6. SUMMARY

Six minor lepidopteran leaf feeding rice pests were investigated with reference to morphological description of different stages, including morphometric studies both for the pest species and their dominant natural enemies and biological studies including seasonal abundance, biology of the pest and the food plant range. Natural enemy complex active, against the selected pest species, rate of parasitism/predation and biology and seasonal history of the natural enemies were studied and information on hyperparasitoids was obtained. The role of natural enemies in keeping the test pest species under check has been discussed.

6.1. Pests

6.1.1. Pest species abundance and damage

Of the six pest species studied, *Parnara naso* and *Parnara mathias* appeared in fields immediately after transplantation and continued till tillering stage. *Melanitis leda ismene* was active at the tillering stage of the crop, especially in the late planted rice fields. The order of their abundance was: *Parnara* spp. > *M. leda ismene* > *Euproctis xanthorrhoea* > *Psalis pennatula* > *Laelia fasciata*. Generally all the test pest species were available both during kharif and rabi seasons. *P. naso*
population commenced increasing from 1st week of March, attained peak during middle of June and then started declining. It rose again from middle of July attained peak in September and started declining from beginning of November onwards. *P. mathias* population commenced increasing from 1st week of March, attaining peak during middle of April and then started declining. It rose again from 1st week of July attaining peak in 1st week of September and thereafter declined. *M. leda ismene* population commenced increasing from 1st week of March reaching peak in middle of April and subsequently declined. It rose again from middle of August reaching peak in beginning of November and then started declining. *E. xanthorrhoea, P. pennatula* and *L. fasciata* were found in negligible numbers, both in rabi and kharif in the field. *P. mathias* and *P. naso* damaged the rice plant by direct feeding as well as removing leaf parts for making tubes. *M. leda ismene, E. xanthorrhoea, P. pennatula* and *L. fasciata* damaged rice plant by direct feeding.

6.1.2. *Pest morphology*

*P. naso* adult is olive brown with 5 to 8 and 3 to 5 whitish spots on either side of fore and hind wings respectively. Antennae is club shaped forming a fork anteriorly. Adults are diurnal. Female measured 16-17 mm in length and a wing span of 16-18 mm and the male 16-16 mm in length and
A wing span of 16-17 mm. Sexual dimorphism is present. While the female genitalia is surrounded by hairs the male genitalia is surrounded by three spiny projections. Eggs of *P. naso* are dirty green in colour, generally laid on apical portion of the leaf (both on dorsal and ventral surfaces). There are five larval instars. The external morphology of the larva is practically same in all instars except certain minor characters which develop in later larval instars. Pupa is obtect, yellowish-green and enclosed in a whitish cocoon formed out of rice leaf.

Adult *P. mathias* is also olive brown with eight white spots and hind wing with a white spot. Eggs are similar to that of *P. naso*, except being larger in size and bluish-white in colour. There are five larval instars. Larva is green in colour with two oblique pinkish stripe bordered by white. Pupa has a characteristically pointed head which is attached to the leaf by posterior abdominal tip and a girdle like silken thread at the thoracic region.

*M. leda ismene* adult is dark brown with large ocular spots on the upper surface of forewings. The underside of the fore-wings are brown with dark transverse stripes and ocelli. Hind wing possesses six ocellar spots. Adults exhibit seasonal dimorphism i.e. dry- and wet-season forms. Eggs are bottle green, transparent, smooth, hemispherical and laid singly. There are five larval instars. The larva
is fusiform, greenish with rough and wrinkled body, possessing characteristic pair of horns anteriorly and posteriorly a bifurcation of anal segment. Pupa is green, smooth attached to the leaf/stem, by a peduncle. Pupae hang with head downwards.

