EPILACHNA BEETLE COMPLEX IN VEGETABLES

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled "**Epilachna beetle complex in vegetables**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title, of any other university or society.

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CERTIFICATE

Certified that the thesis entitled "**Epilachna beetle complex in vegetables**" is a record of research work done independently by **Ms.S.Sreekala**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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To

the lively memories of

Rao Sir

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Introduction

INTRODUCTION

The lady bird beetles belonging to the family Coccinellidae possess considerable economic importance due to their diverse feeding habits. The members of the subfamily Epilachninae, commonly known as the epilachna beetles are phytophagous causing serious damage to crops mainly belonging to the families Solanaceae, Cucurbitaceae and a few crops in Leguminosae while the members of the other subfamilies are mostly predaceous and aid in biological control of crop pests.

The epilachna beetles are distributed in the tropical and subtropical regions of the world. About one sixth of the described species of coccinellids belong to the subfamily Epilachninae. Nearly 600 phytophagous species placed in 30 genera have been described. Both the grubs and adults skeletonize the leaf surface in a characteristic pattern, by scraping the chlorophyll tissues, leaving the veins and veinlets intact.

The members of Epilachninae are readily recognised by certain characteristics such as hemispherical shape, pubescent dorsum, eleven segmented capitate antennae, seruciform maxillary palpi and cryptotetramerous tarsi. They are usually small to medium sized reddish-brown beetles with black spots or bands on the elytra. The adults possess remarkable uniformity in their external appearance. Due to the apparent resemblance among individuals belonging to the different species of this subfamily, there is a lot of confusion regarding the identity of the species. Earlier workers considered the number of elytral spots as a basis for

identification of epilachna beetles. As a result, the records of occurrence of Epilachninae is shrouded with perplexities arising out of wrong identities.

For many years there was an assumption that only two species, namely *Epilachna vigintioctopunctata* and *Epilachna dodecastigma* occurred as major pests of both solanaceous and cucurbitaceous crops depending on whether they had twenty eight or twelve spots on the elytra. Husain and Shah (1934) first suggested that these two species were found only on brinjal and the one on cucurbits was a different species. Basavanna (1954) followed by Krishnamoorthy (1956) confirmed that the species feeding on solanaceous plants did not feed on cucurbits and vice versa. The identification based on elytral spots being incorrect, the genitalial features are being used as key characters for establishing the correct identities of the species. Though, the species identification based on genitalia is getting a sound base, the generic concepts are still very vague. Till date the taxonomy of these beetles is in a muddled state. Study of the biology will be helpful to generate informations on the nature of affinity between these beetles and their respective host plants.

With this background the present studies were undertaken with the following objectives.

1) to determine the correct taxonomic identity of the epilachna beetles infesting brinjal, bittergourd and cowpea
2) to study the biology of the epilachna beetles on these host plants
3) to study the morphology and morphometrics of these beetles and
4) to ascertain the natural enemies associated with these beetles.

Review of Literature

REVIEW OF LITERATURE

The epilachna beetles, unlike the other lady bird beetles are quite unique in being phytophagous. The relevant literature relating to the aspects of taxonomy, host range, morphology, biology and natural enemies are reviewed in this chapter.

2.1 Taxonomy

The subfamily Epilachninae belongs to the family Coccinellidae which comes under the superfamily Cucujoidea.

The majority of coccinellids are carnivorous with, the exception being epilachnines and psylloborines, the former feeding on plant tissues and the latter on fungal spores. The epilachna beetles are important pests of cultivated crops belonging to the families, Solanaceae, Cucurbitaceae and Leguminosae.

2.1.1 Classification of Coccinellidae

Korchefsky (1932) classified Coccinellidae into three subfamilies, Epilachninae, Lithophilinae and Coccinellinae. Of these, Epilachninae include ten genera, Lithophilinae consist of a single genus and Coccinellinae contain two hundred and thirty five genera.

Based on the comparative morphology of the larvae and adults, Sasaji (1968) recognised six subfamilies and nineteen tribes under Coccinellidae. These are:

Subfamily	Tribes
Sticholotinae	Sukunahiconini, Serangiini, Sticholotini, Shirozeullini
Scymninae	Stethorini, Scymnini, Ortalinii, Aspidimerini, Hyperaspini
Chilocorinae	Telsimiini, Platynaspini, Chilocorini
Coccidulinae	Lithophilini, Coccidulini, Exoplectrini, Noviini
Coccinellinae	Coccinellini, Psylloborini
Epilachninae	Epilachnini

The subfamily Epilachninae are phytophagous and differ in this habit from the other coccinellids. About one sixth of all the described species of the coccinellids are classified under Epilachninae.

2.1.2 Classification of Epilachninae

The subfamily Epilachninae include a single tribe Epilachnini in which all the genera are placed. The genus *Epilachna* was first proposed by Chevrolat (1837). Korchefsky (1931) in his catalogue listed 451 species under Epilachninae under a single genus *Epilachna*. The most comprehensive work on Epilachninae till date is by Dieke (1947). He included eight genera under Epilachninae which are *Epilachna*, *Afidenta*, *Afissa*, *Subcoccinella*, *Cynegetis*, *Epiverta*, *Ballida* and *Microlasia* and used the nature of the sixth abdominal segment of female, tarsal claws, epipleurae and punctuation of the elytra to distinguish between these genera.

Dieke (1947) described and illustrated 105 species of epilachna beetles coming under these genera.

Kapur (1955) proposed two new genera *Afissula* and *Afidentula* under Epilachninae.

Li and Cook (1961) erected a new genus *Henosepilachna* and separated it from *Epilachna* by the presence of basal tooth on the tarsal claw and a divided sixth abdominal sternite of female in the case of the former one. They classified the tribe Epilachnini into three genera, *Epilachna, Henosepilachna* and *Afidenta* and described thirty species. *Afissa* and *Solanophila* were treated by them as synonyms of *Epilachna*. Sasaji (1971) accepted the genus *Henosepilachna* Li and differentiated it from *Epilachna* by the presence of a basal tooth on the tarsal claw of *Henosepilachna*.

Gordon (1975) redefined *Epilachna* of the western hemisphere in which work he ignored the controversial claw character and the nature of the sixth abdominal sternite of female hitherto used to differentiate *Henosepilachna* from *Epilachna*. He considered *Henosepilachna* as a synonym of *Epilachna*. Richards (1983) reported that the characters on which the genus *Henosepilachna* was erected were not consistent and hence *Henosepilachna* was regarded by him as a synonym of *Epilachna* chevrolat.

Anand *et al.* (1988) listed the Indian Epilachninae under five genera. They included two species under the genus *Afidenta* Dieke, three species under *Afidentula* Kapur, four species under *Afissula* Kapur, fifty seven species under *Epilachna* chevrolat and eight species under *Henosepilachna* Li.

2.1.3 Genitalia of Epilachninae

In earlier literature, the identification of the species was based on superficial characters such as, colour and spot pattern. But later, these characteristics were found inadequate and therefore taxonomic studies were based on the structure of genitalia. The characterisation of the genitalia and its illustration was adopted by several workers for taxonomic studies in Epilachninae.

Weise (1901) proposed a new species, *Epilachna misera* Weise on the basis of its genitalia which was later transferred to the genus *Afidenta* by Bielawski (1961). Pradhan (1935) described and illustrated the male and female genitalia of *Epilachna indica*. Dieke (1947) studied and illustrated the genitalia of 105 species of epilachna beetles.

Bielawski (1957) characterised the genitalia of five species, *E. sparsa* Herbst, *E. keiseri* Bielawski, *E. quinta* Dieke, *Afidenta herbigrada* (Mulsant) and *Afissa undecemspilota* (Hope). Kapur (1959) described *E. implicata* Mulsant which was till then regarded as a variety of *E. vigintioctopunctata* Fabricius from the host plant *Coccinea indica* and figured the genitalia of the species. Lal and Kanakavalli (1960) studied the genitalia of twenty nine species belonging to twenty genera of Coccinellidae and described a new species of *Epilachna*.

Bielawski (1961) described and illustrated the genitalia of *E. pytharga* Dieke, *Afissa formosana* Weise, *Afissa alternans* (Mulsant), *Afissa decipiens* (Crotch) and *Afidenta misera* (Weise). Kapur (1961) gave descriptions on the genitalia of *E. indica*.

Bielawski (1965a) accepted the new genus *Henosepilachna* proposed by Li and Cook (1961) and described the genitalia of twelve species under this genus. Bielawski (1965b) described the genitalia of four new species of *Afidentula* Kapur from New Guinea. Bielawski (1965c) presented a study on the genitalia of fifteen Indo Malayan and Australian species of epilachna beetles with the description of two new species.

Kapur (1966) studied the Coccinellidae of Andamans and gave an account on the genitalia of nine species of epilachna beetles. He proposed to regard *E. sparsa* as a synonym of *E. vigintioctopunctata*. Miyatake (1967) described and illustrated the genitalia of *E. gibbera* Crotch and *E. marginicollis* (Hope) from Nepal. Bielawski (1972) gave the genitalial descriptions of *H. sparsa orientalis* (Dieke), *H. vigintioctomaculata coalescens* (Mad), *H. vigintioctopunctata* (F.), *H. ocellata* (Redt.), *Afidenta misera* (Weise), *E. dumerili* Muls., *E. maculivestis* Muls., *E. nepalensis* Kapur, *E. militaris* (Dieke) and *Afissula rana* Kapur from Nepal.

Pang and Mao (1977) studied nineteen species of the epilachna beetles belonging to the genera *Epilachna*, *Henosepilachna*, *Afidentula* and *Afissula* of which six are new species. Singh and Garg (1978) described the female reproductive system and genitalia of *E. vigintioctopunctata* Fabricius. Richards (1983) studied the genitalial characteristics of *E. vigintiocto-punctata* complex in Australia and he determined the identities of three different species which have been incorrectly named as *E. vigintioctopunctata*.

Gordon (1985) described three new species of *Epilachna* from Columbia. Miyatake (1985) described *H. vigintioctopunctata* (Fabricius), *H. pusillanima* (Mulsant), *H. kathmanduensis*, *Afidenta misera*, *Afissula rana* Kapur, *Afissula mysticoides* (Sicard) and six species of *Epilachna* from Nepal. Fuersch (1988) gave

the key to the species of African Epilachninae. Katakura *et al.* (1988) recorded four species of epilachna beetles from Indonesia.

Singh and Singh (1990) reported four new species of *Epilachna* namely, *E. shilliensis*, *E. convextata*, *E. septemocellata* and *E. crecentomaculata* and illustrated their genitalia. Li (1993) presented a review of Australian Epilachninae. Katakura *et al.* (1994) recorded twenty two Indonesian and Japanese species of epilachna beetles and described their genitalial characters.

2.2 Host range of Indian Epilachninae

In India, the first record of an epilachna beetle attacking crops was by Cotes (1891) who reported *E. vigintioctopunctata* feeding on brinjal in West Bengal. Subramaniam (1923) recorded the host plants of *E. vigintioctopunctata* and *E. dodecastigma* as *Solanum nigrum*, *S. tuberosum*, *S. melongena*, *Datura*, *Momordica* and pumpkin. Trehan and Pingle (1949) reported *E. 28punctata* and *E. dodecastigma* as pests of brinjal and cucurbits.

For many years, there was an assumption that only two species, *E. vigintioctopunctata* and *E. dodecastigma* were involved as the major pests of the solanaceous and the cucurbitaceous plants based on whether they had 28 or 12 spots on the elytra, respectively. Basavanna (1954) confirmed that two distinct species of *Epilachna* were involved, one feeding only on solanaceous and the other on cucurbitaceous plants. His observations with regard to feeding tests and differences in the male genitalia proved that the two species exhibited definite specificity with regard to the choice of their hosts. The one confined only to the solanaceous plants was identified as *E. vigintioctopunctata* (Fabr.) while the identity of the other one restricted to cucurbitaceous plants was not determined.

Krishnamoorthy (1956) also confirmed that the species feeding on solanaceous plants did not feed on cucurbits and vice versa.

Trehan (1956) recorded *E. dumerili* as a minor pest of cucurbits. Murthy (1958) reported the unusual mode of feeding of *E. sparsa* on brinjal fruits.

Kapur (1959) recorded *E. implicata* as a pest on *Coccinea indica*. Batra and Jangyani (1960) reported *E. 28punctata* in *Solanum sodamemum*. Mathur and Srivastava (1964a) reported the damage by grubs and adults of *E. vigintioctopunctata* on leaves of *S. indicum* and *S. nigrum*. Mathur and Srivastata (1964b) also reported *E. vigintioctopunctata* as a defoliator of some solanaceous medicinal plants such as, *Datura, S. aviculare* and *Withania somnifera*.

Kapur (1966) indicated that *E. septima* Deike was the species feeding commonly on bittergourd and he also validated *E. vigintioctopunctata*, making *E. sparsa* Herbst a synonym, based on his studies on specimens from the type localities of both. He recorded *E. dodecastigma* as a pest of cucurbits especially *Luffa cylindrica* in north-eastern India, *E. septima* as a pest of *Momordica charantia, E. vigintioctopunctata* as a pest on solanaceous crops and *Afidenta mimetica simplex* Dieke as a pest of beans. Feeding activity of *E. vigintioctopunctata* on *Luffa aegyptiaca* was reported by Krishna and Sinha (1969).

Nagaich *et al.* (1972) reported that the potato virus X and S were transmitted by *E. ocellata*. Venugopal and David (1972) reported the occurrence of *E. delesserti* Guer. on *Trichosanthes cucumerina*. *Epilachna gangetica* (Wse) was recorded as a new pest on brinjal grown near *S. verbascifolium* by Siddappaji (1973).

Mohanasundaram and Uthamasamy (1973) studied the host range of epilachna beetles and reported that the grubs and adults collected from brinjal did not feed on the leaves of bittergourd and *vice versa*. Even the first instar grubs of the epilachna beetle from brinjal immediately after hatching did not feed on the leaves of bittergourd and the one from bittergourd did not feed on brinjal. Thus host specificity was noticed among the beetles. From a study of the genitalia, they confirmed that the species on brinjal was *E. vigintioctopunctata* while the one on bittergourd was *E. implicata*.

Mandal (1974) conducted a study on the host preference of *E. vigintioctopunctata* and the decreasing order of preference was potato, tomato, brinjal, cucumber and bean among vegetables and *S. nigrum*, *S. xanthocarpum* and *Datura* spp. among medicinal plants. Feeding activity of *E. vigintioctopunctata* Fabricius on the fruits of brinjal in the characteristic ladder like manner was reported by Rai and Gopal (1975).

Nigam and Gupta (1977) studied the orientational response of adult *H. sparsa* Herbst (= *E. vigintioctopunctata*) towards solanaceous and cucurbitaceous plants. They concluded that *H. sparsa* showed good orientational response towards the leaves of only five plants, all belonging to solanaceae. The order of preference was *S. melongena, S. indicum, S. nigrum, Datura alba* and *S. tuberosum*.

Narang and Ramzan (1984) reported *Amaranthus viridis* as a new host plant of *H. vigintioctopunctata*. They reported that *Amaranthus viridis* grown near *S. nigrum* was infested in Punjab and the leaves showed characteristic feeding injury. Ganga *et al.* (1985) reported that *E. septima* when fed on *Trichosanthes anguina*, the rate of conversion of ingested food was more than on *Momordica charantia* and *Luffa acutangula*.

Singh and Mukherjee (1987) investigated the food plant range, survival and development of *H. dodecastigma* (Weid.) and *H. vigintioctopunctata* (F.). It was revealed that emergent grubs of *H. dodecastigma* accepted only cucurbits and it could not survive on any of the food plants belonging to solanaceae. *Henosepilachna vigintioctopunctata* failed to survive on cucurbit plants and survived well on various solanaceous plants.

Anand *et al.* (1988) presented a check list of Indian Epilachninae for 74 species under five genera. These included two species, *Afidenta misera* and *Afidenta minima* in the genus *Afidenta*, three species under *Afidentula*, four species under *Afissula*, fifty seven species under *Epilachna* and eight species under *Henosepilachna* which included *H. vigintioctopunctata* and *H. septima*. Their food plants and distribution in different states of India are listed.

Lal (1990) studied the food preference of *E. ocellata* and reported that the food preference was in the preferential order, potato, tomato, brinjal, okra, cucumber, radish, capsicum, french bean, green gram and black gram. Yadav and Rizvi (1994) recorded *H. 12punctata (E. duodecimpunctata)* as a major pest in *Syzigium cumini* and *Morus alba*.

2.3 Morphology

2.3.1 Adult beetle

Krishnamurti (1932) studied the morphological characters of *E. vigintioctopunctata* adult and recorded that the presence of 28 dark roundish patches on the dorsal surface of elytra rendered the identity of the beetle. He studied the characters of antennae, mouth parts, shape and punctuation of pronotum, shape and maculation of elytra and tarsal claws. Dieke (1947) gave morphological

description of adults of the epilachna beetles. The morphological characters used by him to differentiate between the species were the shape of the mandibles, structure of tarsal claws, tip of the elytra, maculation of pronotum, elytral spot pattern, shape of the first abdominal sternite etc.

Basavanna (1954) studied the typical number of elytral spots, their distribution and arrangement on the dorsal surface of the beetle. He reported the representative variations in the number of spots in beetles on solanaceous and cucurbitaceous host plants. Wesley (1956) carried out studies on spot variation in epilachna beetles and concluded that 12-spotted and 28-spotted are one species and designated it as 12-28 *Epilachna* sp.

Lall and Mandal (1958) noted the inheritance of spot variation in epilachna beetles. They could obtain nine types of spot variations by the cross breeding between the 12-spotted females and the 28-spotted males. The spot variants were 12-spotted, 14-spotted, 16-spotted, 18-spotted, 20-spotted, 22-spotted, 24-spotted, 26-spotted and 28-spotted ones. They concluded that the nine groups of the epilachna beetles were not different species but were variants of cross breeding between 12-spotted and 28-spotted beetles in nature.

