Mulberry forms the exclusive food plant of the silkworm, *Bombyx mori* L. Hence, production of an appreciable quantity of superior quality leaf assumes great significance in order to realize silkworm rearing as a profitable venture. Besides, with the implementation of WTO regulations recently, the focus has shifted towards quality production for meeting the international standards. The process of mulberry leaf production is often hampered due to interference caused by insect and non-insect pests. Being perennial, evergreen with luxuriant growth, mulberry plant offers suitable conditions for feeding and breeding of pests due to its mono-cropping nature, often leading to their rapid proliferation which culminates in qualitative and quantitative loss to mulberry. The pests are reported to cause 10-20% reduction in leaf apart from causing quality decline due to some pests (Manjunath, 2004). At the same time, cost of leaves has been worked out to about 60% of the total cost of silk production (Rangaswami *et al.*, 1978). As a result, the expected returns from sericultural practices are not fully realized. Therefore, major thrust has been laid on how to render the sericultural practices sustainable. Concerted efforts by sericultural scientists have led to the development of a host of diseases and pest management strategies. These chiefly involve the use of cultural operations, chemical agents, bioagents,
botanicals etc. which need to be employed judiciously to alleviate the potential dangers that these agents can cause if left unattended.

Mulberry pyralid, *Glyphodes (=Margaronia=Diaphania) pyloalis* Wlk. is one of the serious pests of mulberry in most of the countries of the world practising mulberry sericulture. In Kashmir valley the pest was observed to cause infestation to all the mulberry genotypes chosen for the survey. Highest incidence (4.91%) was observed in Chinese white followed by Goshoerami (4.45%), while the lowest incidence among the observed mulberry genotypes was found in Ichnose (3.09%). These results are in agreement with those of Illahi et al. (2003) who made similar observations on seven genotypes of mulberry under temperate conditions of Kashmir valley.

It was observed that incidence of this pest started from first week of June and remained till leaf shedding i.e. last week of October. A steady increase in pest incidence with considerable overlapping of generations (Table 4.22) was also observed from June to October. A slight decline in the population of pest observed during August could be attributed to high temperature coupled with low humidity, which is a phenomenon normally encountered during this period in Kashmir valley. Similarly highest pest incidence observed during October could due to low temperature and high humidity (Tables 4.23 & 4.24) an environmental condition which is normally favorable for the multiplication and growth of most of the insects. Mehto et al. (1985) while working on chick pea reported that the incidence of this pest declined when the average daily temperature rose beyond 25°C and relative humidity fell below 55%. Similar observations where made by Faleiro et al. (1990) while studying influence of abiotic factors on the population build up of important insect pests of cow pea *Vigna unguiculata* (L.) Walp. Khan et al. (2006) have made similar observations on six mulberry genotypes in
Kashmir. Kikuchi (1976) also found that incidence of this pest in Japan was mainly in summer and autumn, particularly in September and October.

While estimating percent damage index during 2005, it was found that all the five genotypes examined for this purpose were damaged by *Glyphodes pyloalis* Wlk., but the extent of damage varied with the genotype. Highest PDI was observed in Chinese white which was followed by Goshoerami variety. Similarly lowest PDI was found in Rokokuyaso which was followed by Ichinose. This trend was prevalent during all the observation seasons viz., spring, summer and autumn. Khan *et al.* (2004) have made similar observations and highest PDI was observed in Chinese white (14.99%) followed by Goshoerami (7.12%). Lowest PDI (1.10%) was observed in Rokokuyaso.

