MORPHOLOGICAL AND ECOLOGICAL STUDIES ON THE LADY BIRD BEETLE, *Cheilomenes sexmaculata* Fabr. (COCCINELLIDAE - COLEOPTERA)

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INTRODUCTION

Lady bugs, lady birds, or the lady bird beetles belong to the family Coccinellidae (Coleoptera). The majority of the species are predaceous on other insects and mites and they form the subfamily Coccinellinae. A few others are phytophagous which comprise the subfamily Epilachninae. Tetrabrachynae forms a third subfamily, the biology and habits of which are not quite clear. The predaceous forms have a wide range of insect and mite hosts, most of which are injurious to cultivated plants. Taking advantage of this habit, attempts have been made to utilise many of the species in the field of biological control. The introduction of the Australian lady bird, *Rodolia cardinalis* Muls. was the first dramatic case in the field of biological control. But for the services of these beetles, the future of citrus industry in many a country would have presented a dim picture. Perhaps less famous, but just as important, are the naturally occurring species, because without these species in our croplands, pest problems would have been far more intense. Thus the family Coccinellidae is of paramount importance from the agriculturists' point of view in its twofold aspects, viz. the beneficial nature on one side and the injurious nature of some of the phytophagous species on the other.

Most of the early works on this group in India are confined to short accounts of the biology and host range of different species. Detailed biology of a few species has been worked out by Ayyar (1925a, 1925b), Kapur (1942, 1948), Bagal and Trehan (1949) and Trehan and Malhorta (1959). Taxonomical studies are those by Fowler (1912), Fletcher (1926) and Kapur (1948a, 1948b, 1949a, 1949b). Studies on the morphology of Coccinellids in India are rather few. Kapur (1950, 1959), has worked out the morphology of a few species while Lal et al (1960) made a study of the male genitalia of some Indian Coccinellidae. Studies on the internal morphology of Coccinellids include those of Pradhan (1939, 1942) and Singh and Nayyar (1961).

So far very little attention has been paid to the larval characters of the predaceous forms, which may well lead to better taxonomical concepts. Probing the possibility of utilising one or more of the naturally occurring species for biological control is a field with vast scope which has not received full attention in India. Huffaker and Kennett (1956) showed that in evaluating these predators, their well developed searching capacities, synchrony with the prey, environment and seasonal activities and the behavioural patterns and adaptations that are highly specialised to reduce the prey densities and to survive at low prey densities, should form the criteria.

With a view to add up to the information on the morphological aspects, a detailed study of the external morphology of the grub, pupa and adult of Cheilomenes sexmaculata F. which is one of the commonest species in South India, has been undertaken. In order to study the synchrony of the predator with its prey and to collect information on the effect of various weather factors individually on the predator and prey and also on the predator prey coaction, population studies of this beetle and its prey Aphis craccivora K. (Aphididae-Homoptera) on Gliricidia maculata H.B. & K. in the field, have also been undertaken.

REVIEW OF LITERATURE

A. Systematic Position of the Family Coccinellidae

Coccinellidae Latreille 1807, a very large family in the order Coleoptera and suborder Polyphaga was included in the superfamily Cucujoidea by Beeson (1941) and Essig (1958). But Brues et al (1954) have placed it in another superfamily Colydioidea. Imms (1960) treated the family in the superfamily Cucujoidea and section Clavicornia under the suborder Polyphaga. Two sub families viz. Coccinellinae and Epilachninae were recognised by Lefroy (1909), Fowler (1912), Fletcher (1926) and Beeson (1941). Kapur (1948b) erected a new subfamily Tetrabrachynae with a single genus Tetrabrachys. The subfamily Coccinellinae which comprises the carnivorous forms contains a number of tribes, many of which are without clear keys for identification. *Cheilomenes sexmaculata* F. belongs to the tribe Coccinellini of the subfamily Coccinellinae.

B. General Characteristics of the Family Coccinellidae

The family Coccinellidae comprising nearly 5,000 species have a wide range of distribution (Imms, 1960) and are mostly brightly coloured and spotted insects with convex bodies. The characteristic features of the family are the four segmented tarsi with the third segment concealed in the deeply furrowed second segment, except for the subfamily Tetrabrachynae (Kapur, 1948b) where all the four segments of the tarsus are well developed. The tarsal claws are toothed at the base. Last segment of the maxillary palpi are securiform and the antennae usually 11 segmented with a terminal club.

Larvae with their body usually setose; mandibles sickle shaped with molar bases (except in Epilachninae); legs without a distinct tarsus. Pupae exarate, usually conspicuously coloured and attached by their caudal extremity to the substrate.

C. Size and Shape

The members of the family Coccinellidae are small to medium sized (rarely exceeding 6 mm. in length, Subramaniam, 1923), oval, convex and ventrally flattened beetles with the head partially concealed beneath the pronotum. Some of the smallest species are the European *Clitostethus arcuatus* Rossi. which measures 1.2-1.5 mm. and the American *Stethorus picipes* Casey. measuring 1-1.5 mm, while the largest species are *Anatis ocellata* (Linn.) of Europe with 8-9 mm. and *Anisolemnia dilatata* (Fab.) with 11.2 mm. and *Synonycha grandis* Thunberg. with 13.6 mm. both of Southern Asia and Malayasia.

D. Colour and Colour Variation

The lady bird beetles are often brightly coloured and are remarkable for the wide range of colour variation which they exhibit. Different shades of black, orange, or yellow are common but the predominant colour, especially in most common species is yellow with characteristic spots or lines (Subramaniam, 1923). *Cheilomenes sexmaculata* F. is remarkable in exhibiting colour variations within the species. Typically each elytra carries three chevron like markings as well as a black line on the anal margin. Subramaniam (1923) and Kapur (1939) reported three main types of colour variations in the above species. Rakshpal (1951) observed that the elytral spots develop gradually after 2½ hours of emergence and the full compliment of colouration is accomplished in ten hours. This gradual development of colouration was noted by Fitzgerald (1941b) in *Chilocorus distigma* Klug. Varma (1954) recorded nine varying grades of colour pattern between *Coccinella septempunctata* Linn. and its variety *C. septempunctata* Linn. var. *divaricata*. Lal and Mandal (1958) observed that cross breeding between species lead to colour variation in *Epilachna* while Dryltsov (1958) found that in some species melanization is positively correlated with humidity. Effect of temperature on colouration in *Adonia variegata* (Goeze.) has been reported by Kapur (1942).

E. Habitat and Distribution

The sub family Epilachninae is exclusively phytophagous, attacking mostly Cucurbitaceous and Solanaceous plants and they are usually found on the host plants itself. The members are cosmopolitan in distribution (Essig, 1958). One of the tropical species common in India is *Epilachna vigintioctopunctata* F. (Subramaniam, 1923).

Very little is known regarding the biology and habits of the subfamily Tetrabrachynae. The habitat in which the members were found vary considerably and they have been recorded under stones, dried moss, under the bark of trees and in soil. *Tetrabrachys robusta* and *Tetrabrachys gandhara* have been recorded from North India (Kapur, 1948b).

The members of the sub family Coccinellinae, with the exception of the fungivorous Psylloborini, are exclusively predaceous both in the adult and larval stages (Imms, 1960) and have a world wide distribution. Further they have been recorded from low plains upto the high mountains. As reported by Beeson (1941) *Adonia variegata* (Goeze) were found in the Himalayan ranges upto 10,000'. Rao *et al* (1956) recorded *Chilocorus nigritus* (Fabricius) from high altitudes of 4,500 - 5,000' in South India. *Coccinella distincta* is found in association with ants (Imms, 1960).

The species under study has a wide distribution and has been recorded from various parts of North and South India and as observed by Subramaniam (1925), it is the most widely distributed species in South India. Places recorded in India include Behar, Calcutta, Dehra Dun (Stebbing, 1903, 1914) Orissa (Kapur, 1940) Punjab (Rahman, 1941) New Delhi (Pruthi, 1942), Kanpur (Sharga, 1948) Bombay (Sagal and Trehan, 1949) and various localities in South India (Subramaniam, 1925, Puttarudriah and Channabasavanna, 1955). It has been recorded also from Philippines (Otanes and Butac, 1935) and U.S.A. (Thompson, 1943).

F. Food Habits

The food habits of Tetrabrachynae are unknown. As already mentioned the Epilachninae are all phytophagous, feeding on various species of green plants. The subfamily Coccinellinae consists of the predaceous forms preying upon various arthropods especially insects. But the tribe Psylloborini are largely fungus feeders. The food habits of only the Coccinellinae are reviewed here.

(i) Prey Preference:

Schilder and Schilder (1928) and Balduf (1935) quoted by Hagen (1962) are of opinion that some degree of specificity for certain prey groups existed at the Coccinellid tribal level. Thus Hyperaspini feed mostly on Coccids, Hippodamini on Aphids and

Psylloborini on fungi (Hagen, 1962).

Brumus Spp. and *Cheilomenes sexmaculata* F. are polyphagous. The latter has been reported to feed on various species of aphids (Bagal and Trehan, 1949), Citrus psylla (Hussain and Nath, 1927), Sugarcane white fly, *Aleurolobus barodensis* Mask. (Kapur, 1940) *Pyrilla perpusilla* (Rehman, 1941) and on scales and mealy bugs on mango (Sharga, 1946).

Among the prey species, the various members of the order Hemiptera stand first, followed by rare records of Lepidoptera and Coleoptera. Kanirvo (1947) reported that the larvae of *Autographa gamma* (Noctuidae-Lepidoptera) were eaten by the Coccinellid, *Anatis ocellata* (Linn.). Alfaro (1945) observed *Coccinella septempunctata* destroying the eggs of *Leptinotarsa decemlineata* Say. (Chrysomelidae-Coleoptera). The genus *Stethorus* feed mainly on mites (Kapur, 1949). Puttarudriah and Channabasavanna (1953) reported that *Stethorus pauperculus* Weise. feed on Sorghum mite, *Olygonychus indicus* H. An interesting case of the adults of *Exochomus flavipes* feeding on the corpses of small Diptera attracted to light in Madagascar was reported by Fitzgerald (1941a).

(ii) Feeding Behaviour:

The lady bird beetles and their larvae attack all stages of its prey such as eggs, larvae, nymphs, pupae and adults (Besson, 1941). The young Coccinellid larvae usually pierce and suck the contents from their prey. Later larvae develop, in addition, a chewing action and the whole prey may be consumed or the heavily sclerotised parts may be left behind as observed by Kapur (1942) in the case of *Adonia variegata*.

Delucchi (1955) described the mode of feeding of the larva of *Pullus impexus* (Muls.). The grubs after sucking the contents of the eggs of the aphid for some time, eject a fluid from its gut into the egg sac and suck up the contents again. This process of regurgitation and sucking back is repeated until the whole content of the egg is digested and absorbed. Extra oral digestion occurs in *Scymnus* (Davidson, 1924, Kapur, 1942), Stethorus (Fleshner, 1950; Collyer, 1955; Putman, 1955) and *Brumus* (Kapur, 1942).

The adults of *Adonia variegata* (Goeze.) nibble through the body wall eating the inner contents bit by bit and the heavily sclerotised parts are left behind (Kapur, 1942).