Katakura (1973) reported the geographical polymorphism of *E. vigintioctomaculata* and *E. pustulosa*. Katakura (1974) reported two distinct groups of the epilachna beetles, *H. vigintioctomaculata* and *H. pustulosa*, based on his studies on the morphology and distribution of the forms of *H. vigintioctomaculata* complex. The characters used by him to distinguish between the two groups were the colouration of hind leg, shape of elytral maculation, shape of spermatheca, colour and tint of elytra etc.

Abbas *et al.* (1988) reported the geographical variation in elytral spot pattern of *E. vigintioctopunctata* based on which, the populations were segregated into four groups. The extremes were group I and group IV, the former occurred in coastal plains and inland low lands and the latter was confined to highlands. The group IV beetles had many more non-persistent spots that confluence with larger body size and advanced melanism than group I. The spot variation represented a complicated intraspecific variation, rather than two distinct sibling species.

2.3.2 Larvae

Kapur (1950) described the external morphology of the larvae of Epilachninae. He presented a key to the genera *Epilachna, Afissa, Chnootriba, Cynegetis, Subcoccinella* and *Merma*. The larval characters of *E. borealis, E. varivestis, E. argus, E. eusema, E. vigintioctopunctata, E. chrysomelina* and *E. dentulata* were studied. Gage (1952) dealt in detail with the morphology of the larvae of Coccinellidae. Kamiya (1965) gave a comparative study on the morphology of larvae of Coccinellidae.

Based on the larval morphology studies of *H. ocellata, H. vigintioctopunctata, H. vigintioctomaculata* and *Afidenta misera*, Singh and Phaloura (1995) stated that the presence of setulae on the scoli of *Henosepilachna* was exclusive to the genus and could prove to be a taxonomic character at the generic level.

2.3.3 Pupae

The structure of the pupae of 32 known genera and 49 species from 11 tribes of Coccinellidae was studied and described by Phuoc and Stehr (1974). They

presented keys to the known subfamilies and furnished the tribal relationship within the family based on the pupal characters.

2.4 Morphometrics

Krishnamurti (1932) observed the size of the adult beetle, different instar grubs and pupae of *E. vigintioctopunctata*. Kapur (1950) has given the measurements of the length and breadth of different instar grubs of epilachna beetles. Phuoc and Stehr (1974) described the length and width of pupae of epilachna to be 7.5-8 mm and 4.5-5 mm respectively. Das and Das (1976) recorded the length and breadth of egg, different instar grubs, prepupa and pupa of *E. vigintioctopunctata*. Dhingra *et al.* (1983) recorded the measurements of different life stages of *E. ocellata* on bittergourd.

2.5 Biology

2.5.1 Solanaceous hosts

Krishnamurti (1932) studied the life history details of *Epilachna* sp. on potato and recorded the egg, grub and pupal periods as 3, 13 and 5 days respectively. Patel and Basu (1948) recorded the bionomics of *Epilachna* spp. in brinjal and studied the life history details.

Thomas *et al.* (1969) studied the host-biology relations of *E. vigintioctopunctata* on solanaceous plants including brinjal, tomato, *Solanum insanum*, *Physalis maxima* and *Datura stramonium*. They reported that host plants had significant effect on larval duration and percentage survival of the grubs. No definite association existed between the type of food and duration of pupae. *Physalis maxima* appeared to be the most suitable host and tomato the least.

Mandal (1975) studied the duration of different stages and life cycle of *E. vigintioctopunctata* Motsch during different months under indoor condition. He recorded that during April-May, the incubation period, larval period, pupal period and life cycle were observed to be 3, 11.5 ± 0.5, 3 and 17.5 ± 0.5 days respectively, when the average temperature and relative humidity were 88.3 ± 4.65 F and 57.35 per cent respectively. During December-January, the incubation, larval and pupal period and life cycle were 7.5 ± 1.5, 29 ± 1, 10 and 46.5 ± 2.5 days respectively when the temperature was 65.5 ± 3.79 F and relative humidity was 71.25 per cent. He reported that the duration of different life stages was inversely proportional to temperature of the rearing room and directly proportional to the relative humidity.

Das and Das (1976) recorded the life cycle of *E. vigintioctopunctata* in brinjal. They reported the incubation, first instar, second instar, third instar, fourth instar, fifth instar, prepupal and pupal periods as 98, 58, 63, 75 95, 48, 27 and 70 hours respectively.

Dhamdhere *et al.* (1990) recorded the biology of *E. vigintioctopunctata* Fabr. on six food plants and found tomato and brinjal as the most suitable host plants.

2.5.2 Cucurbitaceous hosts

Krishnamurti (1932) studied the life history details of *Epilachna* sp. on cucurbits and recorded the egg, grub and pupal periods as 2, 30 and 4 days respectively. Aly and Ghabn (1951) recorded the biology of *E. chrysomelina* on cucurbits. The biology of *E. chrysomelina* was also studied by Badawy (1965) on cucurbits and recorded the duration of different developmental stages, the egg laying behaviour and the number of generations of the beetle.

Koshta and Dhamdhere (1981) noted the biology of *E. ocellata* Redt. on bittergourd and recorded the duration of different life stages and longevity of adult beetles. The biology of *E. ocellata* Redt. on bittergourd was studied by Dhingra *et al.* (1983) and reported that the incubation, larval and pupal periods lasted for 3.6 to 5.6, 12.5 to 15.4 and 5.14 to 7.32 days respectively. The total life cycle from egg to adult took 21.3 to 28.3 days. Longevity of male and female beetles varied from 20.0 to 28.6 and 27.3 to 35.0 days respectively. The pest completed four generations during July to November and it underwent hibernation in the adult stage.

Richards and Filewood (1990) studied the influence of cucurbitaceous weeds on the bionomics of *E. cucurbitae* Rich. and reported that the fecundity was reduced and less than half the number of generations were produced in a year compared with the bionomics on crop plants. The impact of food quality and mating on the reproductive performance of *E. vigintioctopunctata* Fabr. was studied on *Luffa aegyptica* by Sinha and Chandra (1990).

Abdin and Siragelnour (1991) reported the incubation period, larval period and pupal period of *H. elaterii* on cucurbits to be 5 ± 0.45, 13 and 6.47 ± 0.33 days respectively. Tripathi and Misra (1991) studied the effect of temperature on the development of *E. dodecastigma* on the leaves of ghiatorai and the duration of development was found to be the longest at 20°C and the shortest at 40°C.

Takeuchi (1994) compared the life cycle of *E. admirabilis* on different host plants and found that the larval and pupal periods were shorter in beetles fed with *Trichosanthes kirilowii* than those fed with *T. ovigera*.

2.6 Natural enemies

Barlow (1896) reported the occurrence of parasites on *Epilachna* for the first time in India. Krishnamurti (1932) stated that the third and fourth instar larvae of *Epilachna* were attacked by a parasite which was later identified as *Pediobius foveolatus*. He also recorded *Tetrastichus ovulorum* parasitizing the eggs of the beetle, *H. vigintioctopunctata* on potato. Fresh eggs not more than 1-2 days old were preferred by the parasite. The percentage of parasitisation was 2.45 in summer and 1.5 during monsoon. He also gave notes on the life history of the parasite. Ayyar and Margabandu (1934) reported *Pleurotropis foveolatus* Crawford and *Pleurotropis epilachnae* Rohwer from the grubs of epilachna beetles.

Lal (1946) gave some biological information on the life history and parasitism of *Pleurotropis foveolatus* and recorded that the fourth instar larvae of epilachna beetles were parasitised by the female parasite. Each female parasitised 8-10 larvae on an average. The parasitised larvae turned brown and died in 5-6 days. The percentage of parasitism ranged between 3 to 16.9. Lal and Gupta (1947) reported *Pleurotropis* sp. from epilachna grubs.

Appanna (1948) reported *Pleurotropis foveolatus* from the grubs and pupae of *E. vigintioctopunctata*. He gave a description of the parasite, symptoms of parasitisation, field incidence, age of host suitable for parasitisation, number of parasites per host and its life cycle. Bhatnagar (1952) described *Solindenia vermai*, a eupelmid from the grubs of *Epilachna* sp. Krishnamurti and Usman (1954) listed *Pleurotropis foveolatus* as a larval parasite and *Tetrastichus ovulorum* as an egg parasite of *Epilachna* sp. Puttarudriah and Krishnamurti (1954) reported that the insecticidal control of *Epilachna* was found inadvisable when the natural incidence of parasites was high.

Rao (1957) described a eulophid, *Chrysocharis johnsoni* from larvae of *E. 24-punctata*. Usman and Thontadarya (1957) showed for the first time the existence of a complex of atleast seven species of parasites in the primary, secondary and tertiary roles on the grubs of the epilachna beetle. *Pleurotropis foveolatus* Crawford, *Pleurotropis epilachnae* Rohwer and *Tetrastichus* sp. were described as primary parasites, *Tetrastichus* also as a secondary parasite through *Pleurotropis foveolatus*. *Pleurotropis* sp. and *Aximopsis* sp. (Eurytomidae) were obtained as secondary parasites through *Tetrastichus* sp. and *Pediobius foveolatus* respectively. Lall (1961) studied the biology of *Pediobius foveolatus*. Mating occurred in the parasite soon after emergence from the grubs and lasted 15-20 seconds. The highest percentage of parasitism observed was 37.8 during November and lowest 9.03 during April.

Sengupta and Satpathy (1962) reported heavy parasitisation of the grubs of *E. vigintioctopunctata*. They reported that *Pleurotropis* was a junior synonym of *Pediobius*. The details on life history, biology, symptoms of parasitisation, field incidence and age of the host suitable for parasitisation were given. Usman *et al.* (1964) established the presence of a complex of seven parasites of *E. vigintioctopunctata*. Angalet *et al.* (1968) stated that the introduction of *P. foveolatus* and *T. ovulorum* from India to U.S.A. as larval and egg parasitoids against *E. varivestis* was found very potential in controlling the pest.

Richerson (1970) listed all parasites recorded for Coccinellidae from the world. Mathew and Abraham (1973) studied the biology of *Chrysocharis johnsoni*, a larval parasite of *E. vigintioctopunctata*. Azam *et al.* (1974) recorded *Uga menoni* parasitising the larvae/pupae of *E. vigintioctopunctata*. Schaefer (1983) published a world list of the natural enemies and host plants of species in the Epilachninae. Abbas and Nakamura (1985) reported that the egg parasitoid *Tetrastichus* caused

41.1-64.2 per cent of egg mortality and the larval-pupal parasitoid *P. foveolatus* killed upto 59.1 per cent of the pupae of *Epilachna* sp.

Nong and Sailer (1986) studied the reproductive biology of *P. foveolatus* Ohgushi (1988) reported the earwig *Anechura harmandi* as an egg predator of *E. niponica*. Dhamdhere and Dhingra (1990) reported the parasitoids, *T. ovulorum*, *P. foveolatus* and *Uga menoni* from *E. ocellata*.

Garcia and Graziano (1990) described a tachinid parasite *Aplomyiopsis epilachnae* from the pupae of *E. varivestis*. Paik (1991) reported *P. foveolatus* parasitising the grubs of *E. vigintioctopunctata*. Weidenmann and O'Neil (1991) recorded the pentatomid *Podisus maculiventris*, a predator of the grubs of *E. varivestis*.

Shing and Wang (1992) recorded the biology of *P. foveolatus*. It parasitised all the larval stages of *H. vigintioctopunctata*, but preferred later instars. When provided with fourth instar larvae, female wasps parasitised on an average of 6.21 larvae and produced 74.57 offspring. The maximum natural parasitisation occurred in June (28.47%) on potatoes and in July (64.5%) on *Solanum nigrum*. Qian *et al.* (1992) described *Uga hemicarinata*, parasitising the grubs of *H. vigintioctomaculata*.

Mehta *et al.* (1993) reported that *P. foveolatus* and *Tetrastichus* sp. were found parasitising the larvae of *H. vigintioctopunctata*. Schroder and Stamp (1993) reported the mite (*Coccipolipus epilachnae*) Smiley which is ectoparasitic on *E. varivestis*. Nandakumar and Saradamma (1996) reported *Tetrastichus* sp. *Chrysocharis johnsoni*, *Tetragnatha* sp., *Oxyopes* sp. and orb-web spiders as the natural enemies of *E. vigintioctopunctata*.

Materials and Methods

MATERIALS AND METHODS

The objectives of the studies on the epilachna beetle complex occurring in vegetables were to investigate the taxonomy, morphology, biology and natural enemies associated with epilachna beetles attacking the vegetables namely, brinjal, bittergourd and cowpea. This study was conducted at the College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during 1995-1997.

3.1 Source of the materials

Field surveys were carried out in three districts of Kerala, namely, Thrissur, Palakkad and Malappuram for the collection of epilachna beetles from brinjal, bittergourd and cowpea. From each district, six Krishi Bhavan areas were selected and collections were made from six farmer's plots from each Krishi Bhavan.

3.2 Collection of specimens for study

Epilachna beetles were collected by net sweeping and also by hand picking. The adults and immature stages from each host plant were collected separately. The egg masses, grubs and pupae which showed signs of parasitism were collected for studying the nature and extent of parasitism.

3.3 Rearing

Rearing was carried out in the laboratory in plastic jars of size 16 cm x 12 cm. The mouth of the jar was covered by muslin cloth. A filter paper was placed at the bottom of the rearing jar to absorb excess moisture. The beetles from each host plant were reared in separate lots on the leaves of the respective host from which they were collected. The jars were cleaned and the remnants of the feed materials and excreta were changed on alternate days.

3.4 Killing and preservation

The beetles were transferred to a killing bottle in which ethyl acetate was poured inside the cartridge provided in the lid. After killing, they were dried in an oven at 40-45°C for about five hours. The specimens were properly labelled and preserved for further identification. The grubs were killed by immersing in hot water (Kapur, 1988). The immature stages and parasitoids were preserved in 70 per cent methanol.

3.5 Taxonomy

The structural features of the male and female genitalia were used for the purpose of identification of the species.

3.5.1 Dissection of genitalia

The abdomen of the beetle was removed by inserting a dissecting needle between the abdomen and metasternum. It was then transferred to a vial containing ten millilitres of 10 per cent caustic potash (KOH) and boiled for five minutes. It

was washed twice with water and transferred to glycerine contained in a cavity block. The digested soft tissues were pressed out using the blunt end of a needle. Then the genitalia were taken out following the procedure suggested by Dieke (1947).

An incision was made at the left edge of the abdomen of the male beetle and the dorsal membranes were lifted. Then the male genitalia exposed was taken out with forceps. It was cleared of all the non-sclerotised matter using dissecting needles. In the female abdomen, the connection between the eighth sternite and tergite was detached. The membrane that hold the genitalia to these segments was severed. The genital plates were then separated out using needles.

3.5.2 Identification

The genitalia dissected out were compared with the descriptions and illustrations of such structures of different species of the epilachna beetles furnished by Dieke (1947), Lal and Kanakavalli (1960) and Kapur (1966). The identity was determined after conforming with a specialist.

3.6 Host range

The host range of epilachna beetles collected from brinjal, bittergourd and cowpea was tested by providing the leaves of twelve plants belonging to Solanaceae, Cucurbitaceae and Leguminosae after starving the beetles for a period of 24 hours. The twelve test plants were provided separately under confinement to five beetles each from brinjal, bittergourd and cowpea, there being two replications for this experiment. A known uniform area of the leaf was given for feeding and the area of leaf fed after 48 hours was recorded by super imposing a transparent

photocopy of a graph paper over the leaf lamina and the outlines of the feeding patches were traced out. The damage in terms of the leaf area fed was registered by counting the number of cells coming within the patches. From this the percentage of feeding of epilachna on different test plants were worked out.

3.7 Morphology

3.7.1 Preparation of specimens

The adult beetles after killing were boiled in 10 millilitres of 10 per cent KOH in a test tube for five minutes. It was washed repeatedly with water and transferred to glycerine contained in a cavity block. The required parts were then dissected out using a pair of fine needles under a stereoscopic microscope.

3.7.2 Observations

The morphological characters of the adult beetle such as, shape and colour, mouth parts, antenna, pronotal spot pattern, elytral maculation, first abdominal sternite, shape of the last abdominal segment of male and female and the tarsal claw shape were observed. The characters of eggs, the position and number of branches of the scoli of grubs and pupae were observed.

3.7.3 Morphometrics

Measurements of the immature stages and various body parts of the adult were taken from a sample of twenty specimens of the epilachna beetles from brinjal, bittergourd and cowpea. The size of egg, body parts of the adult such as length and breadth of the head, antenna, mouth parts, pronotum, elytra, tarsal claw and the first abdominal sternite was taken using the technique of micrometry.

The ocular micrometer was placed in the intermediate image plane of the eye piece and stage micrometer on stage. After focussing, the number of divisions between two coinciding divisions on both the micrometric scales were counted. The ocular micrometer was calibrated at,

$$\text{One ocular division} = \frac{\text{Stage reading}}{\text{Ocular reading}} \times 0.01 \text{ mm}$$

From ten such sets of readings, the average was taken. The stage micrometer was then removed and the specimens arranged on a slide was placed. The corresponding ocular divisions were measured and the values were multiplied with the calibrated value to get the actual measurements.

3.8 Biology

The grubs collected from brinjal, bittergourd and cowpea were reared separately till the emergence of adult by providing the leaves from the respective host plant from which they were collected. From the newly emerged adults, the sexes were separated out. Five pairs were collected from each of the three host plants and each pair was confined separately in plastic jars for copulation. The number of egg masses laid per female and the number of eggs per mass were counted. The oviposition period was noted.