_E. xanthorrhoea_ are whitish moths with distinct sexual dimorphism. Males appear whitish with slight fuscous tinge and dorsal side of hind wing and ventral side of both wings are black. The females appear whitish without black tinge but with orange coloured anal tufts. Antennae is bipectinate. Anal tuft in female is longer than male. Adults feign death when disturbed or apprehend danger. Golden coloured eggs are laid in masses on leaf and covered with yellowish anal hairs. Generally there are seven larval instars. Larva is orange coloured and hairy. Larval morphological characters have been described. Pupation takes place in a pinkish cocoon. Pupa is light brown.

Adult _P. pennatula_ is straw coloured with dirty whitish abdomen. Antennae is bipectinate. The female had thicker abdomen than male. This pest also feigns death as in case of _E. xanthorrhoea_. Eggs are round, creamy white and laid in rows on rice leaves. There are seven larval instars. Larva is yellowish hairy and morphological characters of each instar have been described.
Pupation takes place in yellowish silken cocoon. Pupa is light brown.

*L. fasciata* male and female adults are greyish white in colour. Males are distinguished from the female by the presence of 8 black spots on fore-wing, arranged in the form of a semi-circle. These are absent in the female. Adults feign death as in case of *E. xanthorrhoea*. Eggs are straw coloured and dumb bell shaped. There are seven larval instars. Larva is brownish black and hairy. The larval morphological characters have been described. Pupation takes place in a pinkish cocoon.

6.1.3. Pest biology

Adult longevity of all the test pests was studied under laboratory condition at 27°C to 33°C with 10% aqueous solution of honey as food. The male longevity was 24-120, 24-96, 96-216, 48-144, 24-72, 24-120 and the female 48-120, 24-120, 96-240, 48-168, 48-144, 48-168 hr in case of *P. naso*, *P. mathias*, *M. leda ismene*, *E. xanthorrhoea*, *P. pennatula*, *L. fasciata* respectively. Pre-oviposition period of *P. naso*, *P. mathias*, *M. leda ismene*, *E. xanthorrhoea*, *P. pennatula* and *L. fasciata* was 24-72, 24-72, 48-96, 48-72, 24-72, 24-48 hr respectively. Similarly oviposition period was 24-72, 24-96, 48-96, 120-168, 48-96 and 24-96 hr, respectively.
Total eggs laid by a single female during its ovipositional period ranged from 41-101, 45-97, 77-191, 182-199, 45-113, 41-126 for P. naso, P. mathias, M. leda ismene, E. xanthorrhoea, P. pennatula, L. fasciata, respectively. Egg of E. xanthorrhoea is the smallest of all and M. leda ismene is the largest. Larval instars varied in length from 1.5-1.7, 2-2.5, 7-9, 14-18, 21-32 mm for P. naso; 1.8-2.2, 2.5-3.5, 7.8-9, 14-18, 29-33 mm for P. mathias; 4-4.5, 5.5-7, 10.5-12.5, 17-20, 29-36 mm for M. leda ismene; 1.9-2.4, 3.16-3.4, 3.7-3.9, 6.8-7.5, 10-12.5, 13-15, 15-18, 17.5-20 mm for E. xanthorrhoea; 3-3.5, 4-5, 8-11, 11-16, 20-22, 22-25, 27-29 for P. pennatula and 2-2.5, 4-4.5, 5.8-10.5, 10.8-15.7, 20-22, 23-26.5, 27-29 mm for L. fasciata. Pupal length varied from 15-20, 22-25, 20-22, 9-14, 14-16, 15-16 mm for P. naso, P. mathias, M. leda ismene, E. xanthorrhoea, P. pennatula and L. fasciata respectively.