Observations regarding the biology of *Glyphodes pyloalis* were made under laboratory conditions. Moths of opposite sex were found to copulate soon after their emergence. It was found that male moth resorted to random flight for sometime before approaching the female and the duration of mating was found to last from 6-12 minutes. Seol *et al.* (1987) observed that mean mating time in *Glyphodes pyloalis* under laboratory conditions was 4.0 minutes and mating was observed to occur during night. Egg laying was found to occur either during dusk or night. This shows that the pest is nocturnal in its habit. Incubation period was found to last from 2-4 days under laboratory conditions with temperature ranging from 25-28°C and relative humidity 70-75%. Mathur (1980) observed that incubation period in *Glyphodes pyloalis* lasted from 2-3 days in summer and 4 days in autumn. This shows the influence of environmental factors like temperature and humidity is possibly determining the duration of incubation. When the temperature is high and the weather dry, eggs readily dry up and shrivel (Ertian, 2003). Early stage larvae were found to be colorless but later they
were found to turn green. They were found to moult 5 times before changing into pupa. Perhaps the chlorophyll reaching into their bodies during feeding imparts them a greenish tinge. Mathur (1980) also noticed that 4 or 5 larval moults are found in *Glyphodes pyloalis*.

Larval duration was found to last for 10-30 days. Almost similar observations have been made by Mathur (1980) who found the larval duration to last for 10-39 days during summer. Khan and Nighat (1991) observed the larval duration in *Glyphodes pyloalis* to extend from 25-30 days under natural conditions. These slight differences in durations could be attributed to differences in temperature conditions prevalent during observation period.

Young age larvae were found to remain on the underside of leaves but mature larvae were found to spit threads to fold the leaves together and then remain inside the leaves. This habit of larvae to remain in folded or overlapped leaves could be due to the protection which larvae gain against unfavorable climatic conditions and natural enemies.

Before going into pupation, larvae were found to change their color from green to pink or brown with a simultaneous shortening of body. This stage called pre-pupa, was noticed to occur inside a silken cocoon spun by the larva itself. Occurrence of pre-pupal stage in the life history of *Glyphodes pyloalis* has been noticed by Khan *et al.* (1991) also. Jothi and Tandon (1994) while observing the biology of Sapota bud borer *Anarsia achrasella* Bradley, found the last instar larva turning pink and the pre-pupa reddish pink. They observed the pre-pupal period to vary from 1-2 days which is the case with *Glyphodes pyloalis* also. Mathur (1980) observed that in *Glyphodes pyloalis* pre-pupal stage lasted for about one day in summer.

Under laboratory conditions, pupation was found to occur either in folded leaves, on the walls of rearing Jars or on the muslin cloth covering the Jar mouth. Mathur (1980) observed that under natural conditions pupation
occurred in fallen leaves, crevices of mulberry plant trunk or in a suitable place on the ground. Jothi and Tandon (1994) found that in case of *Anarsia achrassella* Bradley, pupation occurred inside the leaf damaged by larva itself. Choice of these sites for pupation could be attributed to the protection provided by them to the pupa against environmental disturbances and biotic agents.

Pupal duration was found to be 5-8 days under laboratory conditions. Mathur (1980) observed the pupal duration in this pest to extend from 5-9 days during summer months and from 14-21 days during spring months. While studying the biology of Jamun defoliator *Metanastria hyrtaca* Cram., Aherkar et al. (1997) found that pupal duration of this pest lasted for 14.8 days in summer and 17.4 days in winter season. This indicated the influence of environmental factors like temperature on the duration of pupation.

Adults were found to remain active during night only. During the day they were found to remain hidden on the lower surface of leaves or attached to wall of rearing jar. Similar observations have been made by Mathur (1980) who found that moths are not often seen unless disturbed in the thick vegetation and shady places where they remain hidden. This shows that moths are nocturnal in habit.

The longevity of adult moth was found to be 3-5 days. Ertech (2003) mentioned the longevity of adult moths of *Glyphodes pyloalis* Wlk. to range from 3-4 days, maximally 11 days. While Mathur (1980) found the life span of these adult moths to last for 6-8 days, maximally 14 days. The variation in the life span of adult moths could be attributed to prevailing temperature conditions which is evidenced by the observation made by Aherkar et al. (1997) while studying the biology of *Metanastria hyrtaca* Cram. This is again attributable to nature of diet on which larvae were fed. Seol et al. (1986)
found that fecundity and longevity of adult moths of *Glyphodes pyloalis* Wlk. differed when fed on different varieties of mulberry leaves or artificial diet.