The egg masses laid were removed along with the leaves. Five egg masses were taken from each of the three host plants and each was kept for hatching in separate petridishes. The incubation period, duration of different instar grubs, pupal period and longevity of adult male and female were found out

The details of length and breadth of various life stages and body parts of the epilachna beetle recorded are presented below:

Stage/organ	Length	Breadth
1. Egg	End to end	Across the widest area
2. Larva	Anterior margin of head to anal margin	,,
3. Pupa	End to end	,,
4. Adult	Anterior tip of head to apex of elytra along the mid dorsal line	,,
5. Head	Anterior margin to posterior margin	,,
6. Antenna	Base of the scape to apex of club	,,
7. Mouth parts		
Labrum	Anterior margin to posterior margin	,,
Mandible	Tip of the apical claw to the posterior margin	,,
Maxilla	Tip of the maxillary palp to the posterior margin	,,
Labium	Tip of the labial palp to the posterior margin	,,
8. Pronotum	Anterior margin to posterior margin	,,
9. Elytra	Base to apex	,,
10. Hindwing	Base to tip	,,
11. Tarsal claw	Base to tip	,,
12. First abdominal sternite	Starting point of the abdominal line to the posterior magrin	,,

separately. The temperature and relative humidity during the rearing period were recorded.

The beetles collected from brinjal, bittergourd and cowpea were tested for their mating compatibility. From each host plant two mating pairs were taken and they were enclosed in separate jars. The beetle of the opposite sex from the other two host plants were then released into the jars and observed for mating and egg laying.

3.9 Natural enemies

The parasitised life stages of the beetle found in the field were collected. The total number of egg masses, grubs and pupae collected from each field along with the number of parasitised egg masses, grubs and pupae were counted. The observations were taken from six fields each in the case of the epilachna beetles collected from brinjal, bittergourd and cowpea. From this, the extent of parasitism in the field was calculated.

The parasitised eggs, grubs and pupae from brinjal, bittergourd and cowpea were kept in separate vials for the emergence of parasitoids. On emergence of parasitoids from the eggs, grubs and pupae they were transferred to new glass vials containing fresh eggs, grubs and pupae respectively, for further parasitisation. The grubs were fed with host leaves until their colour changed to brownish black. The parasitised life stages were then kept for the emergence of adult parasitoids.

The total number of parasitoids emerged from a single egg mass,grub and pupa were counted. The time taken from the oviposition of the parasitoid till its emergence as adult was noted as the life cycle period of the parasitoid.

Results

RESULT

The results of the studies on the 'epilachna beetle complex in vegetables' are presented below:

4.1 Taxonomy

The epilachna beetles from brinjal, bittergourd and cowpea were first grouped into their respective genera under the subfamily Epilachninae following the key outlined by Li and Cook (1961).

1. Tarsal claws with a basal tooth 2

   Tarsal claws without a basal tooth ..... ***Epilachna***

2. Sixth visible abdominal sternite of female longitudinally split in the middle .....***Henosepilachna***

   Sixth visible abdominal sternite of female undivided ..... ***Afidenta***

The beetles from brinjal and bittergourd were placed in the genus *Henosepilachna* due to the presence of a basal tooth on the tarsal claw and longitudinal splitting of the sixth visible abdominal sternite of female. The characters like the presence of a basal tooth on tarsal claw and an undivided sixth visible abdominal sternite of female were observed in the epilachna beetles occuring on cowpea and hence they could be placed in the genus *Afidenta*.

After the identification of the genus, the species were identified based on the structure of male and female genitalia.

4.1.1 General structure of the male and female genitalia

4.1.1.1 The male genitalia

The structure of male genitalia are highly species specific and hence forms the most important character for taxonomic studies. Moreover, the male genitalia of Coccinellidae are quite dissimilar to that of the other Coleoptera.

The main parts of the male genitalia (Fig.1a) are the tegmen and the sipho. The tegmen (Fig.1b) consists of a basal piece, paired lateral lobes (parameres) and a median lobe (penis). A median strut (hypomere) articulates with the ventral edge of the tegmen. The penis is a slender tube with a length wise seam along the middle of its inner side. The penis is almost always curved up near its tip and the shape of this curvature is characteristic for the particular species. At the very tip penis curve again so that a small hook is formed. The sipho is led through the penis and emerges through an orifice, the basal edge of which is formed by the edges of the seam diverging apart. On the upperside of the penis near its base between the roots of the parameres there is a very thin knife like edge called the basal knife edge. Hairs are sometimes present on the upper straight portion of the penis.

The parameres are two elongate processes seen on either side of the base of the penis. They are about the same length as the penis. The parameres have a short thorn at their apex called the apical thorn. The presence of apical thorn is sometimes obscured by the peripheral dense hairs around the end parts of the parameres.

The sipho (Fig.1c) is a slender tube of considerably smaller diameter than the penis, but of greater length. Sipho is dilated at the basal part forming a siphonal

capsule. The apex of the sipho ends in a point, just before which on the dorsal side there is a small oval orifice called the gonopore through which the sperms are ejected during copulation. The apex of sipho offer the most useful character for the separation of closely related species.

4.1.1.2 The female genitalia

The female genitalia consists of the inner part more or less soft and the outer parts which are well sclerotized. The inner part consists of the ovaries, oviducts, vagina, bursa copulatrix and the receptaculum seminis. It is colourless and show little variation in structure. The ninth tergum is represented by two well sclerotized lateral plates, connected dorsally by a thick but transparent membrane. These are usually curved both dorsally and ventrally and enclose between them a part of the genital plates. The ninth sternite is divided longitudinally and consists of two plates called the genital plates (Fig.1d). There is usually a notch or indentation near the base of the inner margin of genital plates. The shape of the genital plates and notch vary in different species and these characters are important for the separation of closely allied species.

In the present study, the epilachna beetles collected from brinjal, bittergourd and cowpea were identified based on the structure of male and female genitalia. They are,

Henosepilachna vigintioctopunctata (Fabricius) on brinjal,
Henosepilachna septima (Dieke) on bittergourd and
Afidenta misera (weise) on cowpea.

The genitalia of these three species are described in detail.

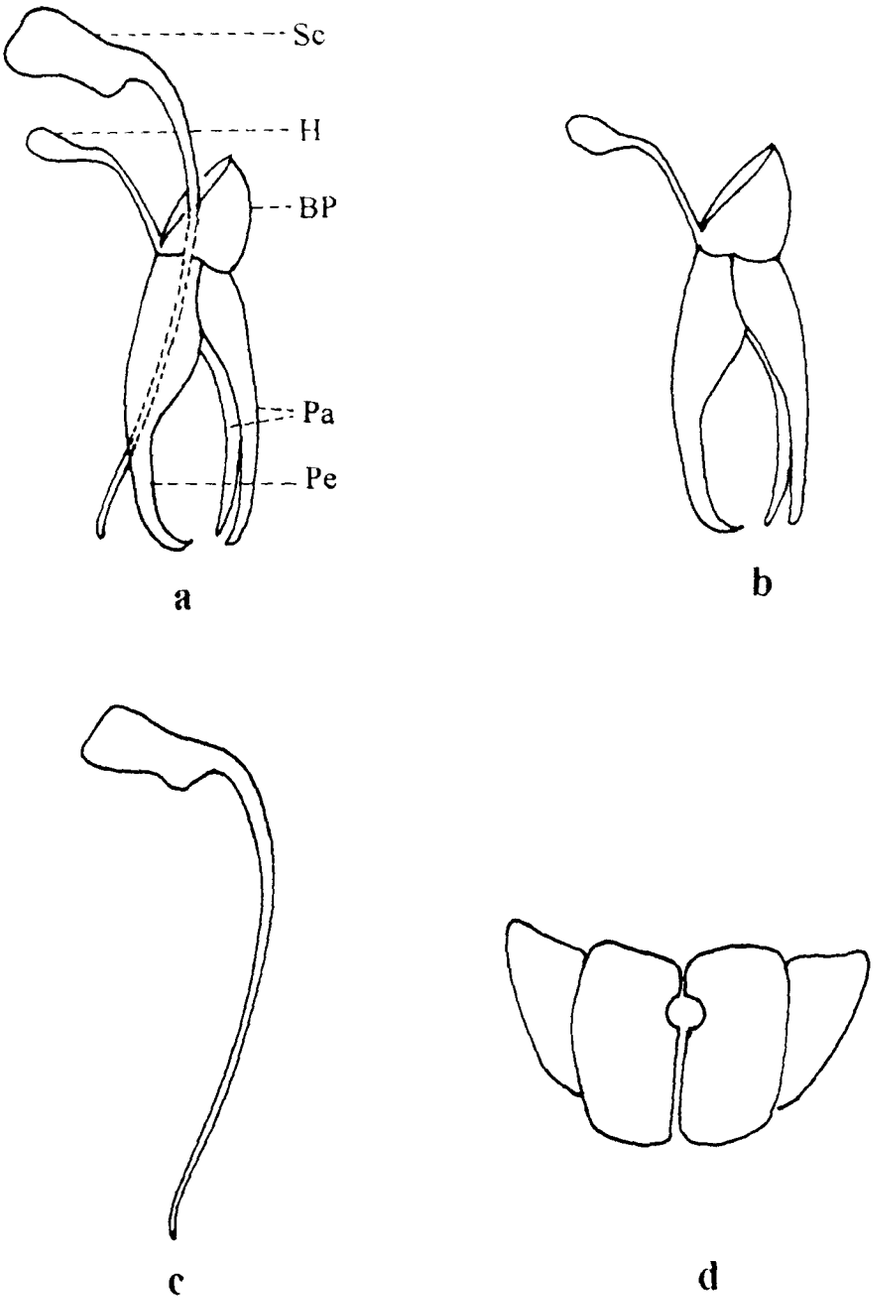


Fig. 1. General structure of the genitalia of the epilachna beetle
(a) Male genitalia; Sc - siphonal capsule, H - Hypomere, BP - Basal piece, Pa - Parameres, Pe - Penis
(b) tegmen (c) sipho (d) female genital plates

4.1.2 *Henosepilachna vigintioctopunctata* (Fabricius)

Coccinella 28-punctata Fabricius, 1775, *Systema entomologiae* : 832

Coccinella sparsa Herbst, 1786, *Arch. Insectengesch.*, **6**:153-182

Epilachna vigintioctopunctata (Fabricius) Mulsant, 1850, *Ann. Soc. Agric. Lyon*, **2**:834

Epilachna sparsa (Herbst) Korchefsky, 1931, *Coleoptm Cat.*, **16**:27

Epilachna sparsa orientalis Dieke, 1947, *Smithson. Misc. Collns*, **106**:34

Henosepilachna vigintioctopunctata (Fabricius) Li and Cook, 1961, *Pacific Ins.*, **3**:31-91

Male genitalia

Tegmen (Fig.2a): 2.53 mm in length, basal piece very slightly sclerotized; median lobe curves upward to a sharp point along its distal one fourth, basal knife edge well developed, setae present towards the apical end; parameres stout and with apical thorn, setae on apical one third; median strut (hypomere) slender.

Sipho (Fig.2b): 2.92 mm in length, sipho bent towards the base of siphonal capsule, apex of sipho curved outwards with a bluntly pointed tip; gonopore dorsal, elongate and terminal.

Female genitalia

Genital plates (Fig.2c): Oval, each plate with 0.46 mm length and 0.32 mm width, a deep semicircular sclerotized notch on the inner edge of the genital plates 0.29 mm from the posterior end, hairs present on the posterior end.

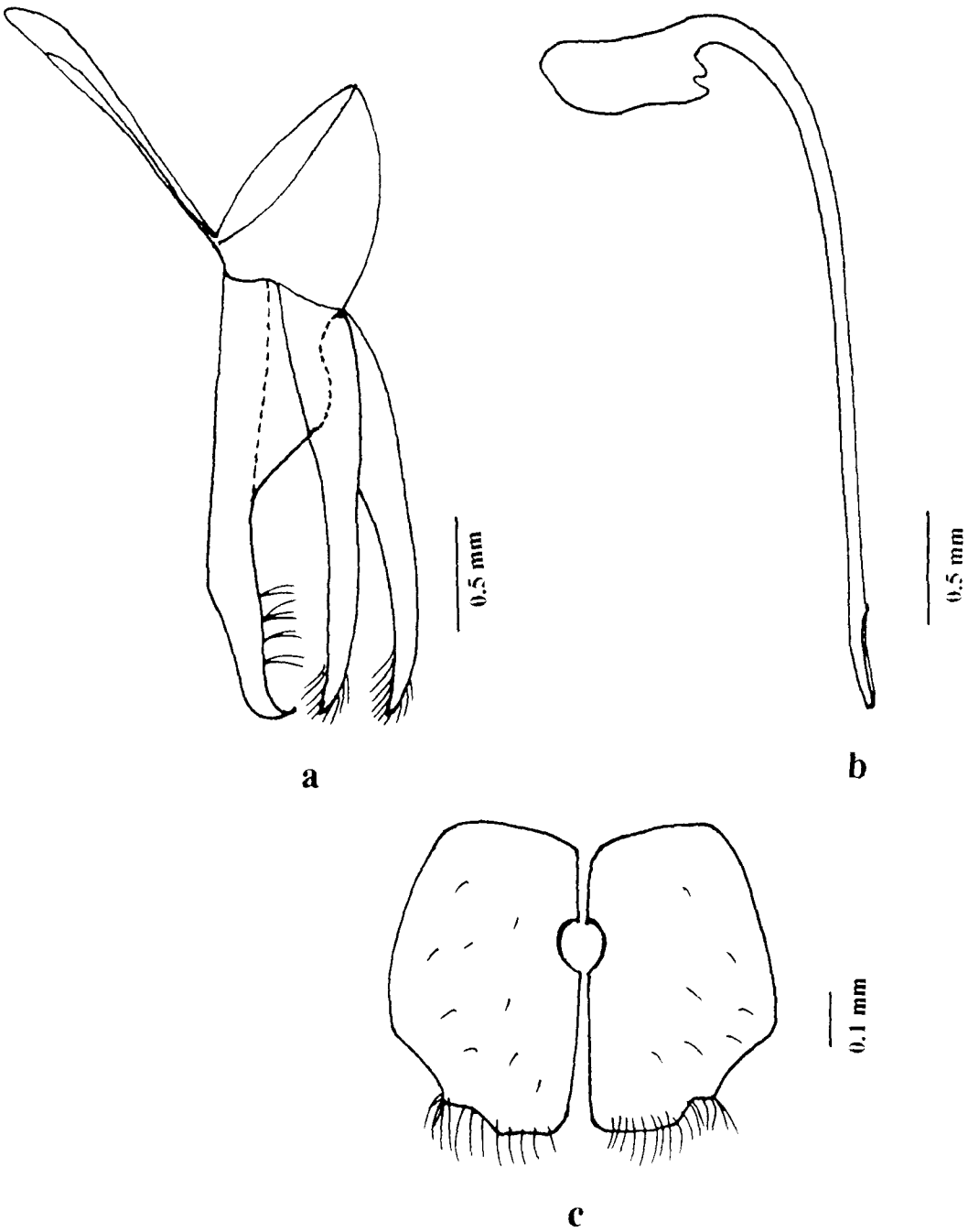


Fig.2. Genitalia of *H. vigintioctopunctata*
(a) tegmen (b) sipho (c) female genital plates

Material examined: 10 ♂, 10 ♀, Thrissur, Malappuram, Palakkad, i-xii, 1996.

4.1.3 *Henosepilachna septima* (Dieke)

Epilachna septima Dieke, 1947, *Smithson. misc. collns*, **106**:58

Epilachna keiseri Bielawski, 1957, *Verh. Naturf. Ges. Basel.*, **68:**73-76

Henosepilachna septima (Dieke) Li and Cook, 1961, *Pacific Ins.*, **3**:31-91

Male genitalia

Tegmen (Fig.3a): 2.6 mm in length, median lobe with a basal knife edge, straight for about four-fifths of its length and bent up shortly before the end, apical point with a hook, two sparse rows of hairs on the middle part; parameres with a sclerotized tip, but no distinct apical thorn, short and sparse pubescence on the apical one third portion.

Sipho (Fig.3b): 3.2 mm in length, sipho bent in middle with a siphonal capsule near base, apex of sipho constricted, curved inwards and with a strongly pointed tip; gonopore dorsal, elongate and subterminal.

Female genitalia

Genital plate (Fig.3c): 0.7 mm long and 0.42 mm wide, bean shaped, deeply notched, with the notched parts overlapping forming a narrow sclerotised slit on the inner edge 0.5 mm from the posterior end, posterior margin with hairs; a small tube like projection from a distinct semicircular region at the posterior margin, provided with setae at its tip.

Material examined: 10 ♂, 10 ♀, Thrissur, Malappuram, Palakkad, i-xii, 1996.

