Infestation of mulberry leaves by Leaf roller/webber-*Diaphania pulverulentalis* (Hampson) and *Glyphodes pyloalis* (~~walker~~Walker) and its management strategies

Abstract

The mulberry is a perennial, ~~fast-growing plant mainly cultivated worldwide for rearing of~~ fast-growing plant mainly cultivated worldwide for the rearing of the mulberry silkworm, *Bombyx mori*. The *B. mori* ~~which is a monophagous insect~~, a monophagous insect, feeds only on mulberry leaves for ~~feeds only on mulberry leaves for its~~ proper growth and development. The mulberry plant ~~during its growth is susceptible to various diseases *viz*., leaf spot, powdery mildew, leaf rust etc. and pests *viz*., leaf roller, Bihar hairy caterpillar, mealy bugs etc. in the field~~, during its growth, is susceptible to various diseases, viz., leaf spot, powdery mildew, leaf rust, etc., and pests, viz., leaf roller, Bihar hairy caterpillar, mealy bugs, etc., in the field, which deteriorates its leaf quality and quantity. Among these pests, defoliators ~~attain significant importance as they cause damage up to 12-25%~~are important as they cause damage up to 12-25%, ~~thereby~~ making mulberry leaves unfit for silkworm rearing. The leaf rollers are major pests currently causing devastation to mulberry plants ~~both~~ in India and other parts of the world. Thus, in this review ~~an attempt has been made regarding new insights about the leaf roller pests and devise more sustainable management of this pest through integrated pest management (IPM) strategy to control it,~~, an attempt has been made regarding new insights about the leaf roller pests and devise more sustainable management of this pest through an integrated pest management (IPM) strategy to control it so that the overall cocoon crop production will be enhanced worldwide.

Keywords: leaf roller, *D. pulverulentalis*, infestation, pest, IPM, mulberry

Introduction

~~The mulberry (*Morus spp.*) is an important~~ Mulberry (*Morus* spp.) is an essential and valuable plant and has commercial significance as it is the ~~only~~ sole food source of *B. mori*. Its contribution is around 38.20% for ~~the successful harvesting of~~successfully harvesting cocoon ~~crop~~ crops(Miyashita, 1986). It is ~~fast growing plant with deep root system present in order Urticales/Rosales and~~ a growing plant with a deep root system present in the order Urticales/Rosales and the family Moraceae. ~~The feeding of~~Feeding*B. mori* on good quality