(iii) *Feeding Capacity*:

The Coccinellids vary in their feeding capacities both in the adult and larval stages. According to Lefroy (1909) the total consumption of aphids by a single larva of *Cheilomenes sexmaculata* F. during its life time is 2,400 while Bagal and Trehan (1948) found it to be 503 for *Cheilomenes* and 420 for *Coccinella septimpuncata* Linn. Adults, however, are heavy feeders. Maximum number of aphids consumed by a pair of *Cheilomenes sexmaculata* F. was 16,521 and that of *Coccinella septempuncata* F. was 22,574 during their life time with an average of 60.84 and 106.29 aphids/adult/day (Bagal and Trehan, 1949).

(iv) *Cannibalism*:

Most species of Coccinellids, both as adults and larvae, exhibit a tendency to feed on the eggs and larvae of its own species. Cannibalism has been reported to occur in various species of lady birds (Stebbing, 1903; Lefroy, 1909; Davidson, 1924; Kapur, 1942; Fleschner, 1950; Banks, 1955, 1956). Putman (1955) found that cannibalism is not an important and regular habit with *Stethorus punctillum* Weise. as it becomes extensive only when the prey is scarce. Cannibalistic adults and larvae may eat prepupae and pupae also (Hagen, 1962). The size of the egg batch, the differential hatching among the eggs of the same batch, and the infertile eggs present are all factors conducive for egg cannibalism (Banks, 1955, 1956). Hagen (1962) has stated that the nature of egg deposition, i.e. either singly or in batches itself is another factor involved, and in most species of *Chilocorini*, *Scymnini* and *Hyperaspini* which lay their eggs singly and hidden, egg cannibalism is rare (Fleschner, 1950; and Banks, 1956).

C. Life History Studies

(i) *Mating*:

Mating in *Cheilomenes sexmaculata* F. usually occurs 3-4 days after emergence and first copulation may last upto two hours (Sagal and Trehan, 1949). Mating continues usually at frequent intervals during the day. According to Mcdowall (1941) females of *Cheilomenes sexmaculata* F. do not copulate unless they are fully fed. Taylor (1935) observed cross pairing between two species viz. *Cryptognatha nodiceps* Mshl. and *C. simillima* Sic. and the offsprings were of a hybrid type.

(ii) *Oviposition*:

Preoviposition period ranges from two to six days. Eggs are often laid in batches of two or three rows on the undersurface of the leaves (Sagal & Trehan, 1949), and are in most cases exposed. But *Scymnus severini* Wse. lays its eggs singly in an empty covering shell of the *Aspidiotus destructor* Sign. (Taylor, 1935) and *Rodolia chermesina* Muls. lay their eggs on the body or the waxen tail tuft of the *Icerya* (Fitzgerald, 1941a).

Clausen (1915) in his study of aphid-feeding Coccinellidae found that, under optimum conditions, the deposition of eggs takes place daily during a period extending from approximately two weeks after emergence until death.

The eggs are usually yellow, cigar shaped and stand on end (Bagal and Trehan, 1949), while in *Chilocorus distigma* Klug and *C. wahlbergi* Muls. the eggs lie on one side (Fitzgerald, 1941b).

(iii) *Incubation Period*:

The incubation period of the egg varies considerably in different species. It also depends on the season (Bagal and Trehan, 1949). The eggs of *Cheilomenes sexmaculata* F. hatch in about two to four days depending upon the weather conditions, the time being longer during cold months. (Bagal & Trehan, 1949). A long period of 20 days has been reported for *Menochilus sexmaculata* during winter (Trehan & Malhorta, 1959).

(iv) *Hatching*:

The eggs of *Cheilomenes sexmaculata* F. hatch by a vertical slit at its free end. Before hatching the egg loses its original yellow colour and turn yellowish white. The grubs rest over the egg shells and commence free movements after about three to six hours (Subramaniam, 1925; Bagal & Trehan, 1949). In *Adonia variegata* (Goeze.) the eggs hatch by irregular cracks in the subapical region (Kapur, 1942).

(v) Grubs:

There are four larval instars in *Cheilomenes sexmaculata* F. (Lefroy, 1909; Kodawall, 1941; Bagal & Trehan, 1949) as in other Coccinellide (Imms, 1960). The duration of the larval stage varies considerably with the species and season. Bagal & Trehan (1949) observed that this extends four to fifteen days in *Cheilomenes sexmaculata* F. Longer periods ranging upto 20 days have been reported by Trehan & Malhorta (1959) in the case of *Menochilus sexmaculata*.

The different instars vary little except for the colouration and size of the body. They are usually slate or black coloured, often spotted with yellow or white. Body is usually beset with spines and tubercles. In genera like *Hyperaspis*, *Scymnus* and *Platynaspis*, the spines are wanting and the whole body is covered with a white floculent secretion (Lefroy, 1909; Subramanyam, 1923; Imms, 1960).

(vi) Pupa:

When about to pupate, the grubs usually suspend themselves by the caudal extremity which is attached by means of a secretion to plants or other objects. The pupae are naked and usually conspicuously coloured (Imms, 1960). Delucchi (1955) observed the formation of a kind of cocoon composed of silk filaments by *Pullus impexus* (Muls.). They are either surrounded by the last larval exuviae as in *Chilocorus distigma* Klug. (Fitzgerald, 1941b) or the exuviae may be pushed back to the anal extremity as in *Exochomus ventralis* (Fitzgerald, 1941a). The pupal period varies with species and seasons and in *Cheilomenes sexmaculata* F. it ranges from three to six days, the period being longer in cold seasons (Bagal & Trehan, 1949). A period of nine days have been reported in the case of Chilocorus distigma Klug. (Fitzgerald, 1941b).

(vii) Adult Longivity and Sex Ratio:

The adult life is usually very long lasting for several months in many species, 18 weeks for Cryptognatha nodiceps Mshl. (Taylor, 1935) and five to eight weeks for Rodolia chermisina Muls. (Fitzgerald, 1941b). The adult life period in Cheilomenes sexmaculata F. ranges upto four months in Bombay as recorded by Bagal and Trehan (1949) and they found that females when kept alone lived for a relatively longer period. The period may be longer in cold season (Kapur, 1942). Sexes are equally represented in Chilocorus distigma Klug. and C. wahlbergi Muls. (Fitzgerald, 1941b) while, females outnumber males with a sex ratio of 4 : 3 in Adonia variegata (Goeze.) (Kapur, 1942). In Cheilomenes sexmaculata F. also, the females always outnumber males with a sex ratio of approximately 59 : 41 as observed by Bagal and Trehan (1949). Beeson (1941) mentioned that there is a range of one to 11 generations annually in the Coccinellids of the temperate and tropical regions. Generally the tropical species are multivoltine (Hagen, 1962). Bagal and Trehan (1949) estimated that Cheilomenes sexmaculata F. and Coccinella septempunctata L. pass through nearly 20 generations during the course of an year.

(viii) Fecundity:

The number of eggs deposited by a female during its life cycle varies with the species and environmental factors. Low fecundity has been reported in species like *Scymnus nubes* Casey. (Davidson, 1924) where, a female lays about 3 1 eggs on an average. *Pullus impexus* (Mulls.) lays about 90-100 eggs according to Delucchi (1955). High fecundity has been recorded for *Cheilomenes sexmaculata* F. and *Coccinella septempunctata* Linn. by Bagal & Trehan (1949). The maximum number of eggs laid by a female of the former species is 2,384 in two months and nine days while, the latter species lays about 3,765 eggs in two months and 21 days.

H. Hibernation

Many coccinellids in the temperate zone hibernate as adults, but the intensity of their dormancy varies interspecifically (Hagen, 1962). The subtropical or tropical multivoltine species, e.g. *Rodolia cardinalis* (Mulsant.), according to Cressman and Dumestre (1930) and Bodenheimer (1932) as quoted by Hagen (1962), are retarded in development and reproduction during mild winter conditions and can be killed by severe winters. The adults of *Stethorus punctillum* Weise. hibernate in the soil (Putman, 1955) whereas those of *Pullus impexus* (Muls.) do so in the crevices of the bark of trees for as long as about six months (Delucchi, 1955). Though hibernation usually takes place in the adult stage (Subramaniam, 1923) *Pullus impexus* (Muls.) overwinter in the egg stage as well as adults (Delucchi, 1955) and *Hyperaspis lateralis* Mulsant. according to Mckenzie (1932) as quoted by Hagen (1962) may do so in the pupal as well as adult stages in California. In North India, Kapur (1942) reported that *Scymnus quadrillum* Motsch. hibernates during the months of January and February while in the moderate climate of South India overwintering is not common (Subramaniam, 1923).

I. Aestivation

Rao *et al* (1964) observed that the adults of *Chilocorus nigritus* assembling in considerable numbers on the undersurface of the leaves of a banyan tree in Coimbatore in summer during 1963-65. The adults of *Coccinella novemnotata franciscana*, *C. californica* and *Hippodamia quinquesignata punctulata* aestivate in California and the period extends to nearly 100 days (Hagen, 1962). The aestivation according to Hagen (1962) is not obligatory.

J. Aggregation

Perhaps the most fascinating phenomenon the Coccinellids display is the formation of "aggregations" (Hagen, 1962) or "Mass assemblage" (Kapur, 1945). The phenomenon consists in the assemblage of large number of adult beetles, usually on prominent objects such as mountain peaks (Eddy, 1939) or upon trees (Malhorta and Krishnaswamy, 1959; Katakar, 1959) or on rocky stratas (Poulton, 1936), which has been referred to as "Hypostatic aggregations" by Hagen (1962). In a few instances the beetles have been found to aggregate in moist situations, such as in the ground at the bases of grasses, as has been observed by Kapur (1964) in the case of *Epilachna bisquadripunctata*. Hagen (1962) called this type as "Climatotactic aggregations". Some of the important common characteristics of aggregating species according to Hagen (1962) are their association with more mobile and active prey species like aphids, the long period of dormancy or diapause exhibited and the mating at the aggregation sites shortly before or after the beetles disperse. The dormancy can be either hibernation or aestivation. Kapur (1945) observed that the aggregating beetles do not feed, lay inert and close together and when disturbed move a little but rarely take to flight.

The size and character of the assemblage are varied. The number of beetles per cluster on banyan trees in the case of *Chilocorus nigritus* Fabr. was two to ten according to Katekar (1949). Largest group of *Epilachna bisquadripunctata* according to Kapur (1954) was 4' long 2½' wide and 2" - 4" deep. Hagen (1962) stated that a large aggregation consisted of about 600 gallons of beetles with about 70,000 beetles per gallon.

The significance of this phenomenon is not yet clearly understood. Hagen (1962) favours the view of Poulton (1934, 1936) that aggregations are formed basically for bringing the sexes together which might have been separated due to the searching for their ephemeral prey. Probably other factors such as hibernation (Poulton, 1934) or search for equitable temperature conditions (Malhotra and Krishnaswamy, 1958) may also be involved. The larger tribes that are not represented by species that aggregate are *Hyperaspini*, *Scymnini*, *Psylloborini* and *Chilocorini* (with the exception of *Brumus octosignatus* and *Chilocorus nigritus*) (Hagen, 1962).

E. Dispersal and Migration

There are all degrees of movement by adult Coccinellids from simple, short, low flights from one part of a field to another part in search of food to extended migratory flights into different habitats where aggregations are usually formed (Hagen, 1962). Migratory flights according to Carnes (1912) may occur with the wind (Hagen, 1962); while Marriner (1934), quoted by the previous author, has observed that migration may also occur against gentle winds. Dispersal occurs upon the termination of dormancy in aggregational sites. Hagen (1962) reported that Hippodamia convergens exhibits "remigration" in the sense, that they return back to the original habitats after migration.