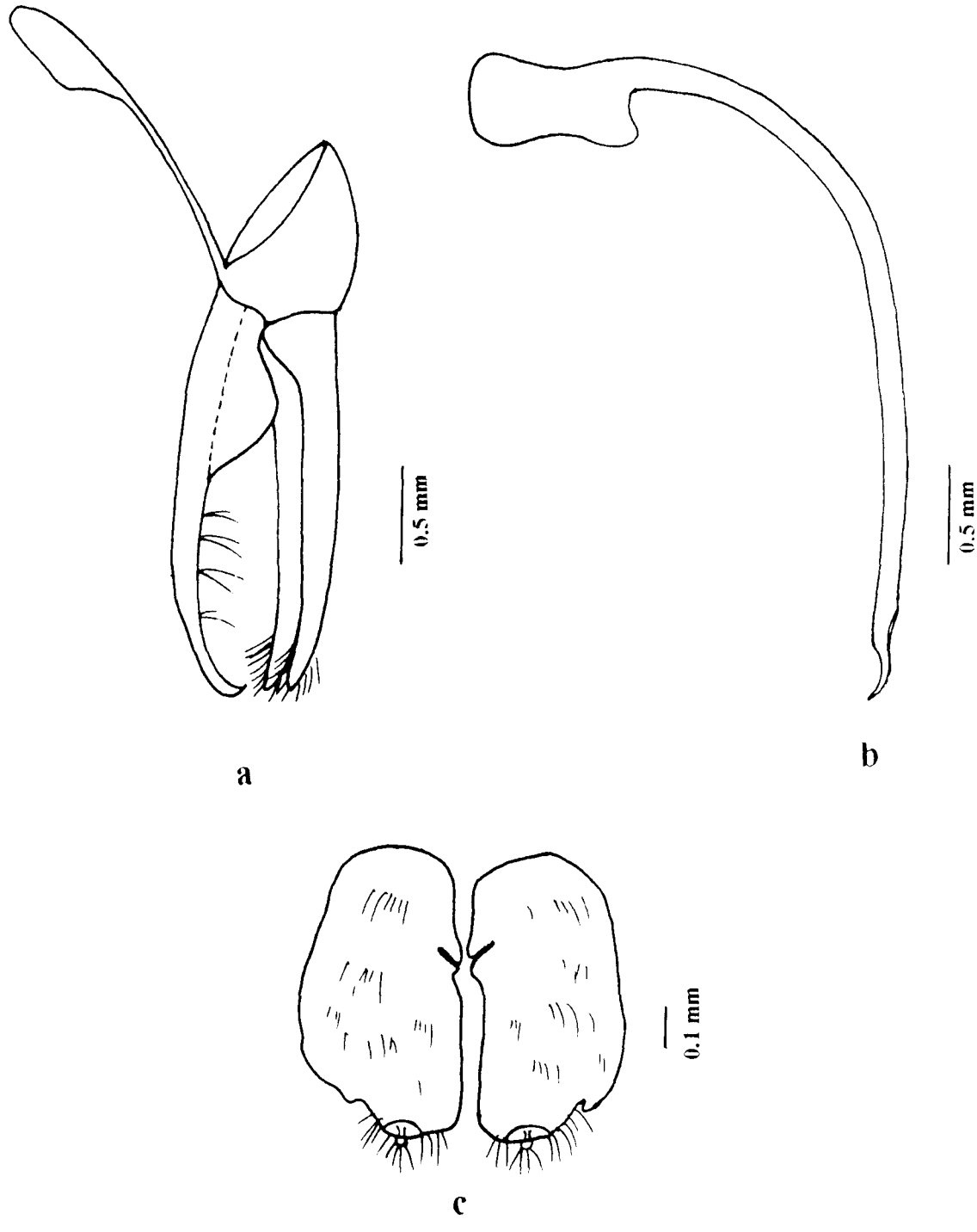


Fig.3. Genitalia of *H. septima*
(a) tegmen (b) sipho (c) female genital plates

4.1.4 *Afidenta misera* (Weise)

Epilachna misera Weise, 1901, Coccinelliden aus Ceylon, *Dtsch. ent. Z.*, **2**:417-445

Afidenta mimetica Dieke, 1947, *Smithson. Misc. Collns*, **106**:110.

Afidenta misera (Weise) Bielawski, 1961, *Ann. Zool.*, **19**:383-415

The size of the genitalia of this species is much smaller compared to the genitalia of the former two species.

Male genitalia

Tegmen (Fig.4a): 0.95 mm in length; median lobe without basal knife edge, inner edge nearly straight and outer edge slightly curved up, apex with a sharp point; parameres slightly curved at apex, without apical thorn, setae on apical one third.

Sipho (Fig.4b): 1.05 mm long, slightly bent near base of the siphonal capsule, apex narrowed and curved outwards with a bluntly rounded tip, apex with dorsal, elongate and subterminal gonopore.

Female genitalia

Genital plate (Fig.4c): 0.32 mm long and 0.21 mm wide, somewhat triangular, slightly emarginate on inner and apical outer edges, notch absent.

Material examined: 10 ♂, 10 ♀, Thrissur, Malappuram, Palakkad, i-xii, 1996.

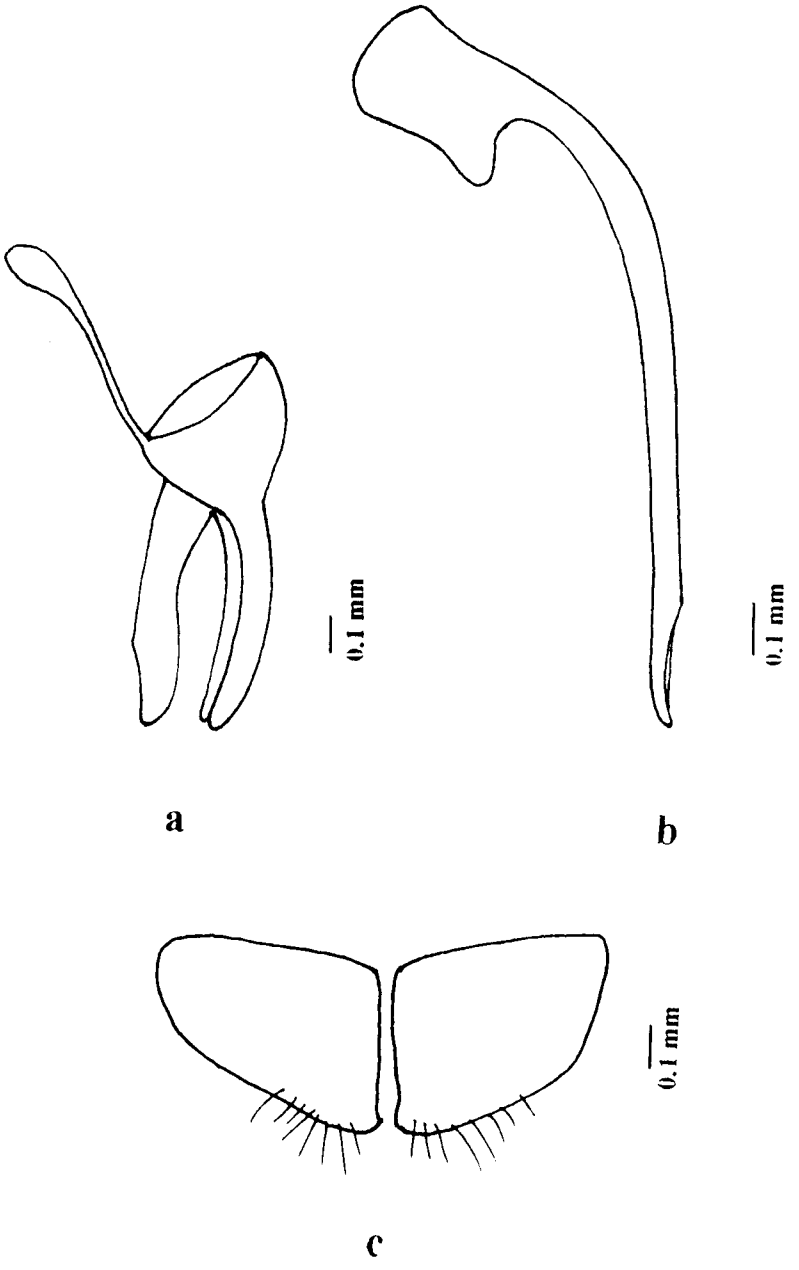


Fig.4. Genitalia of *A. misera*
(a) tegmen (b) sipho (c) female genital plates

4.2 Host range

The host range of epilachna beetles collected from brinjal, bittergourd and cowpea were determined and the details are presented in Table 1. It was found that *H. vigintioctopunctata* when provided with different plants belonging to Solanaceae, Cucurbitaceae and Leguminosae, preferred to feed exclusively on solanaceous plants. It did not feed on any of the cucurbitaceous or leguminous plant. Among the solanaceous plants tested, better feeding was observed in brinjal, tomato and chunda (*Solanum indicum*) with the percentage feeding values of 81.08, 74.13 and 70.92 respectively. In the case of chilli there was no feeding by *H. vigintioctopunctata*.

Similarly the epilachna beetles from bittergourd, i.e., *H. septima* when provided with the test plants, fed only on cucurbitaceous plants and not on any solanaceous or leguminous plants. Among the cucurbitaceous crops, high feeding was noted on bittergourd and sweet gourd with 94.66 per cent and 85.33 per cent feeding respectively. The feeding percentage on snakegourd and pumpkin were 40.00 per cent and 26.63 per cent respectively. *H. septima* could not survive on little gourd, *Coccinea indica*.

The epilachna beetles collected from cowpea, *A. misera* exhibited good feeding response only to cowpea with 83.33 per cent feeding. There was only slight feeding on winged bean (25.04%) and absolutely no feeding activity was noted on redgram. *Afidenta misera* also did not feed on any of the cucurbitaceous or solanaceous plant provided.

Table 1. Host range of *H. vigintioctopunctata*, *H. septima* and *A. misera*

Host plants tested	Percentage of feeding		
	H. vigintioctopunctata	*H. septima*	*A. misera*
(1) Brinjal *Solanum melongena*	81.08	0	0
(2) Tomato *Lycopersicon esculentum*	74.13	0	0
(3) Chunda *Solanum indicum*	70.92	0	0
(4) Chilli *Capsicum annuum*	0	0	0
(5) Bittergourd *Momordica charantia*	0	94.66	0
(6) Sweet gourd *Momordica dioica*	0	85.33	0
(7) Snakegourd *Trichosanthes anguina*	0	40.00	0
(8) Pumpkin *Cucurbita moschata*	0	26.63	0
(9) Little gourd *Coccinea indica*	0	0	0
(10) Cowpea *Vigna unguiculata*	0	0	83.33
(11) Winged bean *Psophocarpus tetragonolobus*	0	0	25.04
(12) Red gram *Cajanus cajan*	0	0	0

4.3 Morphology

4.3.1 Adult beetle - general description

Body: Hemispherical in shape with a strongly convex dorsum and flat ventrum.

Head: Inserted into the prothorax and invisible from above, transverse quadrate in shape, with fine punctures; compound eyes elongate oval and weakly projecting; ocelli absent; antenna inserted between the eyes, eleven segmented, capitate, with the terminal three segments forming a knob.

Mouthparts: Mandibulate type; labrum transverse quadrate; mandibles with an apical tooth and lateral teeth; maxilla complete, galea with round apex, galea and lacinea fringed with tuft of hairs; maxillary palpi four segmented with the basal segment very small and the terminal segment strongly broadened apically with an obliquely truncate apex, namely seruciform; labium with three segmented labial palpi.

Thorax: Pronotum slightly arched, with fine punctures, anterior margin concave, lateral margins round and posterior margin convex. Basic pronotal maculation with seven black spots which is numbered as indicated in Fig.5a. Basic pattern is modified by some spots being smaller, missing, indistinct, enlarged or entirely spot less. Meso and metanotum externally covered by the elytra and invisible.

Wings

Forewings: Elytra spotted. Fundamental elytral spot pattern with six dark persistent spots on each elytron which are numbered as indicated in Fig.5b. The size and

shape of these persistent spots vary between beetles. Additionally one to eight nonpersistent spots present on each elytron which are denoted by the letters a to h as given in Fig.5b. The presence and development of nonpersistent spots vary considerably within one species contributing to the different types of morphological variants met within each species.

Hindwings: Hindwing venation less developed, especially at the apical part as shown in Fig.5c.

Legs: Tarsal formula 444; first and second segment laterally dilated, third segment very small and concealed by the second, fourth segment elongate and broad at the base; tarsi (Fig.5d) are cryptotetramera or pseudotrimera; tarsal claws with a basal tooth.

Abdomen: With six visible segments; abdominal lines on the first abdominal sternite complete or subcomplete, angulate or subangulate, terminal or subterminal.

The morphological characters of the three species, *H. vigintioctopunctata*, *H. septima* and *A. misera* are described in detail.

4.3.1.1 *Henosepilachna vigintioctopunctata* (Fabricius)

The adult beetle (Plate 1a) is hemispherical in shape and yellowish brown in colour.

Body: Pubescent on dorsal and ventral sides.

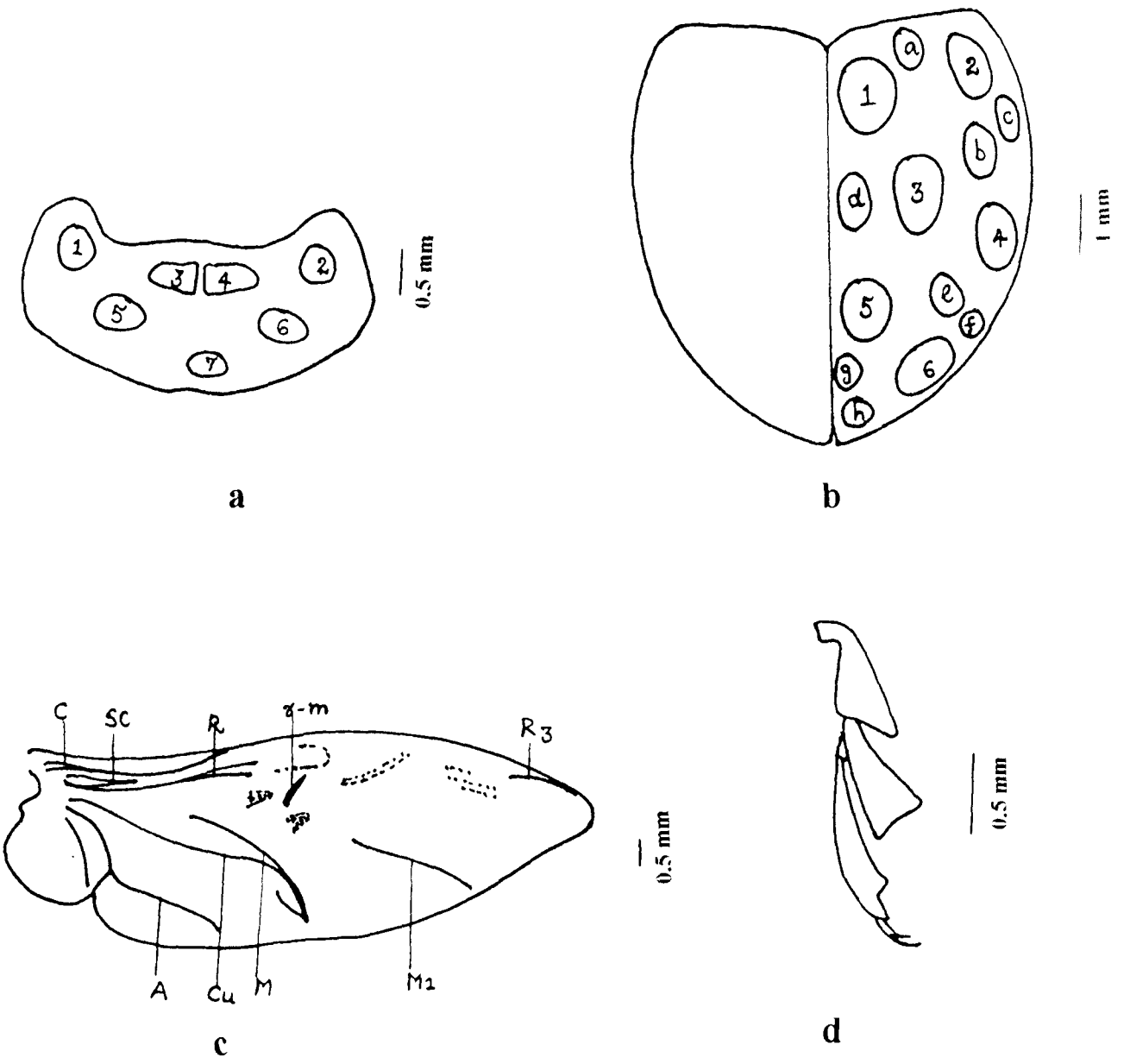


Fig. 5 Pronotal and elytral spot pattern, hindwing venation and tarsal condition of the epilachna beetle
(a) pronotal spot pattern (b) elytral spot pattern
(c) hindwing venation (d) cryptotetramerous tarsi

Head: With fine punctures; compound eyes elliptical; ocelli absent; antenna (Fig.6a) eleven segmented, with the last three segments forming a knob. Mouthparts with labrum (Fig.6b) transverse, anterior margin convex, short setae on anterior and long setae on lateral margins; mandibles (Fig.6c) with an apical tooth, two lateral teeth and small serrations just beneath and below the lateral teeth; maxillae (Fig.6d) complete, galea dilated with rounded apex, galea and lacinea fringed with hairs, maxillary palpi four segmented and seruciform; labium (Fig.6e) complete with submentum transverse, mentum somewhat conical, prementum trapezoidal, ligula conical, labial palpi short, three segmented with the last segment tapering.

Thorax: Pronotum (Fig.6f) slightly arched, anterior margin concave, posterior margin convex and lateral margins rounded. Different pronotal spot pattern met within the species is shown in Fig.7.

Elytra: With fine and coarse punctures and yellowish pubescence. The morphological variants of the species formed by the different elytral maculation are represented in Fig.8.

Legs: Tarsi cryptotetramerous; tarsal claws bifid; basal tooth on tarsal claw conical with a pointed tip (Fig.6g).

Abdomen: First abdominal sternite with abdominal lines (Fig.6h) subcomplete; sixth visible abdominal sternite in female longitudinally split in middle and emarginate in male.