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mulberry leaves results in its healthy growth and development and eventually enhanced silk production (Islam *et al.*, 2022a, 2022b; Islam *et al.*, 2023; Islam *et al.*, 2024). During its growth ~~it also faces many challenges as it is subjected to various kinds of diseases and pests,~~ it also faces many challenges as it is subjected to various kinds of diseases and pests, which hampers its leaf production both qualitatively and quantitatively. The leaf roller, *D. pulverulentalis* is a serious pest in Southern India ~~and also is~~. Also, it is a potential carrier of *Nosema bombycis*, which causes deadly pebrine disease ~~to the silkworms as pebrine spores can get easy entry in~~in silkworms as pebrine spores can easily enter the rearing rooms through contaminated mulberry leaves (Ifat *et al.*, 2011). Similarly, Watanabe *et al.* (1988) found leaf roller *G. pyloalis* as the alternate hosts of densoviruses and picornaviruses. ~~The~~ *D. pulverulentalis* was reported from Karnataka in 1995 and then spread to Tamil Nadu, Andhra Pradesh, and Kerala. Its ~~and its~~ infestation causes leaf yield loss up to 12.8% having an average incidence of 21.77%, causing severe damage to sericulture industry (Siddegowda *et al.*, 1995; Geetha Bai *et al.*, 1997; Rajadurai *et al.*, 1999). Manjunath Gowda *et al.* (2005) stated that 37 parasitoids and ~~6~~ sixpredators are known ~~naturally controlling the leaf roller infestation at different stages, also~~to naturally control the leaf roller infestation at different stages, and 10 entomopathogenic fungi were reported regulating the incidence of leaf roller naturally (Srinivasa Gowda *et al.*, 2000). Around 300 insect and non-insect pest species are known ~~causing attack to~~to cause attacks on mulberry. The insect pests may be sap suckers, defoliators, borers, and residing in soil like Termites. The infestation by ~~major~~ significantinsect pests like leaf roller, pink mealy bug ~~and thrips severely reduces nutrient content of leaves by hampering photosynthesis which eventually reflects in the poor growth of plant~~, and thrips severely reduces the nutrient content of leaves by hampering photosynthesis, which eventually reflects in the poor growth of the plants (Kotikal *et al.*, 1982; Biradar, 1989;Srinivasa Gowda, 2004; Sakthivel *et al.*, 2019). The yield loss caused by major insect pests of mulberry ~~namely Bihar hairy caterpillar (*Siplosoma oblique*), leaf roller (*D. pulverulentalis*) and mealy bugs (*Maconellicoccus hirsutus*)~~, namely Bihar hairy caterpillar (Siplosoma oblique), leaf roller (*D. pulverulentalis*), and mealy bugs (*Maconellicoccus hirsutus*), is up to 25-30%, 12-15% and 10-15% respectively (Manjunath *et al.*, 2005). Mulberry leaf roller is a major dangerous pest of mulberry plant in India ~~causing heavy infestation in the states of Karnataka, Andhra Pradesh, Tamil Nadu, Kashmir, Assam etc. (Mathur, 1980; Chakraborty, 2005; Dandin and Giridhar, 2010; Illahi *et al*~~, causing a heavy infestation in the states of Karnataka, Andhra Pradesh, Tamil Nadu, Kashmir, Assam, etc. (Mathur, 1980; Chakraborty, 2005; Dandin and Giridhar, 2010; Illahi et al., 2013).

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Keeping in view the status of this pest, the current review elucidated this pest in more detail like its biology, nature of damage, period of occurrence and subsequent management strategies for controlling this pest so that the overall silk production will be increased.

Life cycle and management strategy of *D. pulverulentalis*through IPM

Diaphania pulverulentalis is a key seasonal defoliating pest ~~and its maximum population buildup is recorded during September-November and there is a linear relationship between the decrease in temperature and~~ , and its maximum population buildup is recorded during September; there is a linear relationship between the decrease in temperature and an increase in relative humidity resulting in an ~~increase in relative humidity resulting in~~ increased pest population (Kumar *et al.*, 2021). The biochemical components in six mulberry varieties *viz.*, M5, Mysore local, MR2, S54, S36 ~~and V1 were analysed~~, and V1 were analyzed infested by *D. pulverulentalis*. It was revealed that the biochemical composition of mulberry leaves was reduced ~~almost in~~in almost all the varieties (Mahadeva and Nagaveni, 2011). Bhagyamma and Vijaya Kumari (2022) ~~after carrying out study on three mulberry varieties *viz.*, V1, Mysore local and S36 infested by *D. pulverulentalis* found that the photosynthetic pigments in the leaves like total chlorophyll and carotenoids~~, after carrying out a study on three mulberry varieties viz., V1, Mysore local, and S36 infested by *D. pulverulentalis*, found that the photosynthetic pigments in the leaves like total chlorophyll and carotenoids, decreased by 40.17% and 40.85% respectively. Further, the biomolecule components like proteins, carbohydrates ~~and starch decreased by 24.62%, 47.09% and 16.09%~~, and starch decreased by 24.62%, 47.09%, and 16.09%, respectively. However, the phenol content increased by 57.39% ~~than~~ compared to the control. **Life Cycle:** The Eggs of*D. pulverulentalis* (Order-Lepidoptera, Family-Pyralidae) are pale yellow in ~~colour laid singly on the lower surface along the leaf vein of the mulberry leaves~~color, laid singly on the lower surface along the leaf vein of the mulberry leaves, having fecundity around 80-150. The egg period lasts for 3-4 days. The total larval period is 12-15 days, having ~~5~~ five larval instars. The first larval instar is minute and is fluorescent yellow in ~~colour~~color. The second larval instar is light yellowish orange ~~in colour having~~with small sub-median black spots enclosed by white patches. The third larval instar is deep orange in ~~colour and its dorsal, mid-dorsal lines~~color, and its dorsal mid-dorsal lines and spots are clearly visible. The fourth larval instar is dark greenish brown ~~in colour and the fifth larval instar is dark pinkish brown in colour~~, and the fifth larval instar

