249 had lobed leaves. Similar observations were made by Ananda Rao *et al.* (2002), who reported that majority of the indigenous and exotic accession have homophylious unlobed leaves. There is a wide variation in the leaf lobation number ranging from one to

multilobation. According to Katsumata (1974), the leaf is multilobed in *M. australia* and base is broad chordate in case of *M. kagayamae*. Abdullav (1972) reported that both whole and lobed leaves were found in the leaves of hybrids. Gray and Gray (1987) reported that the leaf lobation patterns in mulberry shrubs and trees, which were counted to be maximum of five per leaf.

Summary

VI. SUMMARY

Studies were carried out to findout varietal preference by leaf-webber *Diaphania pulverulentalis* on 15 mulberry varieties/accessions at fortnight intervals at KSSR & DI, Thalaghattapura, Bangalore from October 2006 – February 2007. Based on leaf-webber counts, three mulberry varieties were identified as susceptible (TG), moderately susceptible (248) and tolerant (DD) varieties.

The per cent infestation of *D.pulverulentalis* ranged from 39.03 to 7.40%, during November to January and least (39.08%) during March.

The highest per cent infestation was recorded during January 2007. The per cent infestation was maximum on TG (59.60%) a susceptible variety followed by M_5 (52.53%) and it was minimum in DD (33.36%). But in moderately susceptible variety 248, the incidence was 40.28%.

Biology

The egg incubation period was 4 days. The total larval duration was longest (12.24 days) on resistent DD variety followed by S_1 (10.12 days) and the larval duration was short on TG (10.24 days), a susceptible variety, but in the moderately susceptible variety 248, it was 10.06 days. The weight of final instar larva was more (4.85 g) in TG as compared to 4.06 g on DD. The total pupal period was longer in DD (10.86 days) compared to the individuals developed on TG (7.20 days) but in susceptible variety 248, it was 10.32 days.

The weight of male pupa was more in DD (3.58 g) followed by S_1 (3.22 g) and lowest pupal weight was recorded in the case of TG (3.51 g). But in moderately susceptible variety 248 it was (3.47 g). Whereas the female pupa weight was more in DD (3.58 g) as compared to (3.15 g) in

TG, but in the moderately susceptible variety 248, it was 3.41 g. The pupal diapause duration was lasted for 146.66 days in TG variety compared to 101.4 days in DD and 120.40 days in 248 variety. The adult male lived for 8.92 days when larvae reard on TG variety compared to 8.86 days on DD variety. The oviposition period was 3 days and 2 days respectively, in the case of 10 per cent honey fed and unfed adultsrespectivel. The adult females lived for 12.39 days when larvae reared on 12.39 days compared to adult longevity of 11.39 days which resulted from TG variety. The adults resulted from TG variety deposited 235.50 eggs compared to the fecundity of 176.76 in the case of adults resulted from DD variety of mulberry. However, the fecundity was 235.00 in the case of individuals resulted from mulberry variety 248. The moisture protein, carbohydrates, iron and manganese contents were higher in leaves of TG variety compared to those in DD variety of mulberry. Similarly, higher phenol and tannin contents were observed in TG variety compared to DD, whereas more zinc and copper contents were found more in leaves of 248 variety. The number of trichomes per cm^2 was more in DD compared to TG variety as well as accession number 248. Similarly, the size of the unopend terminal bud was large in TG compared to that of DD variety and accession number 248. It is observes from the present results that the rate of infestation of *D.pulverulentalis* was high on TG variety, and low in DD variety. The durations of developmental stages of *D.pulverulentalis* were shorter on TG variety compared to DD variety. Similarly, the nutritional and morphological parameters were favorable for development of *D.pulverulentalis* on TG variety.

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Appendix

APPENDIX – 1

Proforma used for incidence of *D. pulverulentalis* on different varieties of mulberry

Sl no	Mulberry varieties	Serial No. of plants	Total No. of shoots/ plant	No. of infested shoots/ plant	No. of caterpillars/ shoot
1		1			
		2			
		3			
		4			
		5			
		6			
		7			
		8			
		9			
		10			

APPENDIX – 2

Weekly mean temperature and relative humidity in the laboratory from August 2007 to December 2007.

Dates	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)
Sep 1-7	27.44	18.48	93.28
8-14	30.07	18.44	94.00
15-21	26.84	17.94	93.42
22-28	28.25	18.87	94.85
Sep 29 to Oct 05	29.22	19.57	90.42
6-12	30.15	18.20	90.28
13-19	30.32	17.42	91.71
20-26	27.31	19.04	96.14
Oct 27 to Nov 2	30.02	18.61	94.14
3-9	28.02	18.61	93.00
10-16	27.67	12.52	92.28
17-23	26.75	16.14	92.14
24-30	27.61	12.87	90.28
Dec 1-7	25.72	15.91	93.14
8-14	26.04	15.70	91.00
15-21	23.85	14.11	90.85
22-28	28.14	11.85	96.42