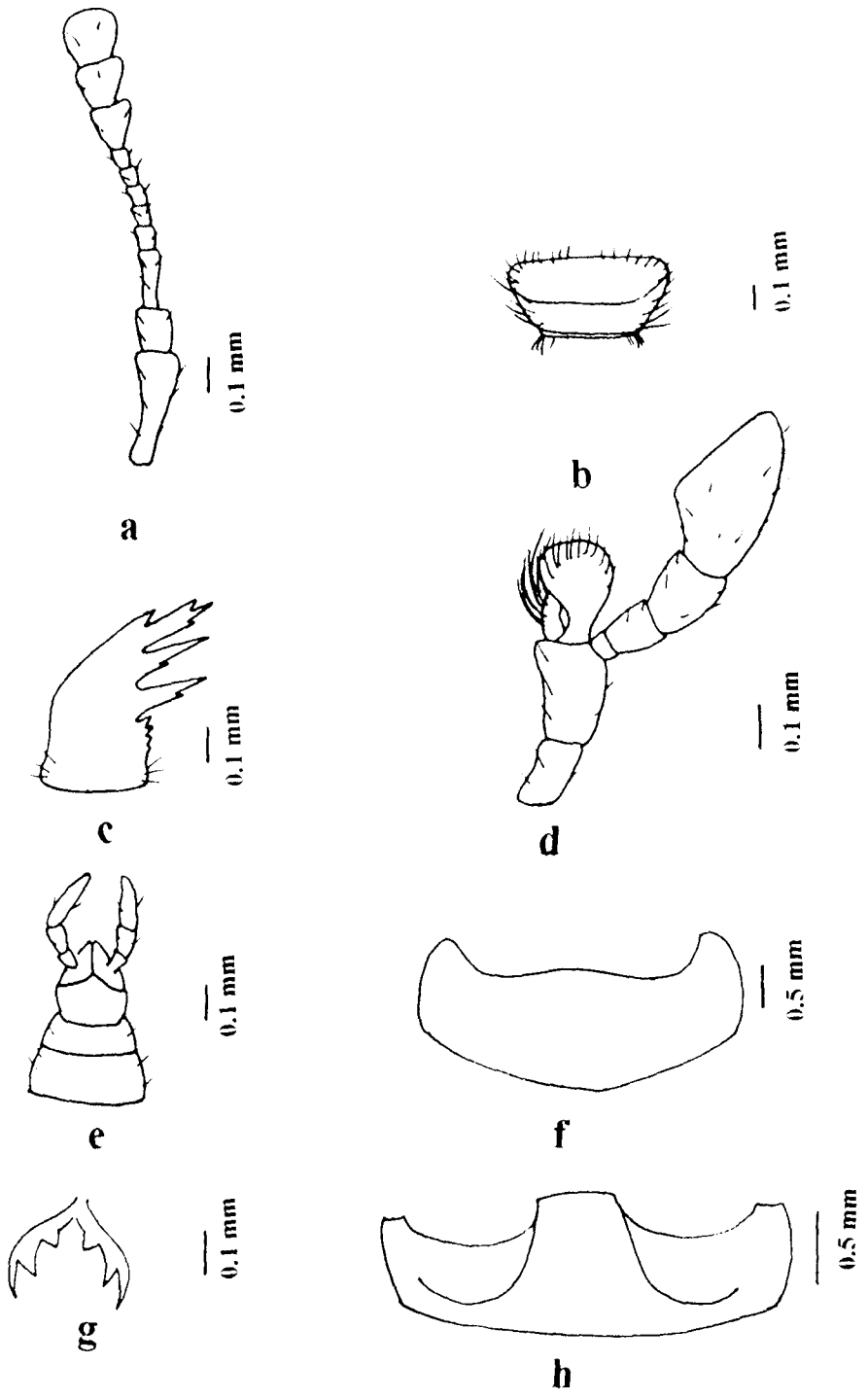


Fig.6. Morphological features of *H. vigintioctopunctata*
(a) antenna (b) labrum (c) mandible (d) maxilla (e) labium (f) pronotum (g) tarsal claw (h) first abdominal sternite

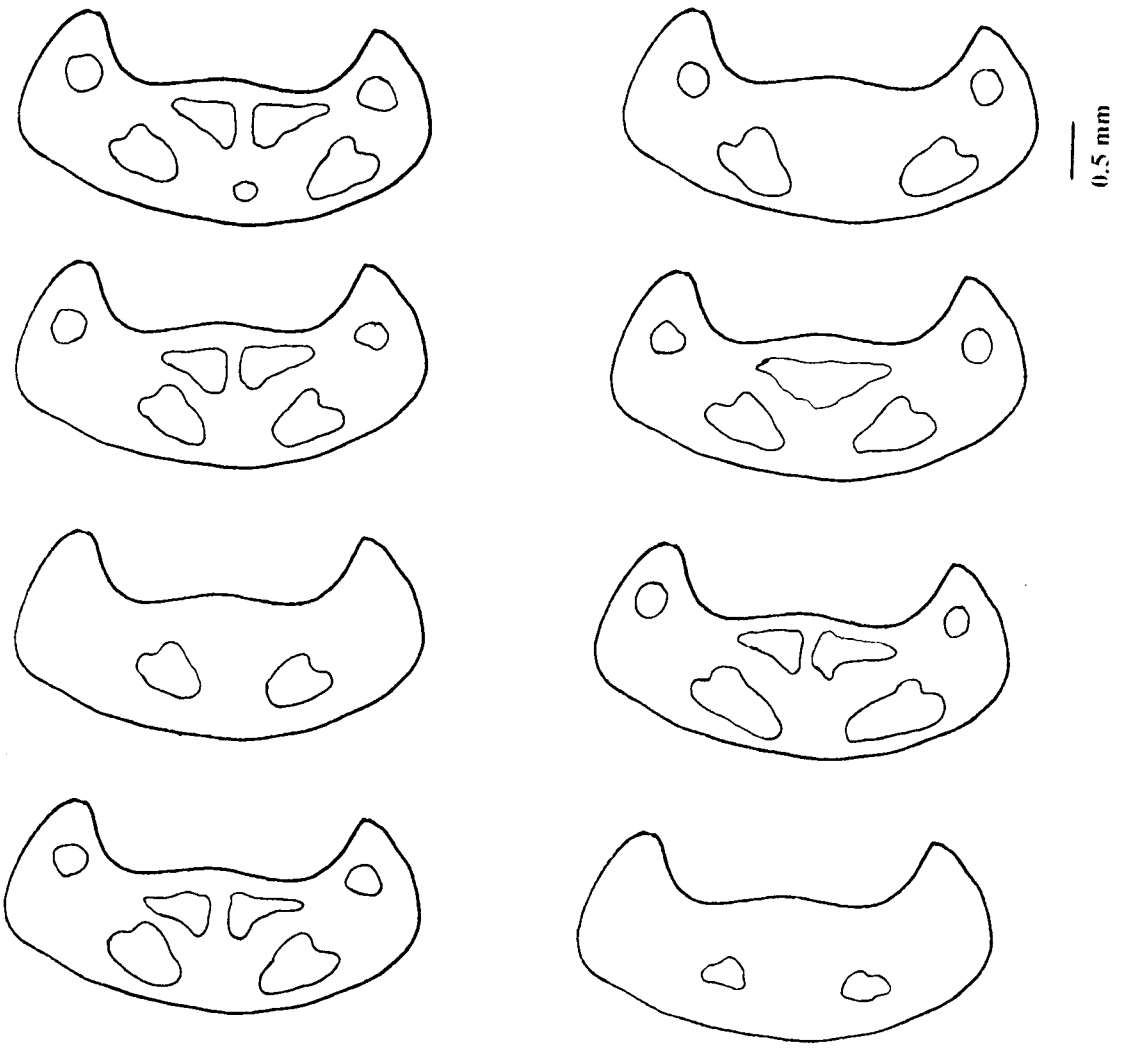


Fig. 7. Pronotal spot pattern of *H. vigintioctopunctata*

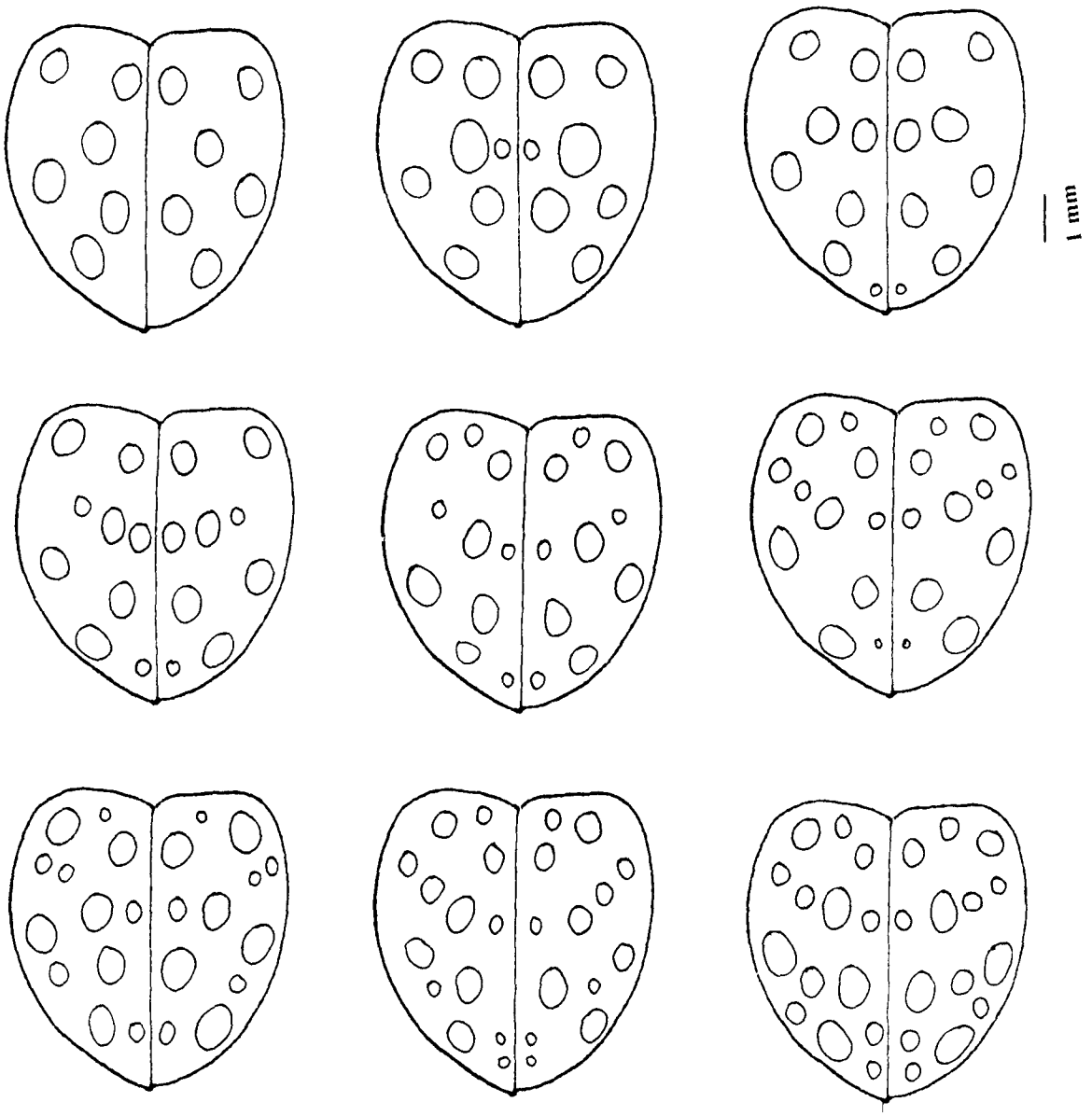


Fig.8. Elytral spot pattern of *H. vigintioctopunctata*

4.3.1.2 *Henosepilachna septima* (Dieke)

The adult beetle (Plate 1b) is hemispherical in shape and pale reddish-brown in colour.

Body: Pubescent on dorsal and ventral sides.

Head: Finely punctured; compound eyes elongate oval; antenna (Fig.9a) eleven segmented with the last three segments forming a knob. Mouthparts with labrum (Fig.9b) transverse, anterior margin straight, long setae on lateral and short setae on anterior margins; mandibles (Fig.9c) with one apical tooth and two lateral teeth, small teeth like serrations between and beneath the lateral teeth; maxilla (Fig.9d) complete with rounded galea, galea and lacinea fringed with hairs, maxillary palpi four segmented and seruciform; labium (Fig.9e) complete, labial palpi three segmented with the last segment tapering, base of the labial palpi closely approximated, ligula conical.

Thorax: Pronotum (Fig.9f) slightly arched and finely punctured, anterior margin concave, posterior margin convex and lateral margins rounded. Variations in the pronotal spot pattern in the species is shown in Fig.10.

Elytra: With fine and coarse punctures and pubescent. The morphological variants formed by the various elytral maculation are shown in Fig.11.

Legs: Cryptotetramerous tarsi; tarsal claws (Fig.9g) bifid; basal tooth on tarsal claw conical with a pointed tip.

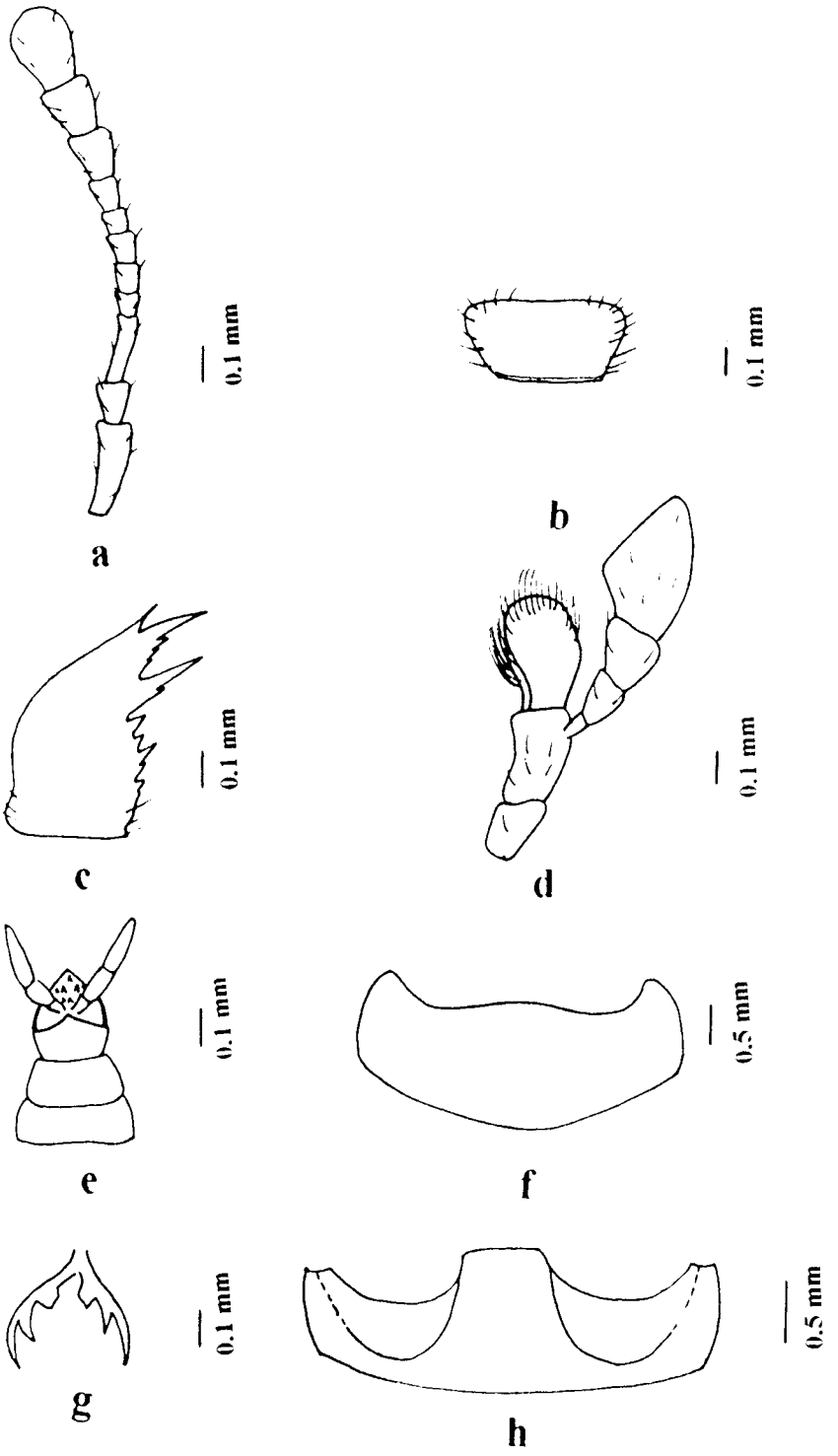


Fig.9. Morphological features of *H. septima*
(a) antenna (b) labrum (c) mandible (d) maxilla (e) labium (f) pronotum (g) tarsal claw (h) first abdominal sternite