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is dark pinkish brown. The Pupal period lasts ~~for 7-9 days and are dark brown in colour~~ 7-9 days and is dark brown and pupates in dried leaves/soil. The adults are ~~yellowish-grey in colour having longevity of 8 and 11 days for male and female~~yellowish-grey in color, having longevity of 8 and 11 days for males and females, respectively. The total lifecycle is completed in 17-24 days (Mahadeva, 2018). **Symptoms:** The early instar larvae occupy the apical parts of the mulberry shoot and feed on the young, tender leaves. The larvae reside on the leaves by forming a web and ~~fold~~ folding~~the leaves~~them,~~and thereby~~ making shelter for ~~itself~~themselves. The leaf margins of apical leaves are rolled and tied by the larval web wherein they live. Occasionally, 1 or 2 leaves are rolled into ~~cup shape with the web secreted from the larvae which remains inside and hence~~a cup shape with the web secreted from the larvae that remain inside; hence, this pest is called ~~as a~~leaf roller/leaf webber. The lower leaves of the infested plants become soiled due to ~~faecal matter of larva~~the larvae's fecal matter.

IPM of *D. pulverulentalis*:(a) Mechanical control: The infested portions are trimmed~~ and collected in a polythene bag~~, collected in a polythene bag, and then destroyed by burning. ~~The~~Flood irrigation and deep ploughing help kill the pupae of pests~~ pupae of the pest~~ residing in the soil. The light traps can be used to attract and kill ~~adults of pest~~adult pests. **(b)Chemical control:** The foliar application of 0.076% DDVP 76% EC (one ml in one ~~litre~~ literof water) 10 days after pruning/leaf harvest is helpful. If the infestation continues~~ then further~~, then 2-3 sprays are needed. The leaf for silkworm rearing can be used after 7 days of DDVP application. The commercial neem pesticide (0.03% AZ) 0.05% can be sprayed having ~~safe period~~ a safe period of 10 days. **(c) Biological control:** The release of egg parasitoid, *Trichogramma chilonis* @ 1 lakh adults/acre in 4 split doses, larval parasitoid, *Bracon brevicornis* @ 200 adult wasps, and ectopupal parasitoid, *Tetrastichus howardii* @ ~~1~~ onepouch /ac. is effective for controlling leaf roller*D. pulverulentalis*(Sakthivel *et al.,* 2019; Kumar *et al*., 2024). The *Apanteles sp*. and *Chelonus sp*. are also reported to be parasitic on leaf roller (Geetha Bai *et al*.,1997; Srinivasa ~~gowda *et al*., 2001), also the *Calosoma sp*. which is a larval predator is predating~~Gowda et al., 2001), the Calosoma sp., which is a larval predator that predates on leaf webber larvae (Annon., 1997). Furthermore, the aqueous leaf extracts of *Catheranthus roseus, Piper betle, Ocimum sanctum, Tagetus patula*~~and *Mentha piperita* are found to be effective against leaf roller larva~~, *and Mentha piperita are found to be effective against leaf roller larvae*. The insecticidal properties of various medicinal plants~~*viz.,Lantana camara*,~~

~~*Allium sativum*, *Zingiber officinale*, *Azadirachta indica* and *Vitex negundo* was~~, viz., *Lantana camara*, *Allium sativum*, *Zingiber officinale*, *Azadirachta indica*, and *Vitex negundo*, were studied against *D. pulverulentalis* ~~and among~~. Among these, lantana extract at a lower concentration of 11% was found to be most effective against leaf roller (Maheswari and Govindaiah, 2017, 2018).