L. Defence Mechanisms

The reddish colour displayed by most coccinellid adults is apparently apposematic in function acting as a warning colouration (Hagen, 1962). According to Folsom and Wardle (1934) the ill-flavoured lady birds possess comparative immunity from birds.

Reflex Bleeding:

Larvae and adults, when disturbed, eject small drops of a glanduler secretion from femoro-tibial articulations which is called reflex bleeding. The liquid has an amber colour and very offensive odour with bitter quinine taste (MacIndoo,1916). This yellow fluid has been reported to exude from the intersegmental pores on the body of the grubs (Taylor, 1935). The primary function according to McIndoo (1916) is that of protection and it may also serve as a means for individual and sexual recognition. Pradhan (1942) believes that the cryptonephridial stage of the malpighian tubes in Coccinellids is strongly correlated with the extra consumption of water due to the reflex bleeding.

M. Natural enemies

Adults, grubs and pupae of Coccinellidae have been reported to be parasitised by certain hymenopterous parasites. But only very few predators have been noticed. Pruthi (1942) reported the occurence of a species of Tetrastichus (Eulophidae-Hymenoptera) on the larvae and pupae of *Cheilomenes sexmaculata* F. Subramaniam (1950) recorded *Homalotylus flaminius* (Dalman.) (Encyrtidae-Hymenoptera) as a parasite on the grubs of *Cheilomenes sexmaculata* F. in Bangalore. Puttarudriah and Channabasavanna (1953) have noted *Homalotylus* sp. *Tetrastichus* sp. and an undetermined braconid parasite attacking the grubs of *Cheilomenus sexmaculata* F. *Perilitus coccinellae* (Schrank.) (Braconidae-Hymenoptera) has been recorded as a cosmopolitan parasite on adult of *Coccinella septempunctata* Linn. and *Adonia variegata* (Goeze.) in Hunan (Liu, 1944), on *Coccinella novemnotata* Hbst. and *Coleomegilla maculata lengi* Timb. in Canada (Hudon, 1959) and on *Coccinella trifasciata perplexa* Muls. in Ontario (Smith, 1960).

The larvae of *Chrysopa rufilabris* Burm. (Chrysopidae-Neuroptera) have been recorded as being predaceous on the eggs of *Stethorus punctillum* Weise. in Ontario by Putman (1955). Chapman (1955) reported the lady bird beetles as food of grizzly bears in Montana.

H. Biological Control and Coccinellidae

The insectivorous coccinellids have played an important role in the development of biological control of crop pests. The introduction of the vedalia beetle, *Rodolia cardinalis* Muls. was the first dramatic case of biological control and the method of mass-culturing and periodically colonising a natural enemy began with the mealy bug destroyer, *Cryptolaemus*. Different species of Coccinellids have been used in many parts of the world including India, to control particular crop pests.

(i) Utilisation of Coccinellids Outside India:

In 1889 the Australian *Rodolia cardinalis* Muls. was introduced into California to control the cottony cushion scale, *Icerya purchasi* Mask. and the pest was brought under control in 18 months (Sweetman, 1936). According to Metcalf and Flint (1962) the beetle has subsequently been introduced into 40 different countries and got established in at least 52 countries giving effective check to the scale.

Cryptolaemus montrouzieri Muls., another Australian beetle has been introduced into California and other countries for the control of the Citrus mealy bug, *Pseudococcus citri* (Metcalf and Flint, 1962).

Taylor (1935) and Fitzgerald (1941b) reported the successful introduction of various Coccinellids for the control of Coccids on coconut in Fiji and Seychelles respectively.

(ii) Utilization of Coccinellids in India:

Rodolia cardinalis Muls. was introduced into South India from California and Egypt in 1929 to control the fluted scale, *Icerya purchasi* Mask. on wattle trees in Nilgiris. The pest was brought under check in a short time but flared up again in 1941 when mass breeding of this beetle had to be resumed (Rao and Cherian, 1944).

An attempt made in Coimbatore in 1952-53 failed to give spectacular results with *Chilocorus nigritus* F. in the control of coccids on coconut and vegetables because of the poor breeding power of this species (Rao *et al*, 1954).

C. Predator-Prey Relationship

Studies designed to throw light upon the fundamental nature of the predator-prey interaction in particular and the interaction of this co-action with other important parameters of the population changes such as weather, food etc. have been made by several workers (Smith, 1935; Thompson, 1939; Debach and Smith, 1941; Debach, 1958; Holding, 1959).

(i) Role of Predation:

Hufaker and Kennett (1956) made a study of the role of predation under field conditions for the control of the cyclamen mite, *Tarsonemus pallidus* Banks. in strawberry plantings in California by the use of a native predatory mite *Typhlodromus* Sp. They came to the conclusion that the predator-prey oscillation, at least in some natural biological systems, is not self exterminating. Sustained equilibrium at very low densities seemed to them as a primary characteristic of cyclamen mite/predator interaction. All populations even if under dominant control by a predator, have certain low levels of density representing security from predation which are associated in one way or other with highly protective refuges and space coverage difficulties at low prey densities by the predator.

Debach (1958) stated that weather factors are regulatory in nature and that its effect is obtained through its interaction with micro-environments where as natural enemies may regulate insect populations at low levels even if all other factors are exceptionally conducive for the increase.

(ii) Role of Dispersion in Predator-Prey Relation:

Hufaker (1958) stated that in one local area the predator-prey relation may be in one phase of oscillation while in an adjacent area it may be in a diametrically opposed phase. The complexity of dispersal and the general ability of the prey species to repopulate after a severe predation determine the period of oscillations.

(iii) Synchrony with the Prey:

Dickson *et al* (1959) made a study of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton) and its natural enemies in California. The authors found that the Coccinellid population is positively correlated with the aphid population. Putman (1955) realised the same relationship with *Stethorus punctillum* Weise. and its prey. But Banks (1955) from an ecological study of Coccinellids associated with *Aphis fabae* Scop. concluded that the populations of predators apparently varied independently of those of the aphids and the abundance of Coccinellids depend on the proximity to other alternate hosts harbouring lady birds and other such factors. According to Hagen (1962) Coccinellids that attack more or less sedentary prey such as scale insects and mealy bugs usually display close synchrony with their prey.

MATERIALS AND METHODS

A. Preservation and Mounting Techniques

The beetles used in this investigation were collected from the field as they were available in plenty in most part of the year on Gliricidia maculata H.B. & K. infested with Aphis craccivora K. The larvae, pupae and adults were preserved in 70% alcohol.

To study the various structures, the specimens were first boiled in 10% KOH for 10 minutes, which dissolves all fatty and muscle tissues. Further the boiling was helpful in rendering the heavily sclerotised parts flexible to a certain extent. The specimens after washing with distilled water to remove the KOH, were transferred to glacial Acetic Acid and the remaining KOH was pressed out by using a bent needle. The transparent structures, like genitalia, were stained with acid fuchsin, by keeping in it for 12 hours. Excess stain was removed by washing with glacial acetic acid and the specimens were cleared in carbol chloral and mounted in chloral gum.

To study the wing venation, the hind wings were separated from fresh specimens and mounted in glycerine.

To study the wing folding pattern, the folded wings were removed carefully from the body, taking care not to disturb the foldings. In fact the folding retained the original pattern for a very long time. A sketch was made showing the folded wing as such. Then the folds were opened one by one in the order of succession and the actual lines and areas of foldings were located with reference to the veins present.

The dissections were done under a stereoscopic binocular microscope and all the figures were drawn with the aid of a camera lucida. Measurements were made with a calibrated ocular micrometer.

B. Rearing Techniques

The grubs used for the present study were obtained from the laboratory rearing. A rectangular glass cage (Plate IX, Fig. I) with enough provision for good aeration was used as oviposition chamber. This cage was placed over a trough of water with a cardboard in between. Through a hole in the centre of the cardboard, the cut end of the terminal portion of a branch of *Gliricidia* infested with *Aphis craccivora* K. was inserted and kept dipped in the water. This arrangement kept up the turgidity of the leaves and stem for at least a day. Eggs were usually laid on the leaves. But occasionally some beetles were found to oviposit irregularly over the surface of the glass. The eggs were collected and kept in petridishes for hatching.

For rearing the grubs specimen tubes of size 5" x 1", with both ends opened and tied over by thin cloth were found successful. A leaflet of *Gliricidia* infested with *Aphis craccivora* was kept inside with a wet cotton swab attached to the tip of the leaf petiole. When the hatching was over, the grubs were transferred to these cages. The leaves were changed every day. For mass rearing 3 or 4 grubs were put in one tube.

C. Predator-Prey Relationship of *Cheilomenes sexmaculata* F. and *Aphis craccivora* K.

The population studies were conducted in the fields of

Central farm attached to the Agricultural College & Research Institute, Coimbatore. The general population trends of both the predator and the prey were assessed by taking weekly counts for a period of 48 weeks from 3-3-1962 to 26-1-1963. The counts were taken in the morning between 8 A.M. - 9 A.M. on all Saturdays.

(i) Experimental Design:

The experimental plot consisted of 18 Gliricidia plants, of nearly equal age and size, planted in three rows. Each week's observations were taken on six plants, selected at random by the use of random numbers. One each plant four branches were selected at random, one on each of the four sides, at a height between 4'-8'. The selection of the branches was done at random taking care to avoid any biassed selection of only infected branches. The unit area taken for observation consisted of the terminal unopened tender leaves and the next eight older leaves, as the aphid infestation was found to concentrate on this region only.

(ii) Counting of *Cheilomenes sexmaculata* F.:

The number of adults of *Cheilomenes sexmaculata* F. present in the unit area on the branches selected was counted directly.

(iii) Counting of *Aphis craccivora* K.:

Manual counting of aphids was too tedious and hence some other method of assessment had to be resorted to. Banks (1954) followed a system of arbitrary classification of aphid infestation into five different groups, which he claimed as giving a fairly good estimate of the population. The same method with suitable modifications was adopted and was found to give better results.

(iv) Classes of Aphid Infestation:

The infestation of aphids was grouped into five arbitrary classes based on the intensity of attack as follows:

(a) Zero (O)	Where there was no aphid present.
(b) Very Light (V)	Where there was one aphid to a small colony or some scattered individuals confined to the young tender leaves.
(c) Light (L)	Where there were several aphid colonies present on the stem and leaves and not confined to the crown and upper leaves.
(d) Medium (M)	Aphids present in large numbers not in recognizable colonies, but diffuse and infesting a large proportion of the stem and leaves.
(e) Heavy (H)	Aphid present in very large numbers, very dense, infesting all the leaves and stem, the stem usually black with aphids.

When any difficulty arose in deciding the appropriate class, the rule adopted was to use the higher of the two probable categories as it was believed that the tendency would be to underestimate than to overestimate the numbers. The selection of plants and branches at random, and the observations on a large number of samples, as 24, avoided all errors that might creep in due to the biassed observations.

(v) Estimation of the Aphid Numbers of the Classes:

The estimated number of aphids for each class was found out by counting seven samples representing each and finding the average of it.

These samples were picked up from the field carefully without causing any disturbance to the aphid colonies and kept sealed in individual labelled bottles containing 95% alcohol and the counting was done later.