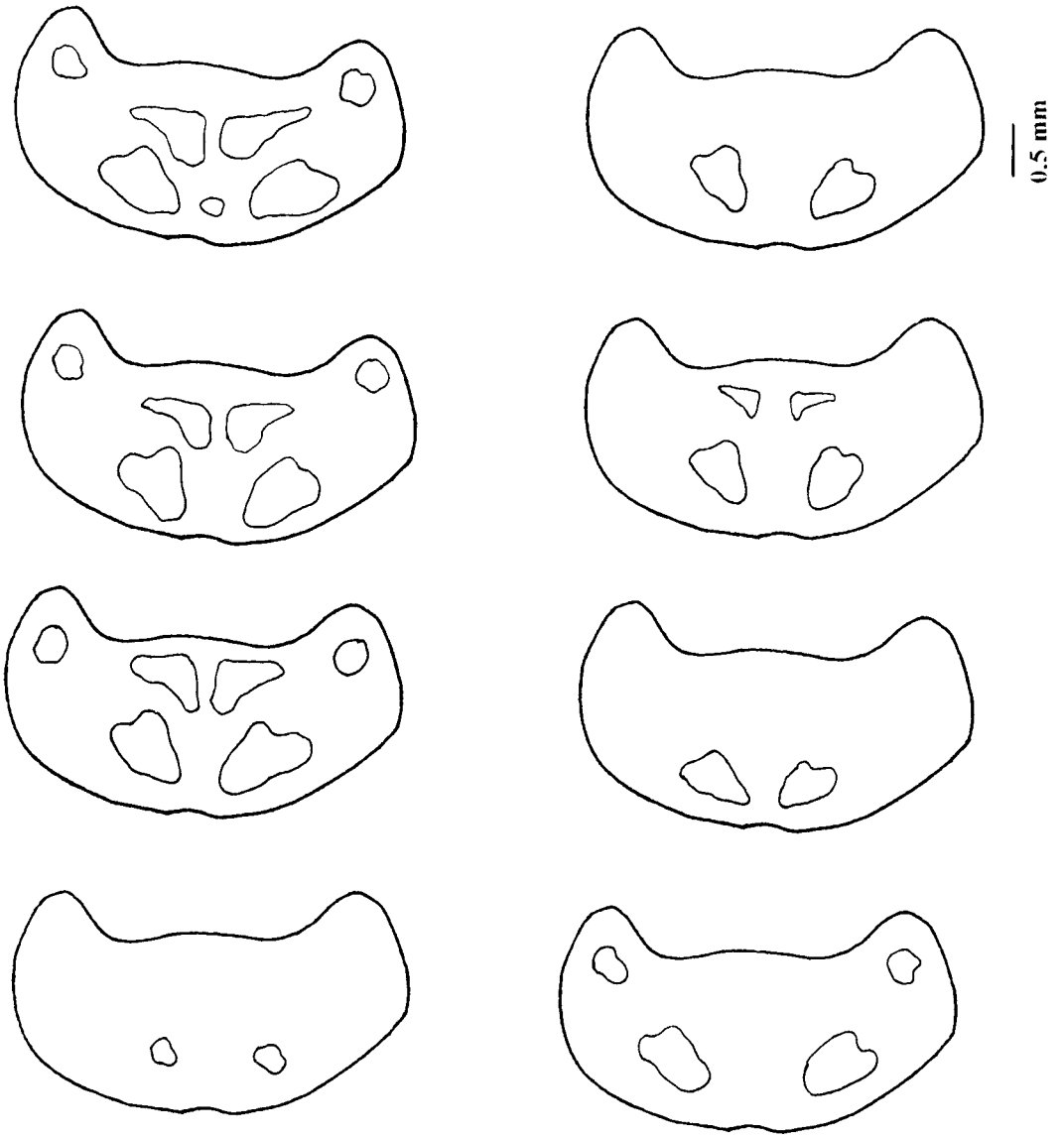


Fig. 10. Pronotal spot pattern of *H. septima*

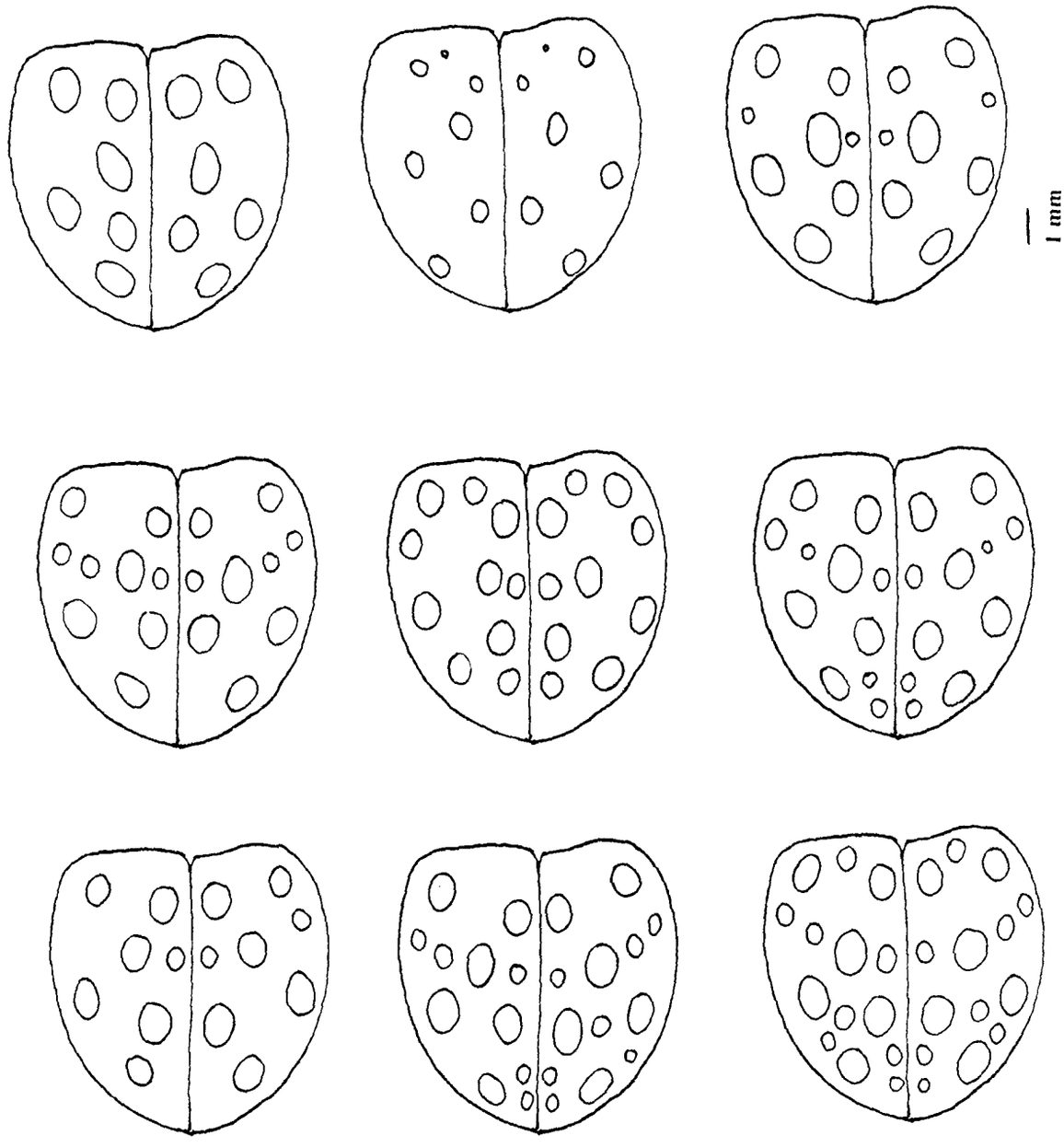


Fig. 11. Elytral spot pattern of *H. septima*

Plate 1a. *Henosepilachna vigintioctopunctata* - The adult beetle (5x)

Plate 1b. *Henosepilachna septima* - The adult beetle (5x)

Abdomen: Abdominal lines on the first abdominal sternite (Fig.9h) complete and subterminal; hind margin of the sixth abdominal sternite in female longitudinally split in middle and emarginate in male.

4.3.1.3 *Afidenta misera* (Weise)

The adult beetle (Plate 1c) is smaller in body size compared to *H. vigintioctopunctata* and *H. septima*. It is deep reddish-brown in colour.

Body: Pubescent on both surfaces.

Head: With fine punctures; compound eyes elliptical; antenna (Fig.12a) eleven segmented with the last three segments forming an elongate club. Mouthparts with labrum (Fig.12b) transverse, anterior margin convex, setae on lateral and anterior margins; mandibles (Fig.12c) broad, without an apical tooth, two serrated lateral teeth with bluntly rounded tip; maxilla (Fig.12d) with rounded galea, galea and lacinea fringed with hairs, maxillary palpi four segmented and seruciform; labium (Fig.12e) with three segmented labial palpi, last segment tapering, ligula conical.

Thorax: Pronotum (Fig.12f) arched with anterior margin concave, posterior margin convex and lateral margins rounded. Pronotal spots four and arranged in a row. The variations in pronotal spot pattern are shown in Fig.13a.

Elytra: With fine and coarse punctures; elytral maculation (Fig.13b) with six persistent spots and the nonpersistent spots are absent. The size of the spots vary in different beetles.

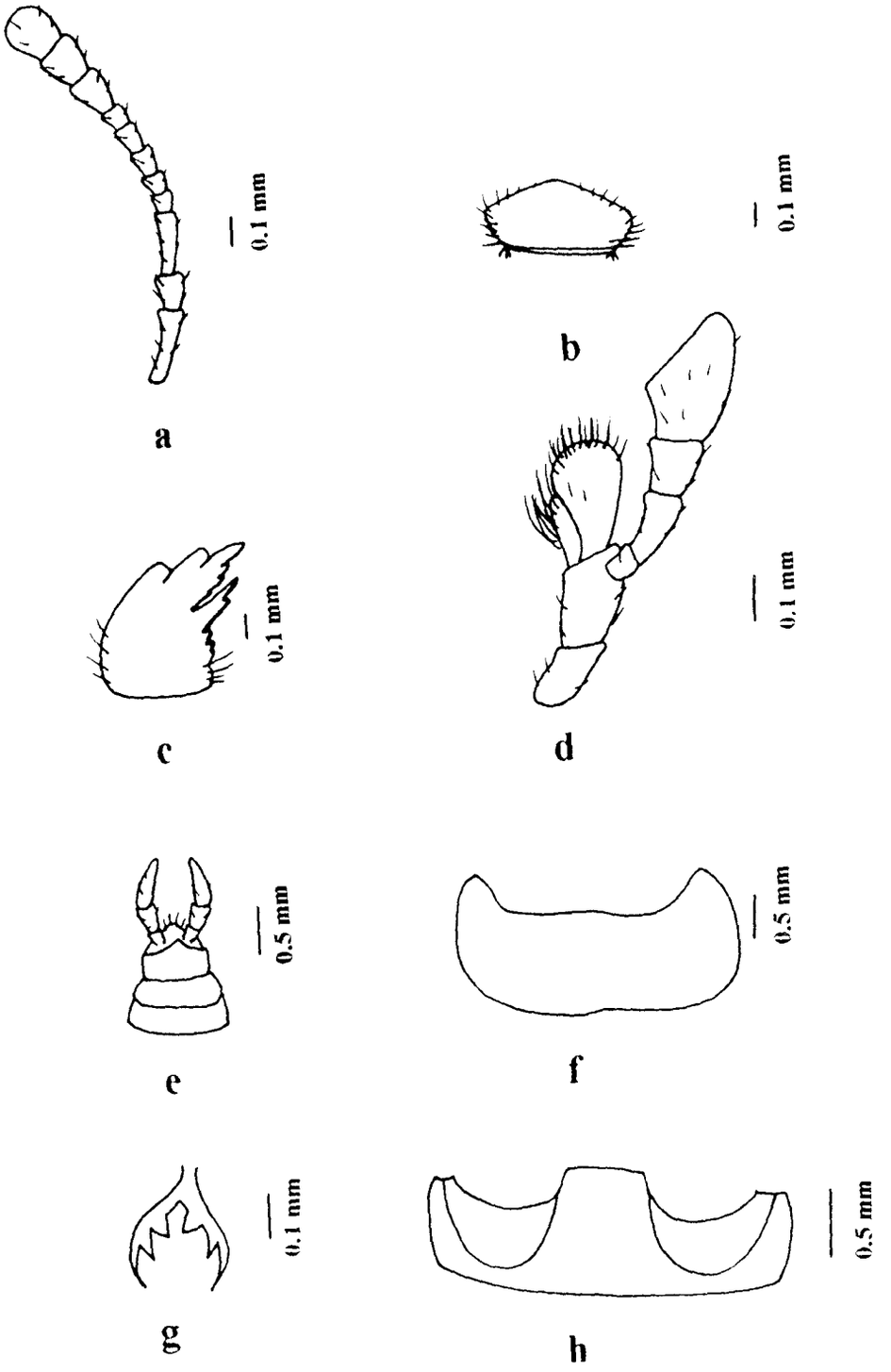
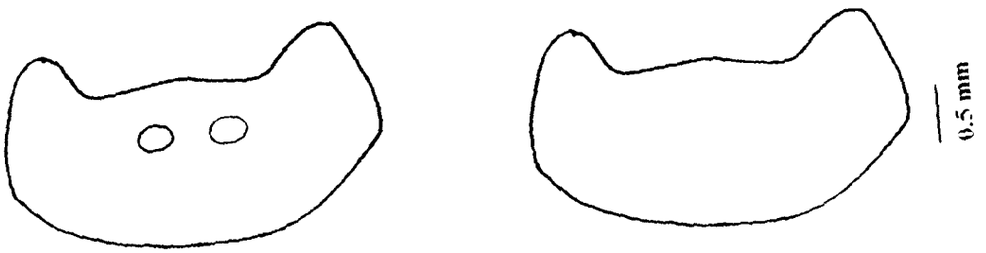
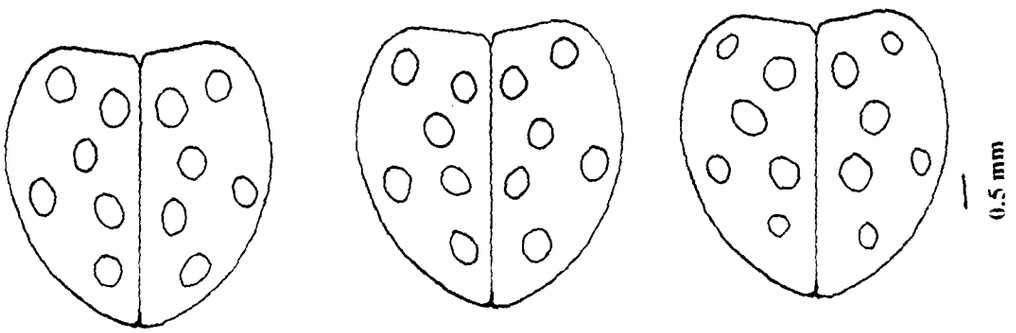


Fig.12. Morphological features of *A. misera*
(a) antenna (b) labrum (c) mandible (d) maxilla (e) labium (f) pronotum (g) tarsal claw (h) first abdominal sternite



a



b

Fig.13. Pronotal and elytral spot pattern of *A. misera*
(a) pronotal spot pattern (b) elytral spot pattern

Legs: With cryptotetramerous tarsi, tarsal claws (Fig.12g) bifid; basal tooth on tarsal claw conical with a pointed tip.

Abdomen: Abdominal lines (Fig.12h) complete and subterminal; hind margin of the sixth visible sternite in female and male slightly emarginate.

4.3.2 The eggs

The eggs of the epilachna beetles (Plate 2) are elliptical oval in shape and yellow coloured. The eggs are laid in clusters on the undersurface of the leaves of the host plants. It is slightly broader at base than apex. The chorion has a honey comb structure all over its surface except a small portion near the base. The shape of eggs are similar in *H. vigintioctopunctata, H. septima* and *A. misera*. The size of the egg is the largest for *H. septima* with 1.71 mm length and 0.84 mm width. The egg of *H. vigintioctopunctata* is 1.52 mm in length and 0.73 mm in width. The length and width of the egg of *A. misera* is 1.23 mm and 0.61 mm respectively.

4.3.3 The larvae

The body of the grubs of Epilachninae is covered with long, branched spinous processes called scoli.

Body: Elongate, usually widest on the second or third abdominal segment and narrowed posteriorly.

Head: Head deflexed. Antenna three segmented. Stemmata three on either side and arranged triangularly. Labrum rectangular. Mandibles without basal teeth and three

Plate 1c. *Afidenta misera* - The adult beetle (6x)

Plate 2. The eggs of epilachna beetle (2x)

to seven major teeth on distal part. The maxillary palpi long and three segmented. Labial palp three segmented.

Thorax: Prothorax longer than meso- and metathorax. Pronotum with two pairs of scoli (a process of the body wall, long and branched, with setae at the apices of the branches) along the anterior margin; a few chalazae (pimple like swelling of body wall with a setae at apex) and setae present on the rest of its surface. Meso and metanotum similar, with three pairs of scoli on its median transverse line, the three pairs being arranged symmetrically on either side of the median longitudinal line. Dorsal scoli nearest the mid-dorsal line, the next subdorsal scoli and dorsolateral scoli on the lateral margin.

Abdomen: Ten segmented; three pairs of scoli in the median transverse line of the first eight segments; scoli dorsal, subdorsal and dorsolateral in position; ninth segment with semicircular tergum, with a few setae; tenth segment short, membraneous, not visible from above.

The characters observed in the grubs of *H. vigintioctopunctata*, *H. septima* and *A. misera*, are outlined in the following section.

4.3.3.1 *Henosepilachna vigintioctopunctata* (Fabricius)

The grub (Plate 3a) is yellowish-brown in colour.

Body: Elongate oval; first instar grub 1.9 mm long and 0.8 mm wide; second instar 3.3 mm long and 1.2 mm wide; third instar 5.5 mm long and 2.3 mm wide; final instar 7.6 mm long and 3.4 mm wide.

Head: Somewhat rounded, slightly sclerotised, with setae; epicranial suture distinct; antennae short, three segmented; stemmata three on either side, arranged triangularly; labrum trapezoidal; mandibles with five teeth, two apical ones large and denticulate, the remaining three smaller and bluntly denticulate; maxilla with the galea broadly oval, sclerotised and distal part with long setae; maxillary palp four segmented with the apical segment long and narrowed distally; labium membraneous for the most part, small area around the bases of palpi sclerotised, labial palpi three segmented.

Thorax: Pronotum larger than meso- and metanotum, anterior margin straight and posterior margin convex; two pairs of scoli along the anterior margin, dorsal and subdorsal scoli with 10 to 12 branches and with short basal and long terminal branches, chalazae present on pronotum. Meso and metanotum with three pairs of scoli, area around the base of the scoli sclerotised giving an yellowish-brown colour to the grub, scoli slightly sclerotised, tip of the branches of scoli and setae more sclerotised, dorsal and subdorsal scoli originate from a common sclerotised region and dorsolateral scoli from a separate sclerotised region, three pairs of scoli with 12 to 14 branches with short basal and long terminal branches.

Abdomen: Ten segmented; three pairs of scoli on first eight segments with 10 to 12 branches, dorsal scoli closer to the median longitudinal line than that of the meso and metanotal scoli, dorsal and subdorsal scoli arise on separate sclerotised region.

4.3.3.2 *Henosepilachna septima* (Dieke)

The grub (Plate 3b) is yellow coloured.

Plate 3a. Grub of *H. vigintioctopunctata* (5x)

Plate 3b. Grub of *H. septima* (4x)

Body: Elongate oval, first instar 3.1 mm long and 1.1 mm wide; second instar 4.1 mm long and 2 mm wide; third instar 8.1 mm long and 3.6 mm wide; fourth instar 9 mm long and 4.2 mm wide.

Head: Somewhat rounded, not sclerotised; antennae short, three segmented; stemmata three on either side; labrum trapezoidal; mandibles with five teeth on apical region and with no basal serrations, two large teeth denticulate; maxilla with the galea oval, not sclerotised and with hairs at the apex, maxillary palp four segmented; labium with short, three segmented labial palpi, ligula conical.