Life cycle and management strategy of *G. pyloalis* through IPM

The *G. pyloalis* (lesser mulberry pyralid) is a serious pest of mulberry in India, China, Japan, Malaysia, Pakistan, Uzbekistan, Burma, and Korea (Madyarov *et al.*, 2006). Borgohain *et al.* (2015) carried out a study on mulberry leaves infested by *G. pyloalis* and revealed that early first and second instar larvae fed by scraping green tissues and mesophyll layer leaving behind only a transparent epidermis layer. The larvae (first and second instar) ~~damaged up to 0.11-0.33 cm^2 area and full-grown larvae~~ were damaged up to 0.11-0.33 cm2 area, and full-grown larvae were damaged up to 0.69-1.75 cm^2 area of mulberry leaf. **Life Cycle:** *G. pyloalis*(Order-Lepidoptera, Family-Pyralidae) is a holometabolic insect consisting of egg, larva, pupa, and adult stages ~~having much similarity~~similar to the silkworm. The moth is nocturnal (Khosravia and Sendi., 2010) and lays around 200 eggs under ~~side of leaf, the egg is pale yellow in colour, round~~the side of the leaf. The egg is pale yellow in color and round,and its size measures about 0.2mm. The eggs hatch within 5-6 days into larva. The larvae measure around 0.2-2 ~~cms in length and are slender, fusiform~~cm in length and are slender, fusiform, and segmented. Each larva has 3 ~~pair of forelegs, 4 pairs of hind legs and a pair of caudal legs and then mature, transform into brown pupae~~pairs of forelegs, 4 pairs of hind legs, and a pair of caudal legs and then matures, transforms into brown pupae, and then into a ~~and then into~~ moth. The whole life cycle takes about a month to complete. **Symptoms:** Under ~~Kashmir climatic conditions the infestation is observed around July October~~Kashmir's climatic conditions, the infestation is observed around July to October. After hatching ~~the larva spin fine silky net of threads around themselves and eat leaves leaving behind~~, the larva spins fine silky nets of threads around themselves and eats leaves, leaving behind a transparent cuticular layer. The larval excreta are held ~~in~~ between fine silky threads, thus making leaves unsuitable for silkworms. After the pest damage, the ~~nutrients in the leaves are lost and this in turn~~leaves' nutrients are lost, which, in turn, inhibits the growth of plants. Mainly ~~the much damage is caused by 4th and 5th instar larva~~, the damage is caused by 4th and 5th instar larvae. The larvae feed inside the leaves after webbing the leaves together. The larvae ~~skeletonise the mulberry leaf after eating all the green portion~~skeletonize the mulberry

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leaf after eating all the green portions of the leaf. The infested part of the leaf becomes dark brown in ~~colour and is devoid of chlorophyll, moisture content, proteins, sugars~~color and is devoid of chlorophyll, moisture content, proteins, sugars, etc. (Hassan and Mir., 2018). **IPM of *G. pyloalis*: (a) Mechanical control:** Hand pick the ~~larval stages of pest and destroy it~~pest's larval stages and destroy them. Ensure deep ~~ploughing~~ plowingand weeding ~~in order to~~to destroy the hibernating larva. Burn the diseased and fallen leaves in September-October. Ensure straw banding of trees and light trapping for moths to control this pest. **(b)Chemical control:** Spraying of 0.04% DDVP on leaves can significantly reduce the infestation level of the pest. **(c) Biological control:** The *G pyloalis* was reported as the most predominant defoliator pest, and its natural enemies like hymenopteran parasitoids *viz.,Apanteles obliquae*, Ichneumonid wasp, *Chelonus carbonator* and the coccinellid predator, *Cheilomeness exmaculata* proved to be active natural enemies against it (Sultana *et al.*, 2023) (Table 1 & 2). Nighat *et al.* (2002) recorded two braconid larval parasitoids *viz.*, *Apanteles glomeratus* and *Chelonus sp*. parasitizing the larvae of *G. pyloalis*, further parasitoids namely *Habrobacon hebetor*, *C. carbonator*, *Glyptapanteles sp.*, *Pristomerus sulci*, *Xanthopimpla sp*., *Perilampus sp*., *Campoletis sp.* and *Brachymeria lasus* could be used for the control of *G. pyloalis* under temperate conditions of Kashmir (Mittal*et al.*, 2011, 2016) (Table 3). The parasitoids *viz.,Apanteles sp., Bracon sp. and Goniozus sp*. and predator spiders *viz.,Philodromus sp. and Tetragnatha sp*. were also recorded as natural enemies for leaf roller (Sathyaseelan *et al.*, 2002). In a recent finding *G. pyloalis* was ~~found as~~ a host of *P. sulci* (Bhat *et al.*, 2020).