Egg stage lasted for 96 hr and 70-87 hr in kharif and and rabi for P. naso; 96 hr in both kharif and rabi for P. mathias; 74-75.30 and 73.30 hr in kharif and rabi for M. leda ismene; 85 and 96-120 hr in kharif and rabi for E. xanthorrhoea; 113 and 144 hr in kharif and rabi for L. fasciata and 120-128 hr in rabi for P. pennatula. Total larval period varied from 384-552 and 429-543 hr in kharif and rabi for P. naso; 432-600 and 419-468 hr in kharif and
rabi for *P. mathias*; 384-465 and 498-574 hr in kharif and rabi for *M. leda ismene*; 551-903 and 622.30-1157.1 hr in kharif and rabi for *L. fasciata* and 489-539 hr for *P. pennatula* in rabi. Pupal period varied from 120-168 and 143.30-168.45 hr in kharif and rabi for *P. naso*; 144-168 hr in both kharif and rabi for *P. mathias*; 144-192 and 142.30-192 hr in kharif and rabi for *M. leda ismene*; 108-216 and 192-264 hr in kharif and rabi for *E. xanthorrhoea*; 192-262 and 144-240 hr in kharif and rabi for *L. fasciata* and 101-168 hr in rabi for *P. pennatula*.

6.1.4. Alternate hosts

The pests were also found to feed leaves of other plants in the field. This feeding habit was later confirmed in the laboratory. *P. naso* larvae fed on leaves of *L. hexandra, E. indica, L. panicoides* and *E. uniloides* which served as alternative host while *P. scrobiculatum, P. distichus* and *E. colonum* acted as food host only because the 1st and 2nd instar larvae did not feed. *P. mathias* fed on leaves of *L. hexandra, P. scrobiculatum, E. colonum, E. indica* and *C. dactylon. L. hexandra, E. colonum* and *E. indica* are new host plant records. *M. leda ismene* fed on leaves of *L. panicoides*, a new host plant record. *E. xanthorrhoea* fed on *Cyperus rotundus* and *Vigna mungo* (new record). *P. pennatula* and *L. fasciata* fed on
leaves of *C. rotundus* which is a new host plant record for *L. fasciata*.

Life cycle of *P. naso* was studied when fed on leaves of *E. uniloides*, *L. panicoides*, *L. hexandra*, *P. proliferum*, *P. scrobiculatum*, *E. colonum* and *E. indica*. Ninety and 80% larval survival was observed respectively on *L. panicoides*, *L. hexandra*. Life cycle of *M. leda ismene* was studied on *L. panicoides* and that of *E. xanthorrhoea* on *V. mungo*. The larval survival was 80 and 100% respectively.

6.2. Natural enemies

6.2.1. Survey

6.2.1.1. Parasitoids: Fifteen Hymenopteran, three Dipteran and a nematode were reared from *P. naso*, out of which five are new host records. *P. mathias* parasitoids included seven Hymenopterans and two Dipterans, out of which two are new host records. *M. leda ismene* was parasitised by three Hymenopteran parasitoids, one being a new host record. *E. xanthorrhoea* parasitoids included four Hymenopteran and a Dipteran, out of which three are new host records. *P. pennatula* was parasitised by four Hymenopteran and a Dipteran parasitoids. Two Hymenopteran and a Dipteran parasitoids were reared from *L. fasciata*, which are new host records.
6.2.1.2. **Predators**: Six predator species were found, out of which one Hemipteran is found to be a predator for first time. Two Hemipteran, a Hymenopteran and two Araena (spiders) were found predating on *P. naso*. Two Hemipteran and a Hymenopteran predators fed on *P. mathias*. Two Hemipteran and an Araena predated *M. leda ismene*. Only Hemipteran predators fed on *E. xanthorrhoea*, *P. pennatula* and *L. fasciata*. Adults and nymphs of Hemipteran predators were observed in field both during rabi and kharif. During kharif, *Andrallus spinidens* was observed in field from September to November reaching peak population in 1st week of November. In rabi it was observed from April to 2nd half of May reaching peak in 1st half of May. *Amyotea* (*A*) *mala barica* population reached peak in 2nd half of October and it was observed in the field from September to November. In rabi, the peak population was observed during 2nd half of April. *Oxyope ratnac* was found in both the seasons. It acted as minor predator.