Observations made by some workers have shown *Glyphodes pyloalis* to be somewhat phototactic in behavior preferring to oviposit and congregate near a lamp. Considering these observations, a locally build light trap was installed in the sericulture farm of CSR&TI, Pampore and significant catches of the adult moth, besides other species of insects, were made during both the study years i.e. 2005 and 2006.

Regarding the appearance and abundance of the pest, initial catches were made during 2nd week of May after which the catch size increased till 2nd week of October, after which the catch size declined till first week of Nov. For the remaining part of year no catches were made. This light trap has helped in monitoring the appearance and seasonal abundance of this pest and the results obtained through light trap with respect to appearance and abundance of this pest are almost identical to those obtained by direct observations made in the field.

Karuppuchamy and Balasubramanian (1990) while studying incidence of Pink boll-worm *Pectinophora gossypiella* Saunders. using a trap, found direct relationship between larval infestation in the field and trap catches.

Difference in the number of catches for 2005 and 2006 could be attributed to prevailing weather conditions, which were slightly different for these two observational years as shown by meteorological data (Tables 4.23 & 4.24). Balasubramanian *et al.* (1985) found positive relationships of sunshine hours and relative humidity with light trap collections of Tobacco cutworm *Spodoptera litura* F., while a negative relationship was noticed with wind velocity. Karuppuchamy and Balasubramanian (1990) however found no correlation between trap catches and weather factors namely relative humidity, temperature and rainfall.
Keever and Cline (1983) have studied the impact of light source and trap height on the capture of *Cathartus quadricollis* and *Callosobruchus maculatus*. But such parameters were not assessed in the current study.

The various methods applied for the control of different types of pests are classified as prophylactic and curative measures, the former being more desirable owing to their low cost and effectiveness in suppressing the pest population. Various cultural methods applied are counted as prophylactic measures and for that reason one was applied in the current study.

Since *Glyphodes pyloalis* Wlk. over-winters as mature larva which becomes the source of next year’s infestation, it was important to determine the diversity of its over-wintering sites which was confirmed by detection of concentrations of over-wintering *Glyphodes pyloalis* larvae in soil, fallen leaves and cracks in the bark of mulberry plants. Fye (1983) while making observations on the winter survival of pear psylla *Psylla pyricola* noted the utilization of leaf duff by this pest for over-wintering. Similarly Lal (1977) found that the bug *Nysius ceylonicus* Mots. over-winters as adult under the bark of *Alnus nitida*. Mathur (1980) while studying the biology of this pest found it to over-winter in fallen leaves. This indicates that the pest utilizes same type of over-wintering sites as used by other insects. However it was observed that fallen mulberry leaves were given more preference over soil while mulberry shoot was least preferred. Highest utilization of fallen leaves for over-wintering by this pest could be because of its easy usage or moisture content in it. Fye (1983) found that leaf moisture acted as one of the factors for the winter survival of *Psylla pyricola*. Limited utilization of soil or bark by this pest for over-wintering could be attributed to stiffness or lack of sufficient moisture at the soil surface. While studying the over-wintering of *Zygogramma bicolorata* Pallister, Jayanth and Bali (1995) found that soil moisture had an important role in the over-wintering of this pest in soil.
Results of the study thus show that fallen leaves provide a major haven for this early-season pest of mulberry foliage and the availability of optimum over-wintering sites in the mulberry garden may account for the presence of large spring population of this pest.