Table 1: Natural enemies present on mulberry

Natural enemies	Order	Family
***Apanteles obliquae* Wilkinson**	Hymenoptera	Braconidae
***Chelonus carbonator* Marshall**	Hymenoptera	Braconidae
Megaselia scalaris	Diptera	Phoridae
Cheilomeness exmaculata	Coleoptera	Coccinellidae
***Disophrys*sp.**	Hymenoptera	Braconidae
Tachinid fly	Diptera	Tachinidae
Ichneumonid wasp	Hymenoptera	Ichneumonidae
Spider	Araneae	Salticidae

Table 2: Defoliator pests present on mulberry

Common name	Scientific name	Order	Family
Mulberry leaf roller	*Glyphodes pyloalis* Walker	Lepidoptera	Pyralidae

Common cutworm	*Spodoptera litura* Fabricius	Lepidoptera	Noctuidae
Tussock caterpillar	*Euproctis fraterna* Moore	Lepidoptera	Lymantriidae
Spanworm	*Hemerophillaa trilineata* Butler	Lepidoptera	Geometridae
Green weevil	*Myllocerus viridanus* Fabricius	Coleoptera	Curculionidae

Sultana *et al.*, 2023

Table 3: Parasitoids of *G. pyloalis*

Name	Family	Order	Stage attacked	Period of activity
***Apanteles obliquae* Wilkinson**	Braconidae	Hymenoptera	Larval instars	July - Oct.
***Bracon hebetor* Say**	Braconidae	Hymenoptera	Larval instars	Sept.
***Chelonus carbonator* Marshall**	Braconidae	Hymenoptera	Late instars	July - Oct.
***Pristomerus sulci* M. & K.**	Ichneumonidae	Hymenoptera	Late instars / Pupae	Aug.
Xanthopimpla sp.	Ichneumonidae	Hymenoptera	Late instars / Pupae	Aug.
Campoletis sp.	Ichneumonidae	Hymenoptera	Late larval instars / Pupae	Aug. - Sept.
***Brachymeria lasus* (Walker)**	Chalcididae	Hymenoptera	Pupal	July - Aug.

Mittal *et al.*, 2016

Conclusion

The incidence of pests poses a ~~great~~ significantthreat to mulberry plants~~ and deteriorates its leaf quality~~, deteriorates their leaf quality, and eventually results in poor cocoon production. The outbreak of pest ~~attack like defoliators on mulberry plants incur heavy losses to silkworm farmers and in turn~~attacks like defoliators on mulberry plants incurs heavy losses to silkworm farmers, and in turn, it becomes imperative to design sustainable management strategies to control it through IPM. As the wide use of chemicals is not a long-term solution to control pests as they harm the environment by leaving more residues, ~~so utilising~~utilizing biological means like its natural enemies is best for naturally maintaining the balance in the mulberry

ecosystem. So, in order to check the leaf roller population like *D. pulverulentalis*and *G. pyloalis,* the multipronged approach using IPM should be followed for better efficiency to boost the silk industry.

Disclaimer (artificial intelligence)

~~Authors~~ The authorsdeclare that ~~no AI technologies like Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used~~ they did not use AI technologies like large language models (ChatGPT, COPILOT, etc.) and text-to-image generators while preparing this manuscript.

Competing interests

~~Authors~~ The authorsdeclare that no competing interests exist

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