Before counting each sample, the aphids were dislodged from the leaves and stem by slow agitation of it in the alcohol and with the use of a brush. From the sample containing the dislodged aphids, a small portion was taken with an ordinary ink filler and poured in a petridish. A white paper with parallel lines drawn on it was pasted at the bottom surface of the petridish. When all the aphids settled at the bottom of the dish the excess of alcohol was carefully drained of with the filler so that the aphid bodies did not move while counting. Counting was done under a stereozoom microscope with the aid of a talley counter. This procedure was repeated and the whole number of aphids in each sample was counted and the number tabulated. The average for each class was calculated (Table I).

The meteorological data were obtained from the Agricultural Meteorologist, Agricultural College & Research Institute, Coimbatore. The weekly absolute values of the weather factors were taken and the correlations worked out statistically.

TABLE I

Number of *Aphis craccivora* Koch in the different classes of infestation

Sl.No.	Class of infestation	No. of aphids in each sample							Mean no. of aphids for each class
		1	2	3	4	5	6	7	
1	V	7	30	59	1	21	71	5	27.71
2	L	905	1916	810	1835	472	1913	507	1192.57
3	M	2303	2125	2037	2242	3016	2806	2858	2481.57
4	H	4370	9196	3623	5327	6123	4125	8033	5828.14

EXPERIMENTAL RESULTS

I. External Morphology of the beetle

A. The Head (Plate II)

(i) General Structure:

The head of *Cheilomenes sexmaculata* F. is transverse, subquadrangular and flat dorsoventrally with a prognathous, chewing type of mouth parts. The various sclerites of the head capsule have fused so closely that all the sutures have nearly or entirely disappeared. The epicranium is partially concealed beneath the pronotum. The head capsule is yellow or yellowish brown with the whole of epicranial surface black in colour.

(ii) Sutures and Areas of the Cranium: (Fig. 1, 2, 3)

The surface of the cranial capsule cannot be divided into distinct areas because of the absence of the usual sutures and ridges. Clypeal region consists of an anteclypeus and a postclypeus. The postclypeus is united with the frons. The anteclypeus is represented by the membranous region giving attachment to the labrum in front. The subgenal sutures form the lower margin of the lateral walls and give rise internally to a distinct subgenal ridge. The ocular suture forms a faint line around the compound eyes.

Gula is the region at the base of the head ventrally between the labium and foramen magnum. The gular sutures bound it laterally. The sutures extend only a short distance cephalad from the foramen where they lead to definite gular pits or the posterior tentorial pits. The body of the tentorium has disappeared leaving only a pair of fine thread like anterior arms and a pair of spur like posterior arms.

(iii) Visual Organs: (Fig. 1, 2, & 3)

The compound eyes are prominent, finely facetted oval organs located on the cephalo-lateral margins of the head, which can be seen from both dorsal and ventral aspects. The eyes are relatively larger in females. Ocelli are absent.

(iv) Appendages of the Head:

(a) Antennae: (Fig. 4)

The antennae are clavate; rather short; 11 segmented; concealed beneath the head and are located mesocephalad of the eyes. Scape is the longest segment and is broader distally with three prominent setae followed by the shorter and narrower pedicel. Funicle with five segments of nearly the same size, the segments gradually increasing slightly in width towards the club. The terminal four segments are greatly broadened, largely on one side, forming a rather distinct club. An oval sensory area is present on the terminal segment. Sensory hairs are located on all segments of the antenna.

(b) Mouth Parts: (Fig. 5,6,7,8,9,10 & 11)

The mouth parts are of the typical chewing type. Labrum is a transverse, quadrangular structure with prominent setae dorsally and attached to the anterior margin of the fronto-clypeus by a membranous portion (anteclypeus of Sweetman, 1930) and it can be retracted back to some extent under the fronto-clypeus.

Epipharynx: Lining the ventral surface of the labrum is the membranous epipharynx which has minute ridges over the anterolateral angles as shown in the fig. 7. It extends caudad under the clypeal region.

Tormae: are a pair of small sclerites of sigmoid shape located ventrally in the lateral angles between the labrum and anteclypeus and it extends slightly to the epipharyngeal surface of the clypeus.

Mandibles are a pair of thick stout organs, bifid at their apices forming two teeth like projections, the inner one being smaller than the outer one. There is a basal tooth which is bicuspidate. A small membranous lobe on the ventral surface above the basal tooth bearing a dense fringe of hairs forms the submola.

Maxilla is well developed with the full compliment of parts viz. cardo, stipes, palpifer, maxillary palpus, galea and lacinia.

Cardo contains a deep groove on its base by which it articulates with the hypostomal portion of the subgenal ridge. An internal projection, the cardo process, extends into the head capsule and serves for muscle attachment. The stipes is composed of a proximal eustipes and a distal subgalea (parastipes of Khatib, 1946). The palpifer, situated dorsad of the basal sclerite of the stipes, is a hollow cylinder bearing the maxillary palpus. The palpi are elbow shaped, pubescent and four segmented with the fourth segment longest followed by the second, third and the first in the order given. The fourth segment is flattened and securiform. Galea is two jointed with a basigalea and a distigalea while, lacinia is a single sclerite partly covered by the galea. Distal ends of the lacinia and distigalea are covered with dense brushes of hairs.

Labium is attached to the head capsule between the maxillae. The submentum is a heavily sclerotised structure firmly attached to the gular region, the only demarcation between them being a faint line, representing the gula-mental suture. Mentum is moveably attached to the submentum; the basal half is heavily sclerotised and the distal half membranous to which is attached the prementum. This allows the prementum to be retracted a little under the mentum.

Prementum (Pars stipitalis labii or labio stipites of Snodgrass, 1935) forms a sclerotic band with an anterior projection, bearing a pair of three segmented labial palpi distally on a membranous area representing the reduced palpiger. Small sensory hairs are present on the palpi. Glossae and para-glossae have become united to form a single lobe, the ligula which is densely covered with very minute setae.

B. Cervix

This is a wholly membranous region, covered under the overlapping pronotum in the natural condition. It is broader caudally and tapers to the cephalic extremity. Cervical sclerites are absent.

C. Thorax (Plate III)

(i) Prothorax: (Fig. 1 & 2)

The pronotum comprises a single sclerite which is transverse, hood like nearly twice as broad as long, and finely punctate dorsally with the anterior margin deeply emarginated. All the pronotal angles are rounded, the caudal angles being more noticeably so. The pronotum extends ventrally along the lateral margins. The ventral extension reaches the precoxale cephalad of the coxae, the line of fusion being marked by the precoxal fold and the furcasternum caudad of the coxae. A lateral carina (humeral carina) is formed at the line of folding between the dorsal and ventral surfaces.

The pleuron is a single plate formed by the ventral extension of the pronotum, known as the pseudopleuron (Crampton, 1926). The precoxale is present as a lateral extension of the basisternum cephalad of the coxae. The postcoxale is but slightly differentiated.

The prosternum is composed of a basisternum and a furcasternum. The former is a large sclerite which extends laterally and becomes united with the pseudopleuron at the precoxal fold. Posterior extension between the coxae, forming a process, is termed the prosternal lobe (Rivnay, 1928), intercoxal process (Maulik, 1936) or the eusternal lobe (Khatib, 1946). A long and narrow 'U' shaped carina is present on the ventral surface of the prosternal lobe. The furcasternum is between and behind the coxae. The furcal pits are a pair of very shallow slits produced by invaginations forming the furcae. The trochantin (Plate IV, Fig. 4) is a small pleural sclerite that has been drawn internally with the basal portion of the coxae. It is moveably attached to the coxae and to the body wall by a membrane.

(ii) Mesothorax: (Fig. 3 & 4)

Mesothorax is the smallest of the three thoracic segments. The notum can be divided into three areas: the prescutum, scutum and scutellum. The cephalic margin of the mesonotum is 'V' shaped with a deep inflection which forms the prephragma. The prescutum is a small triangular area of the notum middorsally near the anterior margin. The scutum is the largest division and lies between the prescutum and scutellum. The slender anterior extensions of the scutum are the prealar bridges or prealare. The scutum bears a pair of pointed anterior notal wing processes (suralare of Sweetman, 1950) and a pair of blunt posterior notal wing processes (Adanales of Sweetman, 1950) which support the elytra. The parascutellum is beneath the scutellum and extends laterad as a narrow band along the posterior margin of the scutum and gives rise to the axillary cord laterally. The scutellum is a prominent triangular raised area separated from the scutum by the scuto-scutellar suture. A groove is formed along the lateral margins of the scutellum and serves for the reception of the antero-mesal margins of the elytra when at rest.

The mesopleuron consists of an anterior episternum and a posterior epimeron, the two being united along the pleural suture. A longitudinal carina on the epimeron and a transverse one on the episternum (shown in the figure in dotted lines) divide them respectively into two regions. Ventrally the episternum rests upon the basisternum and bounds the coxal cavity antero-laterally. Epimeron surrounds the coxal cavity laterally. The middle coxal cavities are oval in shape and do not have trochantins.

The mesosternum is made up of an anterior basisternum (eusternum of Khalib, 1946) and a posterior furcasternum which is not visible externally. The former comprises the greater portion of the mesosternum and extends in front of and between the coxae. The portions in front of the coxae form the precoxalia. In the mesal region there is a pit, and a transverse carina passing through the centre of this pit divides the basisternum into anterior and posterior divisions. The furcasternum is not clearly marked externally as a distinct sclerite. When the coxae are removed, an inflexed portion bearing the slender rod like furcal arms antero-laterally can be seen which is considered as the furca sternum. A sclerotised rod in the middle connects these inflexed areas internally while they fuse with the cephalic margin of the metasternum posteriorly along an indistinct suture.

The mesothoracic spiracle is located ventrolaterally in the intersegmental membrane connecting the pro and meso thorax.

(iii) Metathorax: (Figs. 5, 6 & 7)

Metathorax is the most highly developed and largest of all the thoracic segments and is twice as broad as long. It shows special modifications both internally and externally to accommodate the highly developed wing muscles.

The notum can be divided into four areas viz., the prescutum, scutum, scutellum and post scutellum. The prescutum is an arched sclerite narrowed in the middle and broadened laterally. The anterior margin is semicircular and infolded which projects into the body cavity forming the prephragma. Anteriorly it is connected to the mesothorax with a membrane while the posterior margin blends with a semimembranous region connecting it with the scutum. The lateral extensions anteriorly form the prealar bridges.

The scutum constitutes the major part of the metanotum and is divided longitudinally by the median groove which is carried on to the scutellar region. The prescutal suture separates it from the prescutum while the scuto-scutellar suture differentiate it from the scutellum posteriorly. Two oblique sutures extending from the anterior end of the scuto-scutellar suture divide the scutum into anterior and posterior divisions. The scutum gives off two lateral projections viz., an anterior notal wing process and posterior notal wing process. A small muscle disc is present in the membrane anterior to the anterior notal wing process.

The scutellum is formed by two triangular sclerites, the portion of the median groove dividing them.

Post scutellum (Postnotum of Snodgrass, 1935) is a narrow sclerite connected to the posterior margins of the scutum and scutellum. Its projecting lateral arms are the postalar bridges (Postalare) while the posterior margin which projects into the body cavity forms the postphragma which is roughly divided into four lobes.

The metapleuron is divided into two areas, the episternum and epimeron, separated by the pleural suture. One peculiarity noticeable in the metapleuron is the extensive infolding and change of position undergone by the component parts. The episternum is divided into the katepisternum, which connects the pleuron to the sternum, the anepisternum and preepisternum. The katepisternum presents an infolding of its lateral margin at the basal half to get attached to the pleural suture. The dorsal extremity of the anepisternum is rounded forming the greater part of the pleural wing process. The epimeron is sub divided into the katepimeron and anepimeron by an indistinct suture. The katepimeron is subquadrangular in shape while the anepimeron is a long narrow band. The postalar bridge is connected to the katepimeron on the dorsal margin. An oval muscle disc is present in the membranous region cephalad of the postalare bridge.