6.2.1.3. **Diseases**: *Serratia marcescens*, a red bacterium was isolated from cadavers of *P. naso* and *M. leda ismene* larva and pupae. Nuclear Polyhedrosis Virus (NPV) was isolated from *P. mathias* larva.
6.2.2. Parasitism by natural enemies

Maximum *P. naso* pupal parasitism was observed in April and November. The dominant pupal parasitoid was *Brachymeria albotibialis*. The dominant larval parasitoids were *Apanteles* sp., *Charops bicolor*, *Thecocercelia oculata*, *Halidaya* sp. Pupal parasitism was maximum in April and September to November in case of *P. mathias* also. There was only one larval parasitoid species. The dominant pupal parasitoid was *T. oculata*. No larval parasitoids were reared from *M. leda ismene* during the investigation. The pupal parasitoids were *B. lasus* and an unidentified Ichneumonid. Pupal parasitoids of *E. xanthorrhoea* also were active during April and November. The dominant egg parasitoid was *Telenomus* sp. which was active during March, September and October. *P. pennatula* was parasitised by a larval and two pupal parasitoids, the peak population being in March-April and October, respectively. *L. fasciata* larval parasitism reached peak in October and April and that for pupal parasitoids in April, October and November.

6.2.3. Biology of natural enemies

Biology of two egg parasitoids, three larval parasitoids, two pupal parasitoids and two predators were studied in the laboratory.
6.2.3.1. *Telenomus* sp. : The total life cycle of *Telenomus* sp. was studied on *E. xanthorrhoea* eggs. Rate of parasitism by this parasitoid was studied in the field by exposing laboratory laid eggs of *E. xanthorrhoea*. Maximum longevity of the parasitoid was seen when fed 10% aqueous solution of honey. It ranged from 119.30 hr to 168 hr as compared to 55.45 hr to 73 hr, when no food was provided and 65-80 hr when only water was provided. The parasitoid is solitary and emerges in morning hours. The host eggs parasitised by *Telenomus* sp. had one emergence hole.

6.2.3.2. *Trichogramma achaeae* : The total life cycle of *T. achaeae* was studied on eggs of *P. naso*. It ranged from 199-216 hr. The parasitism of *P. naso* eggs by *T. achaeae* varied from 55.4-81.6%. Adult longevity was 96-144 hr when fed aqueous solution of honey, 72-120 hr when fed on water and 72-96 hr when no food was provided. After parasitoid adults emerged, 2-5 emergence holes were seen in the chorion of parasitised host eggs.

6.2.3.3. *Apanteles* sp. *incogn* group *A.? colemani* : The life cycle was studied on *P. naso* larva. Developmental stages of the parasitoid were described in detail. The egg-larval period ranged from 146-168 hr. Pre-pupal period was 4-5 hr. The pupal period varied from 113 hr to 160 hr. Males and females mated immediately after emergence. Both sexes exhibit polygamous habit. The female parasitoid
readily oviposited on any part of the host larva except head. Parasitoid is gregarious in habit in larval stage. Female parasitoids out-numbered males. Effect of parasitism upon host body was described. Adult longevity was highest when fed 10% aqueous solution of honey as compared to no food and when fed water only.

6.2.3.4. *Bracon* sp. : The life cycle of *Bracon* sp. was studied on *P. naso* larva. It is an external parasitoid. The egg-larval period varied from 96 to 248 hr. Pupal period ranged from 96-144 hr. Pupation took place inside papery silken cocoons of light yellow colour. Adult longevity was highest when fed 10% aqueous honey solution. The effect of parasitism upon host larva was described.

6.2.3.5. *Charops* bicolor : *C. bicolor* is an internal larval parasitoid. The life cycle was studied on *P. naso* larva. Egg-larval period varied from 120-144 hr and pupal period from 120-168 hr. Adult longevity was highest when fed 10% aqueous solution of honey. Effect of parasitism upon host larva was described.

6.2.3.6. *Brachymeria albotibialis* : *B. albotibialis* was reared from *P. mathias* pupae. The incubation period was 24 hr. Larval period varied from 98-122 hr and pupal period from 264-360 hr. Parasitoid larvae were gregarious. The parasitoid adults emerged from host pupae by cutting
number of holes on host pupa. Adult longevity was highest when fed 10% aqueous solution of honey.