Thorax: Pronotum larger than meso and metanotum, with round anterior and posterior margins; two pairs of scoli along the anterior margin, dorsal and subdorsal scoli with 10 to 12 branches; base of the scoli originating from a swelling, area around the base of scoli not sclerotised, the terminal two to three branches of scoli and setae sclerotised, branches of scoli more stouter than *H. vigintioctopunctata*, chalazae present on pronotum.

Meso- and metanotum subequal, with three pairs of scoli, dorsal and subdorsal scoli arise from a single swelling, terminal 2 to 3 branches of scoli and setae sclerotised, three pairs of scoli each with 12 to 14 branches.

Abdomen: Ten segmented; three pairs of scoli on first eight segments, each with 10 to 12 branches, dorsal scoli closer to the median longitudinal line than that of the meso and metanotal scoli; ninth segment with a semicircular tergum, with setae at the posterior margin; tenth segment membraneous and concealed by the ninth.

4.3.3.3 *Afidenta misera* (Weise)

The grub (Plate 3c) is yellowish-brown in colour.

Body: Elongate, narrower towards the posterior end; first instar grub 1.1 mm long 1.0 mm wide; second instar 2.5 mm long and 1.6 mm wide; third instar 3.9 mm long and 2.1 mm wide; fourth instar 6.2 mm long and 4.3 mm wide.

Head: Somewhat rounded, slightly sclerotised; antennae three segmented with terminal segment sclerotised; stemmata three on either side; labrum transverse with flat anterior margin; mandibles with three teeth, one large and denticulate, the remaining two short; maxilla with galea much sclerotised than *H. vigintioctopunctata* and *H. septima*, maxillary palp four segmented; labium with short, three segmented labial palpi.

Thorax: Pronotum rounded, with prominent setae on the posterior margin; two pairs of scoli along the anterior margin, with 18 to 20 branches, the basal branches and setae on scoli sclerotised, tip of scoli not sclerotised; chalazae on pronotum much prominent.

Meso- and metanotum subequal; with three pairs of scoli each with 16 to 18 branches, dorsal and subdorsal scoli originate from a single swelling on the body wall.

Abdomen: Ten segmented; three pairs of scoli on first eight segments, dorsal and subdorsal scoli with 10 to 12 branches and dorsolateral scoli with 16 to 18 branches, dorsal scoli closer to the median longitudinal line; ninth segment with a semicircular tergum; tenth segment membraneous.

4.3.4 Pupae

A prepupal stage is present prior to pupa. During this stage, the full grown grub secrete a fluid and gets fixed with its anal end firmly to a substrate. The feeding is stopped in this stage and size gets reduced.

Pupa is exarate type. It is anteriorly round and posteriorly tapered. The posterior one third portion of the pupa is covered with the casted last larval skin. Pupa is yellow in colour and change to brown at the time of adult emergence. The pupa of *H. vigintioctopunctata* (Plate 4a) is 7.1 mm long and 4 mm wide while that of *H. septima* (Plate 4b) is 8.5 mm long and 4.2 mm wide. The pupa of *A. misera* (Plate 4c) measure 6.1 mm length and 4.3 mm width.

4.4 Morphometrics

The morphometrics of the eggs, grubs, pupae and adults of *H. vigintioctopunctata*, *H. septima* and *A. misera* are presented in Table 2. It was observed that the size of the egg, grubs, pupa and adult of *H. septima* was the largest among the three species and that of *A. misera* the smallest. The adult male and female of *H. vigintioctopunctata* were 5.82 mm long and 4.6 mm wide and 6.53 mm long and 4.93 mm wide respectively. In *H. septima* the adult male and female were 7.52 mm long and 5.23 mm wide and 8.12 mm long and 6 mm wide respectively. The adult male of *A. misera* measured 4.51 mm length and 3.75 mm width while the female measured 5.15 mm length and 3.81 mm width. The females of the three species are larger than the males.

Table 2. The size* of the life stages of *H. vigintioctopunctata*, *H. septima* and *A. misera*

Life stage	*H. vigintioctopunctata*		*H. septima*		*A. misera*	
	Length (mm)	Width (mm)	Length (mm)	Width (mm)	Length (mm)	Width (mm)
Egg	1.52 ± 0.01	0.73 ± 0.01	1.71 ± 0.01	0.84 ± 0.04	1.23 ± 0.02	0.61 ± 0.01
First instar grub	1.91 ± 0.12	0.84 ± 0.05	3.05 ± 0.13	1.12 ± 0.07	1.12 ± 0.15	1.04 ± 0.03
Second instar grub	3.33 ± 0.15	1.24 ± 0.09	4.14 ± 0.21	2.00 ± 0.07	2.51 ± 0.25	1.56 ± 0.01
Third instar grub	5.51 ± 0.23	2.34 ± 0.13	7.12 ± 0.25	3.61 ± 0.1	3.94 ± 0.27	2.13 ± 0.02
Fourth instar grub	7.56 ± 0.28	3.41 ± 0.05	9.02 ± 0.31	4.23 ± 0.08	6.24 ± 0.21	4.33 ± 0.04
Pupa	7.12 ± 0.25	4.01 ± 0.18	8.51 ± 0.35	4.17 ± 0.11	6.14 ± 0.23	4.32 ± 0.02
Adult male	5.82 ± 0.31	4.64 ± 0.18	7.51 ± 0.25	5.23 ± 0.03	4.51 ± 0.15	3.75 ± 0.01
Adult female	6.53 ± 0.15	4.93 ± 0.11	8.12 ± 0.15	6.00 ± 0.07	5.15 ± 0.21	3.81 ± 0.03

*Each value is an average of 20 measurements ± standard error of means

Plate 3c. Grub of *A. misera* (5x)

Plate 4a. Pupa of *H. vigintioctopunctata* (5x)

Plate 4b. Pupa of *H. septima* (6x)

Plate 4c. Pupa of *A. misera* (8x)

The measurements of the various body parts of the adult beetle such as the head, antenna, mouth parts, pronotum, elytra, hindwing, first abdominal sternite and the tarsal claws are given in Table 3. It was seen that the size of the body parts are also the largest for *H. septima* and the smallest for *A. misera* except in the size of labrum where *H. septima* is having the smallest size.

4.5 Biology

The results of the studies on the biology of *H. vigintioctopunctata, H. septima* and *Afidenta misera* at a temperature of 27.6 ± 1.5°C and a relative humidity of 89.5 ± 3.1 per cent are presented in Table 4. It was observed that the three species had a similar biology. The number of egg masses laid per female were 6.6, 5.01 and 5.7 for *H. vigintioctopunctata, H. septima* and *A. misera* respectively. The average number of eggs per egg mass was the highest for *H. vigintioctopunctata* with 43.2 whereas in *H. septima* and *A. misera* it was 38.3 and 32 eggs per mass respectively.

Henosepilachna vigintioctopunctata recorded the incubation, larval, prepupal and pupal periods as 3.84, 14.48, 1.82 and 5.11 days respectively with a life cycle period of 25.25 days. The incubation, larval, prepupal, pupal and the total life cycle period recorded for *H. septima* were 4.1, 11.76, 1.53, 4.2 and 21.59 days respectively. In *A. misera* the incubation, larval, prepupal, pupal and the total life cycle periods were 5.03, 13.64, 1.11, 4.98 and 24.76 days respectively. The longevity of the adult male and females of *H. vigintioctopunctata* were 19.1 days and 20.8 days respectively. In *H. septima*, males lived for a period of 18.6 days while the females lived upto 22.4 days. The longevity of the adult male and female beetles of *A. misera* were 21.5 days and 24 days respectively.

Table 3. The size* of the various body parts of the adults of *H. vigintioctopunctata*, *H. septima* and *A. misera*

Life stage	*H. vigintioctopunctata*		*H. septima*		*A. misera*	
	Length (mm)	Width (mm)	Length (mm)	Width (mm)	Length (mm)	Width (mm)
Head	0.88 ± 0.01	1.51 ± 0.01	1.06 ± 0.01	1.76 ± 0.01	0.78 ± 0.01	1.41 ± 0.00
Antenna	1.36 ± 0.02	0.15 ± 0.00	1.37 ± 0.01	0.18 ± 0.00	1.19 ± 0.01	0.14 ± 0.00
Labrum	0.24 ± 0.01	0.59 ± 0.00	0.19 ± 0.02	0.64 ± 0.01	0.22 ± 0.02	0.53 ± 0.01
Mandible	0.53 ± 0.02	0.27 ± 0.01	0.71 ± 0.03	0.38 ± 0.00	0.54 ± 0.01	0.28 ± 0.01
Maxilla	1.13 ± 0.01	0.34 ± 0.01	1.23 ± 0.00	0.35 ± 0.01	0.92 ± 0.03	0.28 ± 0.01
Labium	0.43 ± 0.02	0.14 ± 0.02	0.53 ± 0.00	0.28 ± 0.00	0.25 ± 0.01	0.17 ± 0.00
Pronotum	2.94 ± 0.07	1.41 ± 0.01	3.17 ± 0.02	1.58 ± 0.02	2.71 ± 0.04	1.32 ± 0.01
Elytra	6.12 ± 0.18	3.52 ± 0.08	6.52 ± 0.23	4.11 ± 0.05	4.57 ± 0.08	3.51 ± 0.01
Hind wing	9.22 ± 0.25	3.17 ± 0.13	11.20 ± 0.28	4.1 ± 0.11	7.14 ± 0.11	3.03 ± 0.08
First abdominal sternite	3.73 ± 0.01	1.06 ± 0.09	4.05 ± 0.09	1.23 ± 0.04	3.23 ± 0.05	1.05 ± 0.03
Tarsal claws	0.21 ± 0.01	0.07 ± 0.00	0.28 ± 0.00	0.14 ± 0.00	0.18 ± 0.01	0.06 ± 0.00

* Each value is an average of 20 measurements ± standard error of means

Table 4. Biology of *Henosepilachna vigintioctopunctata, Henosepilachna septima* and *Afidenta misera* at a temperature of 27.6± 1.5°C and relative humidity of 89.5± 3.1 per cent

Observations recorded	*H. vigintioctopunctata*	*H. septima*	*A. misera*
Number of egg masses laid per female	6.60 ± 1.6	5.01 ± 0.35	5.70 ± 1.07
No. of eggs per mass	43.20 ± 2.1	38.30 ± 2.60	32.00 ± 1.88
No. of eggs per female	289.20 ± 8.9	191.40 ± 13.1	182.40 ± 7.80
Oviposition period (days)	7.40 ± 1.8	9.60 ± 1.22	8.20 ± 0.72
Incubation period (days)	3.84 ± 0.67	4.10 ± 0.28	5.03 ± 0.48
Grub period (days)	14.48 ± 1.00	11.76 ± 1.39	13.64 ± 2.03
First instar	3.51 ± 0.19	3.12 ± 0.22	3.32 ± 0.25
Second instar	3.01 ± 0.32	2.11 ± 0.45	2.97 ± 0.61
Third instar	3.42 ± 0.27	2.51 ± 0.34	3.08 ± 0.42
Fourth instar	4.54 ± 0.28	4.02 ± 0.41	4.27 ± 0.73
Prepupa	1.82 ± 0.21	1.53 ± 0.18	1.11 ± 0.27
Pupa	5.11 ± 0.23	4.20 ± 0.28	4.98 ± 0.34
Total life cycle	25.25 ± 2.08	21.59 ± 2.11	24.76 ± 3.1
Longevity of adult male	19.10 ± 1.8	18.60 ± 2.5	21.50 ± 3.4
Longevity of adult female	20.80 ± 2.8	22.40 ± 2.08	24.00 ± 2.1

From the studies on the mating compatibility between the beetles from brinjal, bittergourd and cowpea it was seen that there was no successful mating between them which also conforms that the beetles on brinjal, bittergourd and cowpea are reproductively isolated.

4.6 Natural enemies

4.6.1 Larval/Pupal parasitoid

Pediobius foveolatus (Crawford) 1912

Eulophidae:Hymenoptera

The eulophid *Pediobius foveolatus* (Plate 5a) was found to parasitise the grubs and pupae of *H. vigintioctopunctata*, *H. septima* and *A. misera*.

The adult parasitoid is 1.34 mm in size, black and shining. Antenna is seven segmented. Legs are black with tibia and tarsus yellowish brown in colour. Abdomen is ovate and more acutely pointed in female. The second, third and fourth instar larvae are preferred by *Pediobius foveolatus*. On parasitisation, the host larvae and pupae change in colour from yellow to brownish black (Plate 5b).

The extent of parasitism, the number of adult parasitoids emerged from a single parasitised grub and pupa and the life cycle of the parasitoid is presented in Table 5. The percentage of parasitism was more on the grubs than on pupae. The grubs of *H. vigintioctopunctata*, *H. septima* and *A. misera* recorded 32.79 per cent, 37.9 per cent and 17.72 per cent parasitism respectively by *Pediobius foveolatus*.

The percentage of parasitism on the pupae of *H. vigintioctopunctata*, *H. septima* and *A. misera* was 26.88, 16.89 and 16.68 respectively. The number of

Plate 5a. *Pediobius foveolatus* parasitising the grubs of the epilachna (8x)

Plate 5b. Grub and pupa of *H. vigintioctopunctata* parasitised by *P. foveolatus* (4x)

Dead
Parasitic
adult hop
on the gra
and photogra

adult parasitoids emerged from a single parasitised grub was 10.5, 13.31 and 7.5 in *H. vigintioctopunctata*, *H. septima* and *A. misera* respectively. From a single parasitised pupa of *H. vigintioctopunctata*, *H. septima* and *A. misera*, the number of adult parasitoids emerged were 19.5, 9.1 and 16.52 respectively. The life-cycle period of the parasitoid on the grubs and pupae of *H. vigintioctopunctata* was 12.52 days and 11.51 days respectively. On the grubs and pupae of *H. septima*, the life-cycle period of the parasitoid was 14.57 days and 13.53 days respectively. In the grubs of *A. misera*, the parasitoid had a life cycle period of 16 days and on the pupae, it took 12.51 days.

4.6.2 Egg parasitoid

Tetrastichus ovulorum Ferriere.

Eulophidae:Hymenoptera

The egg masses of *H. vigintioctopunctata*, *H. septima* and *A. misera* was found to be parasitised by the eulophid *Tetrastichus ovulorum* (Plate 6).

The adult eulophid is 0.82 mm in size with reddish brown compound eyes. Antenna is 8 segmented and hairy. Thorax is enlarged and black in colour. Abdomen is yellow towards the anterior end and black and tapering towards the posterior end. The surface and margins of wings provided with small hairs.

The incidence of this egg parasitoid was observed on *H. vigintioctopunctata*, *H. septima* and *A. misera* feeding on brinjal, bittergourd and cowpea respectively. The extent of parasitism by *Tetrastichus ovulorum* is shown in Table 6. The attack of *Tetrastichus* was the highest in the host *H. vigintioctopunctata* and the least in *A. misera*. The mean percentage of parasitism

Table 5. The extent of parasitism, the number of adult parasitoids emerged from a single grub and pupa and the life cycle period of the eulophid *Pediobius foveolatus* (Crawford) on epilachna beetles

Species of epilachna beetle	Percentage of parasitism on		Number of adult parasitoids emerged from a single host		Life cycle of the parasitoid (days)	
	Grub	Pupa	Grub	Pupa	Grub	Pupa
H. vigintioctopunctata	32.79	26.88	10.50	19.50	12.52	11.51
H. septima	37.90	16.89	13.31	9.10	14.57	13.53
A. misera	17.72	16.68	7.50	16.52	16.00	12.51

Table 6. The extent of parasitism, the number of adult parasitoids emerged and the life cycle period of *Tetrastichus ovulorum* Ferriere on the egg of epilachna beetles

Species of epilachna beetle	Percentage of parasitism	Number of adults emerged from a single host parasitised egg mass	Life cycle of the parasitoid (days)
H. vigintioctopunctata	10.93	27.20	5.57
H. septima	7.23	35.11	5.11
A. misera	3.61	11.58	4.08

by *Tetrastichus ovulorum* on *H. vigintioctopunctata* was worked out to be 10.93 per cent, on *H. septima* was 7.23 per cent and on *A. misera* was found to be 3.61 per cent. Table 6. indicate that the number of adult parasitoids emerged from a single parasitised egg mass in *H. vigintioctopunctata*, *H. septima* and *A. misera* was 27.2, 35.11 and 11.53 respectively. The life cycle period of *Tetrastichus ovulorum* on the eggs of *H. vigintioctopunctata*, *H. septima* and *A. misera* was 5.57 days, 5.11 days and 4.08 days respectively.

Discussion

DISCUSSION

The results of the present investigations on the taxonomy, morphology, biology and the natural enemies of epilachna beetles on three host plants namely, brinjal, bittergourd and cowpea are discussed in this chapter.

5.1 Taxonomy

Due to the close gross morphological resemblance of epilachna beetles occurring on brinjal, bittergourd and cowpea, they were regarded by many workers as *Henosepilachna vigintioctopunctata* or *H. dodecastigma* based on whether they possess twenty eight or twelve spots on the elytra. In the present study to determine the correct identities of the epilachna beetles, in brinjal, bittergourd and cowpea, the genitalial characteristics were used for the identification of the species.

In the present study, the generic differentiation was attempted mainly following Li and Cook (1961) who erected the genus *Henosepilachna* and separated it from *Epilachna,* based on the structure of the sixth abdominal sternite of female and the basal tooth on tarsal claws. The epilachna beetles occurring on brinjal and bittergourd were placed in the genus *Henosepilachna* owing to the presence of a basal tooth on the tarsal claw and the longitudinal splitting of the sixth visible abdominal sternite of female. The beetles on cowpea could be placed in the genus *Afidenta* by the presence of a basal tooth on tarsal claw and an undivided sixth visible abdominal sternite of female. The characters given by Li and Cook (1961) adopted in the present study were also followed by Bielawski (1965a), Sasaji (1971), Pang and Mao (1977), Miyatake (1985) and Anand *et al.* (1988). Contrary

to this, several authors (Gordon, 1975; Richards, 1983 and Ganga *et al.*, 1985) considered *Henosepilachna* as a synonym of *Epilachna*. They ignored the characters which separated *Henosepilachna* from *Epilachna* and regarded the former as a junior synonym of the latter. The present study does not support this in view of the nature of clear differentiation in respect of the structures of the sixth abdominal sternite of female and the basal tooth on tarsal claw.