Since fallen mulberry leaves were found to offer maximum protection to *Glyphodes pyloalis* Wlk. during winter, treatment of leaves was done and its impact on pest population was studied. A significant reduction in the pest population was noticed in treated plot as against the untreated control plot. Average pest population was found to reduce by about 50% in the treated plot as compared to untreated plot. The same trend was noticed for both the study years viz., 2006 and 2007. Occurrence of the infestation in treated plots could be attributed to other over-wintering sites which were not either studied, unexploited during the observation period or migration of adults from nearby untreated plots. Mathur (1980) reported that since pest passes a great part of his life within the folded leaves on the ground, major control efforts should be directed towards cultural practices, particularly the burning of leaves during winter months or ploughing to destroy the hibernating larvae. Philip *et al.* (2002) while studying the insect pests of mulberry in Kerala have found the destruction of mulberry leaves very effective in reducing the population of *Spilosoma obliqua*.

Observation regarding the application of synthetic insecticides against *Glyphodes pyloalis* Wlk. in field has shown that all the four insecticides used were effective in reducing the pest population through larval mortality. Out of the four treatments, Monocrotophos (0.15%) was found to register highest kill (95.26%) while lowest kill (22.38%) was noticed in B.H.C at 0.05%. Khan *et al.* (1998) while applying monocrotophos, B.H.C and Dichlorovos against *Glyphodes pyloalis* Wlk. in the field found that 0.1% and 0.05%. Monocrotophos and 0.04% Dichlorovos gave highest kill in the range of 90-.
96%. Regarding the safety of monocrotophos to silkworm, they have not found it feasible for the management of *Glyphodes pyloalis* Wlk., while for Dichlorovos, safe period was worked out to be 9 days. Endosulfan and Monocrotophos have also been used by Reddy and Kotikal (1988) in field to control thrip infestation on mulberry and the safe period was worked out as 8-12 days. Reddy *et al.* (2000) have used endosulfan (0.05%) and monocrotophos (0.03%) against *Spodoptera litura* in mulberry fields of Andra Pradesh and safe period has been worked as 15 days. Gupta and Veer (1986) while testing the contact toxicity of nineteen synthetic insecticides against third instar larvae of *Glyphodes pyloalis* Wlk. found that monocrotophos was most toxic. This was followed by Dichlorovos while BHC exhibited least toxicity against this pest.

Paul and Agarwal (1989) while investigating persistent toxicity of some insecticides to the *Trichogramma brasiliensis* reported higher persistence of monocrotophos over endosulfan. Under laboratory conditions, these insecticides have shown good degree of effectiveness against this pest and the order of toxicity was found to be same as under field conditions. It was noted that these insecticides performed slightly better in laboratory than in field. This could be attributed to loss of their toxicity due to exposure to environmental factors like sunlight, high temperature etc. Safe period of these chemicals has been worked out as DDVP, 7 days at 0.01%, endosulfan, 9 days at 0.05%, BHC, 7 days at 0.05%, Monocrotophos, 17 days at 0.05%. This indicated that above mentioned insecticides can be used against *Glyphodes pyloalis* Wlk. but their spray timing should be so adjusted that it may not interfere with the silkworm rearing activities during summer and autumn months. Keeping in view the continuous domestication of silkworm *Bombyx mori* L., it has lost maximum resistance and as such the preference in case of the use of insecticides should be highly selective with relatively shorter safe periods, which may not hinder the silkworm rearing.
Phytochemicals or botanicals, currently used to control different types of pests and diseases of different crops, have been tested against *Glyphodes pyloalis* Wlk. also. Promising results were achieved after applying these botanicals under field as well as under laboratory conditions.

Out of four commercially available botanicals, Achook (neem) 1.5% was found to be most effective in pest population suppression. This was followed by Theta, Delta and X-10 Biotreat. These results are different from those obtained by Desai and Desai (2007) who studied the insecticidal properties of these preparations against *Lipaphis erysimi*. They found Theta more toxic than Delta while Achook was found to be least toxic. This could be due to manufacturing variability when the percentage of effective concentration of active ingredients vary with the manufacturer or batch. Kumar and Mukhopadyay (2005) while studying the efficacy of different botanicals against *Maconellicoccus hirsutus* found 2.0% neem oil to be most effective in controlling mealy bug infestation which was followed by Pongamia oil at the same concentration. Shekhar and Rajadurai (2001) evaluated the efficacy of commercial neem product (0.03% Azadirachtin) against *Diaphania pulverulentalis* in Karnataka and found 85.9% suppression in leaf roller infestation.