6.2.3.7. *Xanthopimpla immaculata*: *X. immaculata* life cycle was studied on *P. naso* pupa. Total life cycle varied from 216-264 hr.

6.2.3.8. *Andrallus spinidens*: The incubation period for *A. spinidens* ranged from 29-264 hr. There were five nymphal instars. The total nymphal period ranged from 288-384 hr. Duration of nymphal stages varied with change in season and food. The total number of host larvae sucked by a single predator nymph during its nymphal life varied from 43-57 hr. The food consumption progressively increased from 2nd instar onwards. The maximum food was consumed by the 5th instar nymph. In general mated females consume more than unmated male and female. Both nymphs and adults prey upon the host larvae and pupae and at times adults. The feeding on pupa and adult has been reported here for the first time. The predator preferred host larva over host pupa and adults. Hairless larvae are preferred over the hairy larvae. Adult longevity was almost the same when fed either water alone or when no food was provided. Maximum longevity was observed when fed both plant sap and insect host.

Mode of attack and toxic effect of attack has been described. Males and females occur in the field in 1:0.77
ratio. They mate several times during their lives. Females lived more than males. A. spinidens devours about 178.2 to 283.2 larvae in its life time, adding average consumption of 47.2 larva during nymphal stage. It can also survive on plant sap in the absence of insect food.

The natural enemies like Telenomus lucullus and Trissolcus sp. as egg parasitoids of the bug limit its population in the field.

6.2.3.9. Amyotea (A) malabarica: A. (A) malabarica has been recorded as a predator of rice pests for the first time. Its host range was studied. The predator also fed on beetles, grass hoppers, spiders and hairless as well as hairy larva in laboratory. There are five nymphal instars. Incubation period varied from 238-308 hr. It also varied with the season. Total nymphal period varied from 461-551 and 594-654 hr in rabi and kharif, respectively. Total number of host larvae sucked by a single predator nymph during its nymphal life varied from 28-33. The food consumption progressively increased from 2nd instar onwards. In general the females consume more food than males. Mated males and females consumed more food than unmated males and females. The nymphs in first instar are gregarious. From 3rd instar, the nymphs attack host larvae and suck the contents of host larvae. The mode of
attacking the host is similar to *A. spinidens*. At the time of attack, the bugs inject some toxic substances into the host body, which not only paralyses it, but also eventually kills it. Males and females mate several times during their life. Males have shorter life span than that of females.

No parasitoids were reared from this predator. However, cannibalism was observed at the time of food shortage. Seasonal variation in the colour i.e. Melanization of last nymphal instar and adult was observed in *A. (A) malabarica*.

6.2.3.10. *Oxyopes ratnae*: *O. ratnae* was a minor predator. It attacked larvae of *P. naso* and *M. leda ismene*. The host larvae were captured by the predator with the help of its chelicerae usually around the neck. Then with the help of mandibles the host skin was ruptured, possibly some poisonous secretion was secreted to paralyse the host. Subsequently the predator ruptured the host larval body through the anal region. It fed either by chewing the host or sucking the haemolymph.

6.2.4. Hyperparasitoids

Hyperparasitoids were studied for the natural enemies of the test pest species. Seven hyperparasitoids, out of which five new host records were reared from primary parasitoids of *P. naso* (Table 89) in addition to one
hyperparasitoid from *P. mathias* (Table 89). Two hyperparasitoids (new host records) were reared from *A. spinidens* eggs. Total life cycle and adult longevity of *T. lucullus* and *E. parnarae* were studied.

6.2.5. Extent of parasitism and role of natural enemies

All the six pest species studied generally maintained lower populations during the study period and did not require application of any control measures. The largest population each year was that of *Parnara* spp. followed by *M. leda ismenia*. Other pest species were found always in negligible numbers. Role of natural enemies in keeping the pest population under check is discussed pest species-wise.