Based on the study on genitalia, the species on brinjal was identified as *H. vigintioctopunctata*. The salient genitalial features include the apex of sipho which is curved outwards with a bluntly rounded tip and the female genital plates with a semicircular notch. The genitalial characters are in conformity with those given by Dieke (1947), Lal and Kanakavalli (1960), Li and Cook (1961), Bielawski (1965a), Singh and Garg (1978) and Richards (1983).

The species on bittergourd was identified as *H. septima*. The male genitalia of this species is with a constricted apex for sipho which is curved inwards with a strongly pointed tip and the female genital plates with a slit like notch. The genitalial characters studied are in perfect agreement with those described by Dieke (1947), Bielawski (1957) and Kapur (1966). Kapur (1966) stated that the species was commonly found on bittergourd and he made *E. keiseri* a junior synonym of *H. septima*. However, Mohanasundaram and Uthamasamy (1973) from a study on the genitalia, based on the characters enumerated by Kapur (1959) fixed the identity of the beetle on bittergourd as *E. implicata* Mulsant and the one on solanaceous plants as *E. vigintioctopunctata* Fabricius. But in the present study on the genitalia of the epilachna beetle from bittergourd, it was found to differ in the structure of female genital plates and male genitalia from those of *E. implicata*. Moreover, this species did not feed on little gourd *Coccinea indica* which has been recorded as the host plant of *E. implicata* by Kapur (1959). Mohanasundaram and Uthamasamy (1973)

also considered *E. dodecastigma*, *E. 12stigma* and *E. 28punctata* as synonyms of *E. vigintioctopunctata*. But Kapur (1966) stated *E. dodecastigma* as a pest of cucurbits, especially *Luffa sp.* occuring in North-East India.

The species of epilachna attacking cowpea was identified as *Afidenta misera* in the present study. *Afidenta* is a genus under the subfamily Epilachninae erected by Dieke (1947). Here the male genitalia is with the apex of sipho curved outwards with a bluntly rounded tip and the female genital plates triangular with no distinct notch. The genitalial characters described in the present study are in accordance with those by Weise (1901), Bielawski (1961), Kapur (1966) and Miyatake (1985).

Regarding the taxonomy of the group of the epilachna beetles, the generic concepts are still confounded, despite periodical revisions.

5.2 Host range

The studies on the host range of the epilachna beetles collected from brinjal, bittergourd and cowpea ensured that the beetles found on these host plants are three distinct species though they show certain morphological similarities. These species were identified as *H. vigintioctopunctata* on brinjal, *H. septima* on bittergourd and *A. misera* on cowpea. The three species showed high degree of specificity with regard to the selection of their host plants. *H. vigintioctopunctata* fed only on solanaceous plants and not on any cucurbitaceous or leguminous plant. *Henosepilachna septima* fed well on bittergourd and sweetgourd and only slightly on pumpkin and snakegourd. It did not feed on solanaceous or leguminous plants. *Afidenta misera* fed only on leguminous plants and not on any solanaceous or cucurbitaceous plant.

The present finding is supported by the observations of Basavanna (1954) who reported that the species *H. vigintioctopunctata* fed only on solanaceous plants and it did not feed on cucurbits. He proved that the beetles feeding on solanaceous plants and cucurbitaceous plants were of two different species with distinct host specificity trends. However, he could not record the identity of the beetle occuring on cucurbitaceous hosts. Stride (1965) reported that although the genus *Epilachna* is associated with a wide range of plant families, a majority of them feed either on Solanaceae or Cucurbitaceae and the various records of *Epilachna* spp. feeding on a wide range of plant families should be treated with reserve. The present finding is also in conformity with Thomas *et al.* (1969) Mohanasundaram and Uthamasamy (1973) as well as Singh and Mukherjee (1987) who reported that *H. vigintioctopunctata* showed a strict host restriction to solanaceous food plants and did not feed on cucurbits.

Contrary to the present finding, several workers have reported that the same species of epilachna beetle was involved as pests of both solanaceous and cucurbitaceous plants. They recorded *H. vigintioctopunctata* as the species feeding on both solanaceous and cucurbitaceous plants (Subramaniam, 1923; Ribiero, 1934; May, 1946; Trehan and Pingle, 1949; Mehta and Varma, 1968; Sinha and Krishna, 1969; Pandey and Shanker, 1975; Schaefer, 1983; Anand *et al.*, 1988; Rajagopal and Trivedi, 1989; Sinha and Chandra, 1990).

Henosepilachna vigintioctopunctata was reported to infest bittergourd by Beevi and Jacob (1982) and Thomas and Jacob (1991) whereas, Srivastava and Katiyar (1972) as well as Singh and Emden (1979) found the species as feeding on cowpea and bean crops respectively. But in the present study, it was found that *H. vigintioctopunctata* could not survive on any of the cucurbitaceous on leguminous plants offered for feeding in confinement. Solanaceous plants alone were found to

be acceptable to *H. vigintioctopunctata*. Incorrect identifiction of the species based on the elytral spots might have been the cause for treating non-solanaceous plants also in the host range of this species. Another reason for enlisting both solanaceous and cucurbitaceous crops as the host plants of *H. vigintioctopunctata* might be due to the mixed population of beetles from both solanaceous and cucurbitaceous plants as the test population. In the above context, the various previous reports on the host range of *H. vigintioctopunctata* remain highly questionable.

5.3 Morphology

The morphological characters of *H. vigintioctopunctata*, *H. septima* and *A. misera* are described in the study. The extent of superficial similarities in the gross morphological features such as shape, colour and elytral maculation have contributed to the present stage of confusion regarding the identities of the epilachna beetles. Krishnamurti (1932) as well as Lall and Mandal (1958) suggested that the number of elytral spots may be used to differenciate the species. However, in the present study it is found that the variation in elytral spot pattern is a purely morphological feature which cannot be relied upon to establish taxonomic identification. It is to be noted that elytral spot pattern variation was similar in the case of *H. vigintioctopunctata* and *H. septima* where both the species showed nine types of spot variants. They were 12-spotted, 14-spotted, 16-spotted, 18-spotted, 20-spotted, 22- spotted, 22-spotted and 28-spotted beetles. But the size and position of spots differed in the two species and also within each species. However, *A. misera* did not show any variation in the number of spots. In *A. misera*, all the specimens under observation showed the same number of twelve spots. But the size of the individual spots differed in these specimens. Comparing the colour of the beetle, it was observed that *H. vigintioctopunctata* possess a yellowish-brown colour, while *H. septima* was pale reddish-brown and *A. misera* was deep reddish-brown.

The morphological characters of the grubs also showed variations. In general, the grubs of *H. septima* is more deeply yellowish as compared to *H. vigintioctopunctata* and *A. misera*. This is because the bases of the scoli are not sclerotised in *H. septima*, while sclerotisation is present in *H. vigintioctopunctata* and *A. misera*. The sclerotisation around the bases of the scoli of grubs is more prominent in *H. vigintioctopunctata* than *A. misera*. The number of branches in the dorsal, subdorsal and dorso-lateral scoli differed between the three species.

The larval characters of *H. vigintioctopunctata* were furnished by Kapur (1950). He recorded the presence of 14-18 branches for the dorsal scoli and 20-22 branches for the dorso-lateral scoli on the pronotum. The scoli on abdomen recorded 8 branches for dorsal and 8-10 branches for sub-dorsal and dorso-lateral scoli. In the specimens of *H. vigintioctopunctata*, only 10-12 branches were observed on the scoli on pronotum and abdomen.

Regarding the morphometrics of the three species, it was found that *H. septima* was the largest and *A. misera* the smallest in gross dimensions. In respect of all morphological characters such as the size of egg, grubs, pupa, adult and the body parts of the adult beetle, *H. septima* showed the largest values. In *A. misera* the corresponding dimensions were of a lower nature.

However, the morphological characters alone cannot be relied upon for the identification of the species. Dieke (1947) observed that due to considerable morphological similarities between many of the species, a key in the usual form would be of little value.

5.4 Biology

The three species *H. vigintioctopunctata*, *H. septima* and *A. misera* showed identical biological attributes. The life cycle period observed for *H. septima* was the shortest with a mean of 21.59 days from egg to adult as compared to *H. vigintioctopunctata* (25.25 days) and *A. misera* (24.76 days) at a temperature of 27.6 ± 1.5°C and a relative humidity of 89.5 ± 3.1 per cent. Contrary to the present finding, Krishnamurti (1932) reported a longer life cycle period from egg to adult in the case of the epilachna beetle on cucurbits (36 days) and a shorter period (21 days) for the epilachna on potatoes. The variations in the life cycle duration are explicable on the basis of the variation in the ambient environment in the localities of testing, especially the temperature and humidity regimes.

In the present study, the egg, grub and pupal periods of *H. vigintioctopunctata* were found to be 3.84, 14.48 and 5.11 days respectively. The results are in conformity with Mandal (1975) who recorded the egg, grub and pupal periods of *H. vigintioctopunctata* to be 3, 11.5 and 3 days respectively. Previous reports are not available on the developmental cycles of *H. septima* and *A. misera*.

5.5 Natural enemies

The grubs and pupae of *H. vigintioctopunctata*, *H. septima* and *A. misera* were parasitised by the eulophid wasp, *Pediobius foveolatus* (Crawford). The percentages of parasitism noted were 32.79, 37.9 and 17.72 on the grubs. On pupae the parasitisation occurred at 26.88 per cent, 16.89 per cent and 16.68 per cent respectively, on *H. vigintioctopunctata*, *H. septima* and *A. misera*. The mean number of adults emerging from a single parasitised grub was 10.5, 13.31 and 7.5 and from a single pupa was 19.5, 9.1 and 16.52 in the case of *H.*

vigintioctopunctata, *H. septima* and *A. misera* respectively. Life cycle period of the parasitoid were 12.52 days, 14.57 days and 16 days on the grub and 11.51 days, 13.53 days and 12.51 days on the pupa of *H. vigintioctopunctata*, *H. septima* and *A. misera* respectively.

The reports on the efficiency of *Pediobius foveolatus* by several workers are discordant. Krishnamurti (1932) observed that the percentage of parasitism has never exceeded 5 to 8 per cent. Lal (1946) recorded the percentage of parasitism to vary between 3.1 to 16.9 per cent in *H. vigintioctopunctata* and found out that the number of adult parasites emerging from a single parasitised grub was 15-20. Appanna (1948) recorded an average of 16 parasites emerging from a single grub and that the percentage of parasitism reached up to 40 per cent. He recorded the duration of development of the parasite as 11 days. Lall (1961) recorded that the percentage of parasitism by *P. foveolatus* ranged from 9.03 per cent to 37.8 per cent. Abbas and Nakamura (1985) recorded 59.1 per cent pupal parasitism on *E. implicata* by *P. foveolatus*. Shingh and Wang (1992) recorded 64.5 per cent parasitism by *P. foveolatus* and found the average number of adult wasps emerging from a single host grub as 13.8. The variation in the degree of parasitism are only quite expected in nature in accordance with parasitoid-host population loads. The variability in the number of adult parasitoid emergence could be mainly due to the extent of superparasitism and/or hyperparasitism.

The eggs of *H. vigintioctopunctata*, *H. septima* and *A. misera* were found to be parasitised by *Tetrastichus ovulorum* (Eulophidae : Hymenoptera) where the percentage of parasitism being 10.93, 7.23 and 3.61 respectively on the three species. Their duration of development were 5.57 days, 5.11 days and 4.08 days respectively. Nandakumar and Saradamma (1996) reported the percentage of parasitism by *T. ovulorum* on the eggs of *H. vigintioctopunctata* as 14-18 per cent.

The results do not agree to Krishnamurti (1932) who recorded the life cycle period of *T. ovulorum* as 6 to 10 days and the percentage of parasitism as 1.5 to 2.45 per cent. The variation may also be due to the effect of climatic factors and also due to hyper parasitism. No reports are available on the parasitisation of *H. septima* and *A. misera* by *P. foveolatus* and *T. ovulorum*.

With organised mass multiplication of *P. foveolatus* and *T. ovulorum* and their subsequent field releases, promising results can be expected in the problem of epilachna control.

Summary

SUMMARY

The studies on the epilachna beetle complex occuring on selected vegetable crops were conducted at the College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala during 1995-1997 to establish the correct identities of the epilachna beetles attacking brinjal, bittergourd and cowpea. The studies also aimed to investigate the morphology and biology of these beetles as well as the natural enemies. The results are summarised in this chapter.

The collections of epilachna beetle from brinjal, bittergourd and cowpea were made from six Krishi Bhavan areas of Thrissur, Palakkad and Malappuram districts. Based on the character of the genitalia of these beetles, they were identified as, ***Henosepilachna vigintioctopunctata*** (Fabricius) on brinjal, ***Henosepilachna septima*** (Dieke) on bittergourd and ***Afidenta misera*** (Weise) on cowpea. The most useful character for the separation of these three species is the apex of sipho which is a part of the male genitalia.

The following key has been suggested for the separation of the three species.

1. Sixth visible abdominal sternite of female divided longitudinally in the middle ..
.....Genus *Henosepilachna* Li...2

   Sixth visible abdominal sternite of female not divided longitudinally in the middle ... .Genus *Afidenta* Dieke...3

2. Male genitalia with the apex of sipho curved outwards with a bluntly rounded tip; female genital plates with a semicircular notch on the inner margin...
... *Henosepilachna vigintioctopunctata* (Fabricius)

Male genitalia with the apex of sipho constricted, curved inwards with a sharply pointed tip; female genital plates with a slit like notch...

... *Henosepilachna septima* (Dieke)

3. Male genitalia with the apex of sipho curved outwards with a bluntly rounded tip; female genital plates triangular with no distinct notch ...

... *Afidenta misera* (Weise)

In the present study, it was confirmed that the beetles occuring on brinjal, bittergourd and cowpea show distinct host specificity. *Henosepilachna vigintioctopunctata* showed a strict host restriction to solanaceous plants, while *H. septima* was confined only to a few cucurbitaceous plants. *A. misera* restricted its choice of food to a few leguminous plants.

The beetles do not show pronounced morphological variation. Of the three species under study, *H. septima* is the largest and *A. misera* the smallest. The variations in elytral spot pattern is a morphological character without any significance in the identification of species.

The grubs of the three species are similar in general appearance, but can be distinguished by the structure and sclerotisation of the scoli on body surface. In *H. vigintioctopunctata*, the area around the base of the scoli and tip of their branches are sclerotised giving a yellowish-brown colour to the grub. In *H. septima*, the area around the base of the scoli is not sclerotised and only two to three terminal branches are sclerotised, thereby giving an yellowish appearance to the grub. In *A. misera*, the area around the base of the scoli and a few basal branches are slightly sclerotised imparting an yellowish-brown hue to the grub.

The three species showed similar biological attributes. The mean life cycle of *H. vigintioctopunctata*, *H. septima* and *A. misera* occupied 25.25, 21.59 and 24.76 days respectively, at 27.6°C and 89.5 per cent relative humidity.

The grubs and pupae of the three species were attacked by the parasitoid *Pediobius foveolatus* (Crawford) (Eulophidae:Hymenoptera). The percentage of parasitism was relatively more on the grubs than on pupae. The eggs of all the three species of epilachna beetles were parasitised by the egg parasitoid *Tetrastichus ovulorum* Ferriere (Eulophidae: Hymenoptera).

The literature on epilachna beetles dealing with the generic concepts, species and host range records are still very unreliable and hence a taxonomic revision of the subfamily Epilachninae with correct host records is to be awaited in the near future.

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*Originals not seen

EPILACHNA BEETLE COMPLEX IN VEGETABLES

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ABSTRACT OF A THESIS

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ABSTRACT

Studies on the epilachna beetle complex occuring on selected vegetable crops were carried out at the College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala during 1995-1997 to establish their taxonomic identities. The morphology, biology and the natural enemy association of these beetles were also studied.

Based on the male and female genitalial characters, the epilachna beetles feeding on brinjal, bittergourd and cowpea were identified as ***Henosepilachna vigintioctopunctata*** (Fabricius), ***Henosepilachna septima*** (Dieke) and ***Afidenta misera*** (Weise) respectively.

The salient features to distinguish between these three species are the curvature of the apex of sipho which is a part of the male genitalia and the shape of the female genital plates. The apex of sipho is curved outwards with a bluntly rounded tip in both *H. vigintioctopunctata* and *A. misera*, while it is curved inwards with a sharply pointed tip in *H. septima*. A semicircular notch is present on the female genital plates of *H. vigintioctopunctata*, while there is a slit like notch in *H. septima*. The notch on female genital plate is absent in *A. misera*.

It was confirmed that the beetles are highly host specific. *Henosepilachna vigintioctopunctata* showed a strict host restriction to solanaceous plants, while *H. septima* and *A. misera* are restricted to a few cucurbitaceous and leguminous plants respectively.

There was not much gross morphological variations between the species except for their body size, *H. septima* being the largest and *A. misera* the smallest. The different spot variants met within the species by the variations in elytral maculation was found to be a morphological character only. Though the grubs of the three species are similar in external appearance, they can be easily distinguished by the structure and sclerotisation of the scoli on body surface and the details have been discussed. The three species showed similar biological attributes with a life cycle period of 25.25, 21.59 and 24.76 days for *H. vigintioctopunctata*, *H. septima* and *A. misera* respectively at 27.6°C and 89.5 per cent relative humidity. Under field conditions, the grubs and pupae of the three species were parasited by *Pediobius foveolatus* (Crawford) (Eulophidae:Hymenoptera) and the egg masses were parasitised by *Tetrastichus ovulorum* Ferriere (Eulophidae:Hymenoptera).