Petroleum ether extracts of five locally available plants when tested in field for their efficacy against *Glyphodes pyloalis* Wlk. have shown variable efficacy. *Datura stramonium* (10ml/l) was found to show highest toxicity (77.77%) after 24 hours of its application in the field while lowest efficacy was found in *Mentha piperita*. The order of efficacy in terms of percent reduction in population was worked out as Datura > Chrysanthemum > Acorus > Artemesia > Mentha. Kaur et al. (198) found that methanol extract of leaves of *Chrysanthemum indicum* caused inhibition of growth and development in nymphs of *Dysdercus similis*. Similarly Gupta et al. (2005)
found *Mentha piperita* effective in causing egg and larval mortality in case of *Trogoderma granarium*. Efficacy of *Acorus calamus* rhizome powder has been tested by Khan (1986) against *Callosobruchus chinensis* and found significant reduction in infestation and effectiveness lasting up to one month after treatment when applied at 0.2% (w/w). *Acorus calamus* has been tested by Teotia and Panday (1979) against *Sitophilus oryzae* and similar results were obtained with respect to infestation reduction. *Datura stramonium* has been found to be highly toxic to *Tylenchulus semipenetrans* and *Anguina tritici* when its methanolic and water extracts were used by Kumari *et al.* (1986). Singh and Rao (1999) have tested *Artemisia vulgaris* against *Spodoptera litura* and *Schistocerca gregaria* and found inhibition of reproductive development in both these insects but no results were found with regard to mortality. The differences in activities between different species of *Artemisia* against different insect species could be due to differences in chemical profile of these plants. When these botanicals were tested for their efficacy against *Glyphodes pyloalis* Wlk., results were found to be better than those in the field. However order of toxicity of different extracts used was same as observed under field conditions. Better performance of these botanicals in laboratory can be attributed to absence of environmental factors like high temperature, direct sunlight etc. which speed up biodegradation of these phytochemicals.

In silkworm rearing, determination of safe period of a new pesticide is a prerequisite before it can be recommended for application against different pests and at the same time may not interfere with different rearing seasons. In the present study safe period of different commercial and local preparations of plant products was estimated and the results of the study revealed that mortality of larvae decreased with increase in the time interval between brushing of silkworm larvae and foliar spray of these botanicals. Highest mortality (8.73%) was reported in X-10 Biotreat at 1.5%, when treated leaves
were supplied to silkworm larvae one day after treatment. Achook (7.11%) and Datura (6.33%) followed this at the same concentration. Lowest mortality (0.01%) was observed in chrysanthemum at 0.5% when fed to silkworms 9 days after spray. It was found that leaves treated with the earlier mentioned botanicals caused no mortality and hence treated leaves can be used safely after nine days of their treatment for silkworm rearing. Sharma et al. (2004) reported that tasar silkworm rearing could be conducted safely after five days of application of aqueous solution of Azadiractin without having adverse effects on the important parameters of tasar silkworm rearing. Sen and Rajodurai (1998) while testing neem seed extract (2.5%) and Neemoil (5%) against *Diaphania pulverulentalis* recommended waiting period of 8 days after safe rearing of silk worm. Raman et al. (2000) found that antifeedant effect of annona products was more on silkworm than *Spilosoma obliqua* at same concentration. They, however, found that residual toxicity to silkworm lasted only up to 10-13 days after which the worms fed on treated mulberry leaves normally. Consumption of leaves sprayed with neem oil 0.5%, 1.0% and 1.5% by silkworm after 7 days resulted in 3.33 to 9.66% mortality. The leaves after 14 days and 21 days of spray caused no mortality (Bandyopathyay et al., 2002). Teotia and Tewari (1977) found that rhizome extract of *Acorus calamus*, when used against adults of *Sitotroga cerealella* Olv., lost toxicity completely on the 8th day after spraying.