The metasternum is flat, smooth and larger than the prosternum and mesosternum. It is composed of an anterior broader part, the basisternum and a posterior narrow region, the furcasternum.

The anterior region of the basisternum is inflexed at the mesothoracic coxal cavities. A sclerotized rod connects these inflexed areas. An indistinct suture separates the mesosternum and metasternum along the inflexed walls of the coxal cavities. It gives off a blunt tongue like process anteriorly which meet the caudal extremity of the mesosternum. A median groove (median suture of Sweetman, 1930; ensigmatic longitudinal groove of Khatib, 1946) divides the basisternum longitudinally while a transverse suture demarcates it into anterior and posterior divisions. The median groove forms a ventral median ridge internally.

The furcasternum, which bears the furcae internally, consists of a small median sclerite anterior to and between the metacoxae and a narrow transverse sclerite in front of each coxae. A median suture divides it longitudinally. The metafurca is highly developed and broadly 'Y' shaped with a ventral median ridge and three projections on either side. The ventral ridge is a continuation of the median ridge of the basisternum.

The metacoxal cavities are elongated formed in part by the inflections of the first abdominal sternum.

The meta thoracic spiracles are present laterally in the membrane below the mesoepimeron and is the largest of all the spiracles.

D. Legs (Plate IV, Figs. 1, 2, 3, 4, 5, 6 & 7)

The three pairs of legs are similar in shape and structure, the length increasing in the order of the pro, meso and metathoracic legs; short spines are present on all the segments of the leg.

Coxa: The pro coxa is long and spatula shaped with the dorsal surface opened for about two thirds of its length for the entrance of muscles and other internal structures. It articulates anteriorly with an irregularly wedge shaped trochantin. The trochantin and the basal third of the coxa is completely extended into the body cavity. The outer articulation of the procoxa is with the pseudopleuron and inner articulation is with the intercoxal process and the inflexed areas of the furcasternum. The meso-coxa is medium sized nearly ovate while the meta-coxae are larger, elongated and cylindrical. A trochantin is absent in both the cases. The basicoxal and coxal sutures are absent in all the cases.

Trochanter: is somewhat triangular in shape with a proximal round condyle which articulates with coxa. The pro, meso and meta trochanters are similar in shape, the size increasing slightly in the order given. Two depressions or fossae on the condyle serve for articulation with the coxal processes. Distally the trochanter articulates with the femur by an oblique hinge and the movement between the trochanter and femur is very much restricted.

Femur is the largest segment of the leg and is about 2½ – 3 times as long as broad. It has the maximum width in the middle tapering towards both the extremities and is deeply and broadly grooved on its flexor surface to receive the tibia when the leg is folded. The distal end contains a cavity for the reception of the condyle of the tibia.

Tibia is more or less equal in length to the femur and bent at the proximal end which permits it to fit into the groove of the femur when the leg is folded. The dorsal surface is deeply hollowed at its distal half for the reception of the tarsus when the leg is folded. The middle and hind tibiae bear a pair of spurs on the flexor surface at the distal end.

Tarsus is distinctly four segmented. The first segment is conical while the second one is flat and triangular with a groove on the dorsal surface. Both the first and second tarsomers are densely pubescent beneath. The third tarsomere is short and cylindrical which is characteristic of the family and is articulated proximally with the second while it is immovably attached to the fourth segment distally. The surfaces are bare. The fourth segment is conical and curved and forms the longest segment among the four. Distally it bears the pretarsus.

Pretarsus consists of a pair of bifid claws which are bent at right angles. The basal tooth is only a conical projection while the apical tooth is long and pointed. No arolium or empodium is present. On the ventral surface is a median oblong sclerite, the unguitractor plate, which is invaginated at its proximal end under the distal end of the fourth tarsomere.

E. Wings (Plate IV)

(i) The forewings or Elytra: (Fig. 8 & 9)

The elytra cover the entire dorsal surface of the body behind the caudal margin of the pronotum, with the exception of the mesoscutellum. They are heavily sclerotised, strongly convex and closely follow the general contour of the surface of the body. The scutellar margins of the elytra are contiguous with the mesoscutellum while the posterior(sutural margins of Richmond, 1931) margins are closely apposed each other and together they fit into the median groove on the metanotum at rest. The sutural and lateral (costal) margins are inflexed, the letter being more so and greatly thickened. The inflexed lateral margin form the epipleura which is flat ventrally so that it fits snugly against the surface to which the beetle is clinging. The inflection extend to the cephalic margin also. The entire surface of the elytron is closely punctated, but they do not arrange to form any definite striae. The elytra are yellowish or orange in colour with three characteristic black markings on the dorsal aspect, arranged one behind the other and a black line along the sutural margin. In some cases, the black spots are either absent or one or two may merge together forming a large spot.

The portion of the elytron serving for attachment to the notum is called the apophysis which is connected to the body by the alar membrane, the posterior margin of which is strengthened by a cord like structure called axillary cord. A median sclerite, considered to be second axillary by Khatib (1946), connects the apophysis with the pleural wing process. The other axillary sclerites are not discernible.

The venation is absent, but two faint lines considered to be tracheae by Sweetman (1930), are present.

(ii) The Hind Wings: (Fig. 10, 11 & 12)

Hind wings are membranous and in repose kept folded beneath the elytra. They are transluscent with a few opaque brown and black patches. The costal margin is entire; apex blunt; and anal margin divided by a short fissure proximally, separating a small trapezoidal area which is kept folded ventrally at repose. The wing membrane shows the presence of microtrechia all over it. When the wings are unfolded they extend beyond the length of the abdomen.

Venation: The wing venation conforms to the cantharid type (Imms, 1960) characterised by the presence of the coalesced M and Cu and the radial recurrent vein. The venation is much reduced and is seen clearly in the basal half of the wing only. All the veins have migrated forward, the costa, subcosta, radius and cubitus being crowded towards the costal margin of the wing.

Costa is a short convex vein lying along the costal border while subcosta is concave and is represented by the basal portion only, both ends being united with the radius forming a loop. The radius is a convex vein and it runs towards the costal margin in the middle and the distal portion is so broken up that the parts are difficult to identify. The Radial sector, RS is present as a backwardly directed spur, the radial recurrent (Forbes, 1922). Two small broken pieces of the veins present distally have been considered by Forbes (1922) as R1 and R5. The media is present as a recurrent vein (Mr) and the branch M4 coalesces with the cubitus (Cu). M1 is present as a faint broken piece distal to the M4 + Cu. Cubitus is a single convex vein to which the M4 fuses distally. The anals are represented by a peculiarly looped three pronged veins and is not so distinct as other veins. The anterior and distal branches are convex while the posterior branch is concave.

Wing articulation: (Plante III, Fig. 5)

Each wing is hinged to two processes of the metanotum, the anterior notal wing process and the posterior notal wing process. The articular sclerites (pteralia of Snodgrass, 1935) that take part in the wing articulation consist of three axillaries and a distal median plate. The first axillary (notale of Sweetman, 1931) articulates with the anterior notal process and is associated with the base of the sub costa. The second axillary articulates with the preceding sclerite anteriorly and with the third axillary posteriorly. The base of the radius is associated with it. The third axillary (basanale of Sweetman, 1931) articulates with posterior notal process proximally and with the anal veins distally. The median plate is an irregular sclerite at the wing base distal to the second and third axillaries and articulates with the base of the Cubitus.

Wing folding: (Plate IV, Fig. 10 & 11)

The folding of the hind wings follows the peculiar venation. The areas concerned in the folding are numbered from 1-7. The positions where the folds occur are shown as solid lines that are lettered from 'a' to 'k'. Dotted lines are used to indicate variations in the places of folding. Area 1 (axillary region of Forbes, 1926) folds under at the oblique line 'ab' and lies flat against the ventral surface of the wing. Area 2 (first dorso apical region of Khatib, 1946) folds over on to area 4 at the transverse line 'cde'. Portions of the area 2 folds over on to area 4 at the longitudinal line 'df' and the rest folds over on to area 5 at the oblique line 'fg'. Area 4 folds under at the transverse line 'hfil', carrying over area 2 with it until area 4 comes into contact with the ventral surface of the wing. The area 7 (Proximal pivot of Forbes, 1926) folds over to the area 6 along the oblique line 'kj', but the point 'g' is approximately above the line 'kj' when the wing is folded.

E. Abdomen (Plate V)

(i) General Structure:

The abdomen is broad at the base gradually tapering caudally. The dorsum is convex while the ventrum is flat and its entire dorsal and pleural surfaces are covered by the elytra. The dorsal surface is dull brown in colour while the ventral surface is shining yellow or orange. Eight abdominal tergites are visible when the wings are spread. Probably the hidden genital segments represent two more tergites. The tergites are not definitely marked from the pleura. The first tergite is membranous while tergites 2-7 are sclerotized but rather flexible in texture. The eighth tergum is heavily sclerotized, boatshaped and has two blunt conical projections antero-laterally kept inflexed under the seventh tergum. It is densely pubescent beneath.

The pleuron is entirely membranous and no distinct pleurites are present. It is marked externally by deep folds which disappear when the muscle attachments are removed.

There are seven visible sternites (2 st - 8 st) the first having fused with the second or else disappeared. They are heavily sclerotized with the exception of the sternite two which is membranous and concealed beneath the meta-coxae. The third one forms the largest sternite and is inflexed on either side to form the posterior part of the meta coxal cavities. These inflections are called abdominal plates (Plaques abdominalis of Fowler, 1912; metacoxal plates of Sweetman, 1930; Femoral lines of Kapur, 1948a, 1949a, 1949b). These are elongate and incomplete laterally. The mesal part of this sternum projects cephalad between the mesal ends of the metacoxae. The eighth sternite is the smallest and is semicircular with long setae on the caudal margin but not emarginate posteriorly in either sex. The whole of the ventral surface is pubescent.

(ii) <u>Female genitalia</u>: (Fig. 3 & 4)

The female genitalia are retracted within the eighth abdominal segment. It consists of the dorsal sclerites, the proctiger and the surstylus (Sweetman, 1930) (Paraprocts of Tanner, 1927). The proctiger is an annular sclerite which bears the anus ventrally. It is considered to represent the tergum of the tenth segment. Paraprocts are a pair of boat-shaped sclerites which extends ventrally and they probably represent the nineth abdominal segment. Ventrally there are a pair of coxites which are rather flat, irregularly triangular sclerites, located inside the boat-shaped paraprocts. Each coxite bears a stylus posteriorly which articulates with it in a membranous area. The posterior margins of the proctiger and styli bear numerous setae. Mesally towards the base the coxites bear a number of short bristles which are considered to be sensory in function (Khatib, 1946) and serve to feel the surface during oviposition. The gonopore is situated between the base of the coxites whereas the anal opening is situated dorsal to the gonopore. The true valvifers and valvulae are absent.

(iii) Male Genitalia: (Plate VI)

The nineth and tenth abdominal segments are much reduced and retracted into the eighth segment, except during copulation. The nineth segment consists of a large dorsal plate which extent ventrally forming two triangular plates on either side. These two plates are connected ventrally by a membrane in which is embeded a chitinized rod with a small rounded head, termed as Spicula ventralis (Delucchi, 1955). The tenth abdominal segment consists of a dorsal semicircular plate representing the tergum, the caudal margin of which is inflexed ventrally and bears numerous hairs. No sternal part is present. The anal opening is situated above the genital opening.