6.2.5.1. *P. naso*: The natural enemy complex active against this pest included 2 egg, 10 larval, 2 larva-pupal, 4 pupal parasitoids, 1 unidentified nematode, 1 pathogen and 5 predators. Though the pest was attacked in all stages (i.e. egg, larva and pupa), the maximum mortality took place in larval stage. The predators also fed on this pest. The hyperparasitoids reduced the effectivity of the larval parasitoids.

6.2.5.2. *P. mathias*: There are 2 egg, 1 larval, 1 larva-pupal, 5 pupal parasitoids, 1 pathogen and 3 predators,
which were active during both the seasons. Though the pest was attacked in all stages, the highest mortality was due to pupal parasitoids. *A. spinidens* was the dominant predator acting against this pest species.

6.2.5.3. *M. leda ismene* : The parasitoids activity against this pest was noticed for comparatively lesser duration as compared to pest activity. The natural enemies include 1 egg, 2 pupal parasitoids, a pathogen and 3 predators. Mortality in this species was chiefly due to disease causing microorganisms i.e. *S. marcescence*. *A. spinidens* was also active against this pest in the field.

6.2.5.4. *E. xanthorrhoea* : The natural enemies that were active included 1 egg, 2 larval, 2 larva-pupal parasitoids and 2 predators. Though the pest was attacked in all the three stages, the egg stage was parasitised the most. No hyperparasitism was recorded. The predators fed the pest in negligible numbers, as it was not a preferred host.

6.2.5.5. *P. pennatula* : There are 2 eggs, 2 larval, 1 pupal parasitoid and 2 predator species active against *P. pennatula*. The pest mortality was maximum in egg stage.

6.2.5.6. *L. fasciata* : The natural enemies active against this pest included 1 larval, 1 larva-pupal, 1 pupal parasitoids and 2 predators.
The maximum pest mortality was due to larval parasitoids. No hyperparasitoids were reared.

In case of *E. xanthorrhoea*, *P. pennatula* and *L. fasciata*, biotic mortality factors appear to keep the pest under check. *M. leda ismene* populations appeared regulated by pupal parasitoids and diseases. In case of *P. naso* and *P. mathias*, population regulation, predators may be equally important as the parasitoids are.

All the test pest species occur both in kharif and rabi. The largest natural enemy complex was active against *P. naso* and *P. mathias*. Certain natural enemies reared from *P. naso* like *Apanteles* sp. *incogn* group *A.? colemani*, *C. bicolor*, *Bracon* sp., *Halidaya luteicornis*, *Microcentrus* sp. (larval parasitoids) and *Xanthopimpla kandiensis* (pupal parasitoids) were not reared from *P. mathias*. Similarly pupal parasitoids of *P. mathias* like *Brachymeria albotibalis* and *Ischnojoppa luteator* were not reared from *P. naso*. For both the pests the mortality observed was obtained due to natural enemies and with peak natural biotic mortality the pest populations declined. The hyperparasitoids limited the populations of the parasitoids of *P. naso* more as compared to *P. mathias* as a number of hyperparasitoids were obtained from primary parasitoids of *P. naso*. Predators were the chief factors in declining the pest population, when the parasitoids were low in number.
In case of *M. leda ismene*, the natural pest population always remained low in fields. Mortality due to parasitoids was not really high and in fact, the larval stages of *M. leda ismene* were not attacked by parasitoids. This perhaps got compensated by high incidence of diseases at larval and pupal stages (Table 88) which were responsible for low pest survival. There was no interaction from hyper-parasitoids which allowed them to play a more effective role.

*E. xanthorrhoea, P. pennatula* and *L. fasciata* maintained lower populations in the field, and at the same time the natural enemies were also less active. Higher egg mortality due to parasitoids in first two pests was the chief cause of low larval population, on which the larval and pupal parasitoids were active. Possibly apart from the natural enemies, other biotic factors like non-preference for crop, or abiotic factors may also be responsible for keeping the pest populations at low level.