Findings of present investigation cannot be compared for want of published information regarding the waiting period of some botanicals used during the present study. However, the results indicate that these phytochemical insecticides have a potential to be used as insecticides for control of mulberry pyralid without affecting the silkworm if proper waiting period is followed for leaf harvesting.
A small community of natural biological control agents was found to be associated with *Glyphodes pyloalis* Wlk. in the sericultural farms of Kashmir. Braconid parasite, *Apanteles obliquae* Wlk. was found the dominant species among the reported bioagents. Others like *Bracon hebetor* Say, *Pristomerous* spp. and two spider species viz., *Tetragnatha* spp. (Tetragnathidae) and *Philodromun* spp. (Philodromidae) were also found associated with this mulberry pyralid. Parasitization of this pest by *Apanteles* and *Bracon* spp. has been reported by Mathur (1980), while studying the natural enemy complex of this pest in Dehra Dun. Khan *et al.* (1997) have reported the presence of these natural control agents in Kashmir with *Apanteles oblique* forming the dominant species. In China, the pest is attacked by a large natural enemy complex like *Trichogramma evanescens, Apanteles heterusiae, Cedria paradoxa, Macrocentrus philippinensis* and others (Ertian, 2003). Mathur (1980) while studying the natural enemies of this pest in Punjab and Dehra Dun could isolate *Chelonus* spp., *Hemiteles* spp., *Microgaster* spp., *Phanerotoma* spp., *Cedria paradoxa, Pimpla* spp. and suggested *C. paradoxa* as a potential parasitoid of *G. pyloalis* Wlk. He reported the predation of the larval stage of this pest by some unidentified spiders also. Bhathal and Dhaliwal (1990) observed the potential of many species of spiders in controlling the population build-up of *Sogatella furcifera* Horvath. Attack of *Glyphodes pyloalis* Wlk. by *Apanteles obliquae* Wlk. has been reported by Nishikawa (1919) also. Veerana (1998) observed that in China the pest is attacked by *Trichogramma evanescens* and *T. Matsumura* in egg stage while *Apanteles heterusiae* and *Macrocentrus philippinensis* attack it in larval stage. Among other natural control agents isolated from the pest are *Nosema* spp., NiSH5 (Hayasaka and Yonemura, 1999). Viruses (*DmDNVI, DNVII* and IFV) (Watanabe, 1988).

While studying the cross infectivity of *Beauveria bassiana* to other insect hosts, Zeya, *et al.* (2002) found *Glyphodes pyloalis* Wlk., besides other
insect pests of mulberry in Kashmir, highly susceptible to this fungus. This fungus has been found to be the commonest devastating pathogen causing white muscardine to *Bombyx mori* L. in all silkworm rearing zones of Kashmir valley. Management of these pests in general and *Glyphodes pyloalis* Wlk. in particular, being the greatest contributor to mulberry leaf destruction in valley, is a pre-requisite for successful sericulture through the reduction in the availability of alternate insect hosts of *Beauveria bassiana* (Bals.) Vuill. Watanabe *et al.* (1988) and Sohaf & Munshi (1995) also have stressed on the control of *Gylphodes pyloalis* Wlk. after making observations similar to those mentioned above.

The above discussion shows that natural enemy complex of *Glyphodes pyloalis* Wlk. is very diverse and if exploited fully will lead to suppression of pest population to satisfactory levels in a sustainable manner. Poor presence of these natural agents in Kashmir valley can be attributed to weather conditions, since weather conditions prevailing in region play an important role in the occurrence and subsequent build up of insect pests and their allocated biotic agents (Falcioro *et al.* 1990). Nevertheless, search for natural enemies in Kashmir range has just begun and should be expanded to include different seasons and localities as the acquisition of suitable biotic agents has historically been proportional to be amount of research effort (De Bach. 1971). more effort deserves to be extended to the native host range.