The male genitalia consists of phallic organs only and it comprises the intromittant apparatus and associated structures. Periphallic or accessary structures like styli are absent. The phallic organs arise from the anterior wall of the genital chamber formed by the nineth segment or the gonosomite. The actual intromittant organ is called the median lobe (Sipho, Bagal and Trehan, 1949; Kapur, 1948b, 1949a, 1959) and it is a long curved whip-like structure. Proximally it forms a boot-shaped, strongly chitinised structure the basal apophysis (Siphonal capsule of Bagal and Trehan, 1949) and receives the ejaculatory duct, while distally it forms a narrow coiled thread known as the virga (flagellum of Bagal and Trehan, 1949). The median lobe is ensheathed in a thin transparent membrane called the first connecting membrane. The supporting structures consists of the basal piece, basal and lateral lobes, and the median strut. The basal piece is the central portion supporting the other structures. The lateral lobes (paramere of Sagal and Trehan, 1949) are outgrowths of the basal piece and are club shaped clothed with setae on the distal portion. The basal lobe is dagger shaped, with a groove on the dorsal side through which the medial lobe passes. The median strut (Trab of Sagal and Trehan, 1949) is an outgrowth of the basal piece proximally and it is expanded at its extremity. The first connecting membrane is attached to the proximal margin of the basal piece.

(iv) Spiracles: (Plate V, Fig. 1 & 2)

The abdomen has seven pairs of spiracles. The first pair of spiracles are the largest, second to fifth of similar size while the sixth and seventh pair are greatly reduced, the latter appearing as mere specks. The spiracles are situated in the membranous lateral aspects of the dorsum.

II. External Morphology of the grubs of *Cheilomenes sexmaculata* F.

All the four instars of the grub are almost alike in the external features except for the size and colouration. For the sake of convenience the fourth instar grub is selected for the study.

A. General Structure of the Body: (Plate VII)

The body of the fourth instar grub is elongate, campodeiform, tapering caudally and somewhat flattened on the ventral side. Colour dull black, except for the more heavily sclerotised parts and areas around the base of the compound spines (Contus of Peterson,1960)

A thin white band is present in between the median pairs of spines especially between those on the thoracic segments.

B. The Head (Plate VII)

(i) The Head Capsule: (Fig. 3 & 4)

The head of the grub is nearly oval in outline and slightly sunken into the prothorax. Brown anteriorly and black posteriorly. Frontal suture is 'V' shaped, diverging to the base of the antennae where it becomes less distinct. Lateral ocelli three on each side; of equal size; arranged triangularly with the anterior one near the base of the antenna. A well defined gula is present ventrally between the posterior margin of the labium and the foramen magnum.

(ii) Head Appendages:

(a) Antennae (Fig. 3, 4 & 5)

The antennae are situated dorsolaterally near the base of the mandibles. They are three segmented and attached to the head by a large membranous region (Antennal membrane of Khatib, 1934). First segment short, broader basally; second with a conical spine like process at the apex which was termed as sensorial appendage by Delucchi (1955); third segment small, attached to the distal end of the second towards the posterior margin with a long seta and a sensory area.

(b) Mouth Parts: (Plate VII, Fig. 5, & 6; Plate VIII, Fig. 1)

Labrum with the dorsal surface beset with 3 conspicuous setae on either side of the mid dorsal line. The epipharynx lines it ventrally and an irregular chitinised ridge bounds the lateral margins.

Mandibles: Bidentate apically with the inner tooth smaller than the outer one. A basal tooth with a conspicuous molar area is present. Posterior articular condyle is prominent. The mandible bears a prominent seta at the base dorsally near the outer margin.

Maxilla: Cardo and stipes are united and appear as a bulged area laterally on either side of the labium when viewed from the ventral side. The palpifer is represented by a membranous area to which is attached the three segmented palpus with its segments nearly equal in length. Each segment has one or two highly coloured sclerotised rings. The third segment is conical in shape with an apical sensory area. Galea and lacinia are represented by a single lobe, mala, which adjoins with the labium medially.

Labium: The submentum and mentum are but slightly differentiated. These areas form a more or less contiguous membranous postmentum. Anteriorly it shows a slightly chitinised area bearing a pair of short and another pair of long setae. The anterior margin shows an indistinct line of sclerotisation called by Khatib (1954) as the semicircular sclerite. The region just above the semicircular sclerite may be termed as a prementum. The glossae and para-glossae have been fused completely to form the ligula. The labial palpus is a two segmented structure of which the first one is broader then the second. The second segment is conical and bears at its tip a sensory area.

Hypopharynx is a membranous structure connected with a ligula by means of a suture and passes backwards dorsal to the labium forming the floor of the pharynx. On the sides posteriorly it is strengthened by strong chitinized bars. Another transverse bar joins with the posterior extremities of the lateral rods at the base and it is termed as Hypopharyngeal Sclerome (Kapur, 1950).

C. The Thorax (Plate VII, Fig. 1 & 2)

The pro, meso and metathorax are clearly defined segments. The prothorax is longer, but less wider than the other two segments, which are equal in size. Each segment has a pair of tergal plates which in the prothorax approximate each other in the middorsal line. Prothorax has a pair of dorsal and another pair of lateral compound spines known as senti whereas the meso and meta thorax have an additional pair along the pleural region. On the ventral side of the thorax they form verrucae with slightly chitinized bases; the prosternum with a single verruca and meso and meta sternum each with a pair of similar verrucae. A pair of thoracic spiracles are present near the cephalic margin of the mesonotum towards the lateral side.

D. Legs (Plate VIII, Fig. 2 & 3)

There are three pairs of thoracic legs, which closely resemble each other in size and shape. Coxa is the broadest portion of the leg; trochanter triangular; femur thick and stout and tibia elongate. A typical tarsal segment is absent which might have been fused with the tibia (perhaps forming the tibio-tarsus of Delucchi, 1955). The claw is single with a subquadrate basal tooth. All the segments are beset with numerous hairs.

E. Abdomen (Plate VII, Fig. 1 & 2; Plate VIII, Fig. 4)

(i) General Structure:

Abdomen is conical in shape, broader at the base and narrowing towards the caudal extremity; 10 segmented: nineth tergite semicircular sclerotised and beset with numerous small spines. The tenth segment is fleshy, mostly covered by the overlying nineth tergum and is bent downwards functioning as an anal foot. The caudal extremity of this anal foot is bulged around and divided into two lobes which when apposed at the surface on which the larva moves, give a firm grip. This portion is called the sucker. The anal opening is situated in between the two lobes of the sucker.

(ii) Chaetotaxy of the Abdominal Segments:

Each abdominal segment except the last two are provided with six compound spines, viz., two median (dorsal), two dorsolateral and two lateral ones. The dorsal and dorsolateral ones are similar in shape with the former slightly longer. The lateral ones are situated below the spiracles and they are comparatively shorter but broader than the preceding ones. Each spine consists of a conical tubercle from which arise short spines on small swellings.

Ventrally each abdominal segment, except the nineth and tenth, is provided with a transverse row of six verrucae. The two lateral verrucae are prominent with more number of setae on a convex tubercle while the median pairs are less prominent.

(iii) Spiracles:

Eight pairs of abdominal spiracles are present, one on each side of segments 1-8 between the dorso lateral and lateral compound spines.

F. Other Instars

The first instar grubs are yellowish white when newly hatched and turns grey subsequently with faint coloured patches and six rows of compound spines on the body. The second and third instar grubs differ only in colouration and size being shining black and deep black respectively. The other characters are the same in all the instars.

III. External Morphology of the Pupa

A. General Structure (Plate VIII, Fig. 5 & 6)

The pupa is naked without any cocoon; broadly oval in shape; light yellow in colour with black spots; attached to the substratum by its caudal extremity. All the body appendages are enclosed in thin membranous sheaths.

B. The Head

The head is directed backwards, covered over by the thorax and is not visible from above. Eyes are faintly pigmented. Antennae are bent, elbow shaped and kept in between the lateral margins of the head and the anterior femora. The labrum is clearly emarginated at the apex. Maxillary palpi are broader than those of the adult and is spatula shaped.

C. The Thorax

Pro and meta thorax are subequal in size. Mesothorax is the smallest. Pronotum is strongly bent downwards on its anterior aspect so that only a portion of its caudal margin is visible from above. Lightly shaded black spots are present. Mesonotum has two lateral black patches while metanotum has a black patch on the posterior margin also. The elytra and wings are curved ventrolaterally passing between the meso and metathoracic legs. Elytra cover the hind wings completely except for the apices which protrude out ventrally. Each elytron has a black shaded area along the posterior margin. A pair of thoracic spiracles are present in the intersegmental region between the pro and meso tergum, laterally near the anterior margin of the elytra.

D. The Abdomen

There are nine abdominal segments, altogether, and the last of them bears a pair of strong recurved processes with slightly swollen extremities which are normally embeded in the old larval skin and serve to attach the pupa to it. The abdomen is widest near the thorax and tapers caudally and shows a curve downwards starting from the fifth segment. The intersegmental region between third to seventh tergites are greatly widened allowing for the curve. The pleural region is clearly separated in the first seven segments while that of eighth and nineth are merged with the lateral extension of the tergites. The terga of segments two to six have a pair of black pyramidal areas, o on either side of the mid dorsal line towards the lateral margins. The last larval skin is pushed backwards and is kept attached to the caudal extremity of the pupa, which covers the posterior two or three segments.

There are five pairs of abdominal spiracles. They are situated one on either side of the first five segments towards the antero lateral angles.

IV. The Predator-Prey Relationship of Cheilomenes sexmaculata F. and Aphis craccivora Koch.

The data collected on the weekly population of the predator, Cheilomenes sexmaculata F. and its prey Aphis craccivora Koch. for a period of 48 weeks from March, 1962 to January, 1963 are given in Table V. The meteorological data for the same period also is given

In Table VI. The correlation coefficients between the different weathe factors and the population of aphid, the weather factors and the populati of the predator and the populations of the aphid and the predator are presented in Tables II and III. The significant relations established have been illustrated by graphs and diagrams (Plates XI XII,XIII& XIV).

(i) Population Trends of *Aphis craccivora* Koch. on *Gliricidia maculata* H.B. and K.

The general trend of the population of the aphid, *Aphis craccivora* Koch. on *Gliricidia maculata* falls into six more or less distinct periods. The peak infestation occurs from the beginning of March to the second wee of June, corresponding to the summer season, from the second week till th end of October and from the last week of December till the end of January corresponding to the cold season. There was practically no infestation of the aphid during the second fortnight of June till the second week of July. However, a mild infestation of the aphid was prevalent from the third week of July to the first week of October and from the first week of November to the third week of December.

(ii) Influence of weather factors on the Population of *Aphis craccivora* Ko

(a) Maximum and Minimum Temperatures do not show any significant influenc on the rate of increase or decrease of the aphid. The correlation coefficients worked are not significant.

(b) Morning Humidity and Evening Humidity: The population of aphid has not been found to be affected by the variations in the morning and evening humidity. The correlation coefficients are also not significant.

(c) Wind Velocity: On a careful examination of the data it is seen that high wind velocities influence the density of the population of aphid.

Th 3

TABLE II

Correlation between the population of *Aphis craccivora* Koch. and weather factors.

Sl. No.	Weather factors	Coefficient of correlation 'r'
1	Maximum temperature (Highest in the preceding week.)	r = — 0.071
2	Minimum temperature (Lowest in the preceding week.)	r = — 0.054
3	Morning humidity (Highest in the preceding week.)	r = 0.165
4	Evening humidity (Highest in the preceding week.)	r = — 0.104
5	Wind velocity (Highest in the preceding week.)	r = — 0.296 *
6	Rainfall (Total for the preceding week.)	r = 0.180

* Significant at 5 percent level.

When the wind velocity is very high, i.e. above nearly seven miles per hour during June-July, there is a corresponding decrease in the population of the aphid. This is substantiated by the significant negative correlati established between wind velocity and population of the aphid.

(iii) General Trend of the Population of *Cheilomenes sexmaculata* F.

The trend of population of the Coccinellid was comparatively low throughout the period of investigation. The peak period of the population of the beetle generally coincides with the peak period of population of the aphid. With the rise in population of the aphid during October there is an increase in the population of the predator which goes down in the first week of November and then gradually increases by the end of December as the population of the aphid also increases.

(iv) Influence of Weather Factors on the Population of *Cheilomenes sexmaculata* F.

(a) Maximum and Minimum Temperatures: These factors do not show any significant correlation with the population of the beetle and they appear to vary independently.

(b) Morning Humidity and Evening Humidity: Morning humidity has no significant correlation with the population of the beetle. However, the evening humidity shows a definite relationship with the population of the Coccinellid. There is a significant negative correlation between evening humidity and the population of the Coccinellid (r = — 0.4592). During March to June second week the evening humidity is generally below 65% when there is also an increase in the population of the beetle. But in the later period when the evening humidity generally exceeded 65%, the population of the beetles also decreases correspondingly.

TABLE III

Correlation between the population of *Cheilomenes sexmaculata* F. and (a) Weather factors and (b) the population of *Aphis craccivora* Koch.

Sl. No.	a) Weather factors	Coefficient of correlation 'r'
1	Maximum temperature (Highest in the preceding week.)	$r = 0.145$
2	Minimum temperature (Lowest in the preceding week.)	$r = -0.080$
3	Morning humidity (Highest in the preceding week.)	$r = -0.057$
4	Evening humidity (Highest in the preceding week.)	$r = -0.439$ **
5	Wind velocity (Highest in the preceding week.)	$r = -0.350$ *
6	Rainfall (Total for the preceding week.)	$r = 0.078$
7	b) *Aphis craccivora* Koch. (Mean weekly population)	$r = 0.699$ **

* Significant at 5 per cent level

** Significant at 1 per cent level

(c) Rainfall: The rainfall does not show any significant effect on the population of the Coccinellid.

(d) Wind Velocity: As in the case of aphid, the beetles are also found to be absent at high wind velocities such as 15 miles per hour. During the peak periods of occurrence of the Coccinellid the wind velocity is generally less than seven miles per hour. From this it is evident that wind velocities above seven miles per hour has got some effect on dispersal of the beetles. The correlation coefficient worked out is highly significant (r = — 0.550).

(v) Predator-Prey Relation

From the data it is seen that the population of the Coccinellid increases with the increase in the population of the aphid. During summer when there are plenty of aphids, the population of the predator is also high. But it falls down along with the reduction in the population of the aphid. To assess the relationship between the population of the aphid and the population of the predator the correlation coefficient was worked out and the same has been found to be highly significant, the 'r' value being + 0.829. In other words it can be concluded that the population of the Coccinellid closely follows that of the prey.

TABLE IV

Regression equations

Sl. No.	Variates		Coefficient of correlation 'r'	Regression equations
	x	y		
1	Wind velocity	*Aphis craccivora* Koch.	— 0.296	y = 9525.142 — 166.295 x
2	*Aphis craccivora* Koch.	*Cheilomenes sexmaculata* F.	0.699	y = 0.167 + 0.0001 x x = 180.40 + 5404.5 y
3	Wind velocity	*Cheilomenes sexmaculata* F.	— 0.350	y = 0.498 — 0.04 x
4	Evening Humidity	*Cheilomenes sexmaculata* F.	— 0.459	y = 1.054 — 0.011 x

DISCUSSION

I. External Morphology of the Adult of *Cheilomenes sexmaculata* F.

The present study was undertaken with a veiw to contribute further information on the morphological characters of the Coccinellidae with special reference to *Cheilomenes sexmaculata* F. that may lead to a better understanding of the group and its classification. In this connection, special attention has been paid to the structure of the head capsule, mouthparts, tarsus, pretarsus, first and last visible sternites, the wing venation and folding pattern of the hind wings.

The close fusion of the sclerites and the absence of the usual sutures of the cranium as noted in *Cheilomenes sexmaculata* F. are common to all the members of the family Coccinellidae. However, Stickney (1923) found a trace of the epicranial arms ventrocephalad of the compound eyes in two species of Coccinellidae vis. *Hippodamia convergens* Guer. and *Adalia bipunctata* L. This may well be a secondary development. The membranous anteclypeus allows more freedom of movement to the labrum and this structure has been observed in *Epilachna corrupta* Muls. by Sweetman (1930).

The poor development of the tentorium is another feature noted in this species. Snodgrass (1935) observed that the tentorium may undergo extensive modifications and reduction in size in various species of insects. Further the fusing of the sclerites and loss of sutures of the head capsule might have been accompanied by a reduction in size and rigidity of the tentorium until it is nothing more than two delicate threads.

The bifid nature of the mandible with a basal tooth is characteristic of carnivorous Coccinellidae while it is multidentate and without basal tooth in phytophagous forms (Kapur, 1943; Imms, 1960). The mycophagous species differ from the above two types in that the incisor portion bears five or more serrations with the basal tooth (Kapur, 1943). In *Cheilomenes sexmaculata* F. the membrane between the mentum and prementum (or the distal portion of mentum) is well developed and this is again a characteristic of carnivorous forms while it is short and allows only slight inflection of the prementum phytophagous forms (Kapur, 1943).

Tormae are two small sclerites in the lateral angles between the labrum and the clypeus. As far as the author is aware, this is the first time that this structure has been noted in the Coccinellidae. Khatib (1946) observed this sclerite in *Galerucella birmanica* Jac. (Chrysomelidae-Coleoptera). Probably this structure may serve to strengthen the suture between the labrum and the membranous anteclypeus.

The suspensorial sclerites have not been described in Coccinellidae. They have been described in *Galerucella birmanica* Jac. by Khatib (1946) and in the grasshopper *Dissosteira* (Acrididae-Orthoptera) by Snodgrass (1935). The suspensorial sclerites according to the latter author give insertion to the retractor muscles of the mouth angle.

Cervix: The membranous cervical region and the absence of the sclerites are special features observed in this species. It can be inferred that the cervical sclerites might not have developed at all or they have become fused with the propleuron as suggested by Snodgrass (1935).

Thorax: The size and shape of the prosternal lobe and the presence of the 'U' shaped prosternal carina have been found to be characteristic features of this species. Kapur (1948a) used the nature of the prosternal carina in preparing the key for different genera of the tribe Aspidimerini (Coccinellidae). A study of this character in other species may likewise be of some value in classification. The presence of a trochantin attached to the forecoxa as noted in *Cheilomenes sexmaculata* has been observed in *Epilachna corrupta* Muls. by Sweetman (1930).

The higher development of metathorax compared to other thoracic segments may only be due to the fact that hind wings are the major operational organs in flight as is common in other Coleoptera. The metafurca shows a greater development in this species. Crowson (1938) made a comparative study of the metafurca of Coleoptera and found that the furcae of Blattidae, Isoptera, Mecoptera, Trichoptera and Lepidoptera do not approach the Coleopterous furcae and hence the beetles remain as an isolated group.

Elytral epipleura of *Cheilomenes sexmaculata* is broad at the base and narrower towards the distal end as is the case in *Rodolia* Mulsant (Kapur, 1949b). Variations in the size and shape of the epipleura have been observed in different species. The hind wings correspond to those of other Coccinellids in its reduced and peculiar venation and manner of folding. The spur like radial recurrent, median recurrent and the peculiarly looped anal veins are characteristic features of Coccinellidae (Forbes, 1922). The wing folding pattern of Coccinellidae according to Forbes (1926) represent a distinct family type and difficult to interpret. The large unfolded apex will distinguish it from otherse at a glance. According to Graham (1922) the position of the folds was influenced by the position of veins.

The pretarsus has a ventral unguitractor plate, which has not been reported so far from any Coccinellidae as far as the author is aware. This sclerite serves for muscle attachment.

Abdomen: The membranous first tergite, the nineth and tenth tergites which are invaginated and the reduction of the first two sternites are all features found in most Coleoptera (Imms, 1930). The third sternite bears a pair of abdominal plates which are elongate and open, while it is conical and closed in *Tetrabrachys connatus* (Panzer) (Kapur, 1948b). This again is another character found to show variation among different species. The last visible sternites of *Cheilomenes sexmaculata* F. in female and male are semicircular and entire. In many other Coccinellids the last sternite in male is notched in the middle at its posterior margin as observed in *Stethorus gilvifrons* Muls. (Kapur, 1949a). This character has been used in many species to differentiate the sexes.

The nineth segment in the male of *Cheilomenes sexmaculata* is represented by a tergal plate and two triangular lateral plates ventrally. These lateral plates might have been formed by the nineth tergum extending ventrally and fusing with the pleura as observed by Sweetman (1930). The spicula ventralis has been considered by Delucchi (1955) as the modified nineth sternum. A consideration of the above two views along with the position and attachment of the spicule may show that the observation of Delucchi (1955) to be a sound one. However, further studies in this direction are required to fix the homology of this part correctly.

The terminology used for the description of female genitalia is that of Sweetman (1930) and the female genitalia is almost similar to that of Epilachna corrupta Muls. as described by the same author. It differs from that of Epilachna in that the coxites do not interlock each other. Crampton (1925) quoted by Tanner (1927) homologised the paraprocts of beetles to the surstylus in other insects and suggested that they are part of the nineth tergite. The term surstylus is used in the present description. The coxites are rather flat and triangular in Cheilomenes sexmaculata F., while it is long and rather heavily chitinised in Chilocorus bivulnerus Muls. as observed by Tanner (1927). The proctiger according to Tanner (loc. cit.) is rather uniform in all the species.

In the male genitalia of Cheilomenes sexmaculata F. the various structures correspond to those described in other Coccinellids by Sharp and Muir (1912) and Dalucchi (1955). However, these structures show characteristic features in this species. The median lobe is a slightly bent whip like structure. While it is an almost completely curved ring in Aspidimerus birmanicus (Gorham.) as observed by Kapur (1948a). A comparison of the various structures in Cheilomenes sexmaculata with those of other species show that there exist wide variations between different species. These characters have been used in the identification of different species.

Sharp and Muir (1912) have attempted to standardise the various terms used in the terminology for male genitalia in Coleoptera including Coccinellidae. However, various authors have used different terms for the same structures. Bagal and Trehan (1949) described the covering of the median lobe as penis whereas according to Sharp and Muir (loc. cit) it is only a covering membrane called the first connecting membrane which connects the median lobe and tegmen together. In *Cheilomenes sexmaculata* F. this covering is a transparent thin membrane which conform well to the observations of Sharp and Muir (loc.cit). The paramera of Kapur (1948a) and Bagal and Trehan (1949) refer to the lateral lobes described by Sharp and Muir (1912) and Delucchi (1955). Kapur (loc.cit) used the term penis to refer the basal lobe of other authors. A standardisation of the different terms appears to be essential to avoid confusion.

II. External Morphology of the Grub

The special features noted in the grubs are the structure of the antennae, mouthparts, legs and the last abdominal segment and the arrangement of the spines over the body. The antennae consist of three segments with the third one very small. This finding is not in conformity with Bagal and Trehan (1949) according to whom there are only two segments. Three segmented antennae have however been reported by Taylor (1935) in *Cryptognatha nodiceps* Mshl. and Kapur (1950) in Epilachninae.

The sickle shaped mandible with a distinct molar surface as observed in the grub is a characteristic feature of Coccinellid grubs except in the Epilachninae. The contiguous nature of the labium as observed in the present study is only a common family character. The semicircular sclerite is only a slightly chitinised region whereas Delucchi (1955) identified a well defined sclerotic ring in this region as mentum and a submental sclerite in the anterior region of the postmentum. However, in *Cheilomenes sexmaculata* F. these areas are only slightly chitinized and the homology of these sclerites has not been possible to fix. Further studies are indicated in this direction. The hypopharyngeal sclerome found in *Cheilomenes sexmaculata* F. has been observed by Kapur

(1950) in *Brumus suturalis* and this structure is not sclerotised in Epilachninae.

The thoracic legs of the grub of *Cheilomenes sexmaculata* F. are typical of the predaceous Coccinellidae in that it is four segmented with a single claw and there being no distinct tarsus present (Peterson, 1960). It has been thought of to be fused variously with the claw to form a tarsungulus (Peterson, 1960) or with the tibia forming a tibiotarsus (Delucchi, 1955).

The modification of the last abdominal segment into an anal foot has been observed in many other predaceous Coccinellids (Taylor, 1935; Delucchi, 1955). This character may well be an adaptation to its predatory life as evidenced by the mode of feeding of the grub. During feeding, the grubs hold the prey with the aid of the thoracic legs, the body being fixed firmly by its caudal extremity to the substrate with the help of the sucker.

Pupa: The observations on the external features of the pupa of *Cheilomenes sexmaculata* F. have shown that it conform in general to those found in the pupae of other predaceous Coccinellidae.

III. *Studies on the Predator-Prey Relationship of Cheilomenes sexmaculata* F. and *Aphis graccivora* Koch.

The population trend of *Aphis graccivora* Koch. on *Gliricidia maculata* H.B. & K. indicates that the peak infestation occurs during the cold and summer months, i.e. from last week of December till the end of January, and from March to the second week of June. The aphids have been reported to occur from July onwards upto April and during summer season in large numbers on the Gliricidia plants (David, 1967). With regard to the influence of weather factors on the population of the aphid, the simple correlations worked out indicate that only wind velocity exerts a significantly negative influence and the other factors viz. maximum and minimum temperatures, morning and evening humidity and rainfall do not have any significant influence on the population of the aphid.

In the present investigation the wind velocity above seven miles per hour has been found to be followed by a reduction in the size of the population of the aphid. This might be due to high wind velocities favouring the dispersal and migration of the aphids. Johnson (1952 and 1954) in his studies on the dispersal and migration of aphids has shown that aphid migration occurs when the mean wind velocity near the ground is above five miles per hour and calm weather do not favour migration. However, Abdul Kareem (1961) found that dispersal of aphids is high in low wind velocity. Mechanical action of wind may have some effect on the population of aphid. Lal and Sing (1967), however, observed that this effect of wind is negligible in determining the incidence or population of the wolly aphis, Eriosoma lanigerum Hausman.

Maximum and minimum temperaturesdo not influence the population of Aphis craccivora Koch. Lal and Sing (1947) in their ecological studies of the woolly aphis, Eriosoma lanigerum Hausman found that temperature upto 90 °F do not affect the population of aphid adversely while temperatures below 37 °F have a retarding effect on reproduction rate. The lowest minimum temperature recorded during the period of investigation is 57.2 °F. which is far above the limit set for the woolly aphis. The maximum temperatures are unusually below 90 °F.

though values over 90 °F. have also been recorded in some weeks. Under the conditions prevalent in Coimbatore it appears that variations within these ranges do not influence the population of *Aphis craccivora* Koch.

It has been noted in the present investigation that the humidity of the atmosphere has no influence on the population of aphid, the 'r' values being not significant. This is supported by Folsom and Wardle (1934) who state that the sap feeding insects are definitely independent of the atmospheric moisture and they are affected by the osmotic concentration of the sap rather than by the atmospheric moisture. Headlee (1918) quoted by the above authors, showed that *Toxoptera graminum* develops at the same rate in a constant atmospheric temperature of 27 °C, whether the atmospheric humidity is 37, 50, 70, 80 or 100 per cent. This view has again been substantiated by Butler (1938) and Avidov (1956) according to whom the humidity has no effect on the population of Aleyrodids.

Rainfall as occurred during the period of study do not appear to influence the population of aphids though heavy rains may have some mechanical beating action. Lal and Sing (1947) however found that the mechanical action of rainfall has negligible effect on *Eriosoma lanigerum* Hausman.

In general the population of the predator *Cheilomenes sexmaculata* F. was comparatively low. This may be due to the fact this species is a polyphagous one and the presence of alternate hosts like Delphacids on Cholam, *Aphis gossypii* G. on cotton and other aphids on various plants in the area, may well account for it.

Among the weather factors wind velocity showed a significant negative correlation. High wind velocities above seven miles per hour is associated with a conspicuous reduction in the population of the Coccinellid. Marcovitch and Stanley (1930) have shown that the prevailing wind greatly influences the spread of the Mexican beetle, *Epilachna corrupta* Muls. Hagen (1962) also supports the present finding, in quoting Carnes (1912) that migratory flight of Coccinellids occur along with the wind. But in the year 1939 Marriner in his studies on the movements of Coccinellidae (quoted by Hagen, 1962) showed that flight may also occur against gentle winds. The reduction in the population of aphid under high wind velocity condition may also be a factor responsible for the smaller number of Coccinellids.

Minimum temperature was found to have no significant influence on the population of the Coccinellid. In temperate regions the beetles become inactive and enter hibernation at low temperatures as has been observed by Belucchi (1955) in the case of *Pullus impexus* (Mulsant). But the lowest minimum temperature recorded during the period of study was 57.2 °F. and it can be concluded that under the tropical conditions this temperature do not have any retarding effect. Maximum temperature also do not show any significant influence on the population of the beetles. This is not in conformity with Marcovitch and Stanley (1930) and Sweetman (1932) according to whom the higher temperatures are unfavourable for the Mexican beetle *Epilachna corrupta* Muls. Perhaps this may be true in the temperate conditions. But under the tropical conditions and with the range of temperatures as observed in the present investigations, the temperature does not appear to be an important factor influencing the populations of the Coccinellid.

Evening humidity showed a significant negative correlation while morning humidity has a slight negative correlation, though not significant, with the population of the beetle. It has been recorded by Marcovitch and Stanley (1930) that both an increase and decrease in relative humidity are unfavourable for the development of Epilachna corrupta Muls.

The rainfall do not show any significant influence on the Coccinellid population. Perhaps a tropical species like Cheilomenes sexmaculata F. may not be affected much by the scanty rainfall as observed during the period of investigation.

Predator-Prey Relationship:

The present investigations on the population of the predator Cheilomenes sexmaculata F. and its prey, Aphis craccivora Koch. show that the fluctuations of the predator and prey populations are interdependent or more clearly that the population of the Coccinellid closely follows that of its prey, the aphid. This finding is in close parity with the observations of many previous workers on predator-prey relationship. Allee et al (1949) according to Huffaker and Kennett (1956) showed that 'the abundance of a predator is usually associated with the abundance of its prey'. Dickson et al (1955) in their study of the natural enemies of the spotted alfalfa aphid, Therioaphis maculata Buckton. found that the populations of the Coccinellid predators closely followed that of the aphid. Huffaker and Kennett (1956) in their studies on predation and Cyclamen mite populations on Strawberries in California observed a fairly regular receprocally dependent oscillations of predator and prey. Vasantharaj (1963) from his studies on the predators of Aleyrodids on Pomegranate in Coimbatore also endorses the view that the predator and prey density are interdependent and the two are positively correlated. However, studies on the ecology of the Coccinellid predators of *Aphis fabae* Scop. on beans in England by Banks (1955) indicated that the predator and prey populations fluctuate independently and the predator population is not dependent on the density of its prey. This may be true for the species he studied and also under the temperate conditions as observed by Hagen (1962).

In conclusion it can be said that the present studies on the morphology of *Cheilomenes sexmaculata* F. and its immature stages has brought to light many salient features that may lead to a better understanding of the family and also the further scope for more detailed work on different species. Further, the present study has highlighted the need for a standardised terminology of the male genital structures.

The investigation on the population fluctuations of *Cheilomenes sexmaculata* F. and *Aphis craccivora* K., though preliminary in nature has gone a long way in bringing out the intricate factors and their interactions in population dynamics. A more detailed study on the combined effect of various weather factors on predator and prey species individually as well as on the predator-prey coaction is a field with vast scope for future work. The study of the populations of the predator and its different prey species, in different localities simultaneously may give an appreciation of the predator-prey oscillation in different situations in a particular period and a comparative idea of the relationship of a polyphagous predator with its different prey species.

SUMMARY

A detailed study of the external morphology of the adult of *Cheilomenes sexmaculata* F. has been undertaken. The salient features are as follows. The anteclypeus is a distinct membranous region while post clypeus is fused with the frons. The mandibles have a bidentate apex with a basal tooth Characteristic of carnivorous species. The presence of a small sclerotic structure, viz., tormae at the postero-lateral angles of the labrum ventrally and the hypopharynx with suspensorial sclerites has been noted and these are being reported for the first time in Coccinellidae. Yet another interesting feature noted in the head is the presence of a poorly developed tentorium represented by the reduced arms. Cervix has been found to be only a membranous region devoid of any sclerites. Prosternum extend posteriorly between the coxae forming the prosternal lobe, with a 'U' shaped prosternal carina on the ventral surface of it. The metafurca is highly developed for muscle attachment. Tarsi are four segmented, third tarsomere being small and concealed in the deeply bilobed second. Pretarsus is characterised by the presence of a pair of claws and an unguitractor plate. Though normally the elytra is orange or yellow with three chevron like markings on each, considerable variations in colour pattern as well as in the markings are met with. Hind wings are membranous with reduced venation and folding pattern.

Abdomen shows eight visible tergites and seven sternites. First visible sternite possesses a pair of abdominal plates which are elongate and open. The last sternite in the male and female are entire. Male and female genitalia conform to the general pattern of Coccinellidae. In male the sipho is long and slightly bent, the basal and lateral lobes

being well developed.

A detailed study of the external characters of the fourth instar grub of the *Cheilomenes sexmaculata* F. showed that the mandibles are sickle shaped and bidentate with a basal tooth. Antinnae are three segmented. Hypopharynx is membranous with hypopharyngeal sclerome. Legs are of equal size without a distinct tarsus. Six rows of compound spines dorsally and six rows of verrucae ventrally are present on the abdominal segments. The last abdominal segment is modified into an anal foot. The distinguishing features of the earlier three instars have been mentioned.

Observations on the external characters of the pupa of *Cheilomenes sexmaculata* have shown that it is naked, conspicuously coloured, bent caudally and attached to the substrate by the caudal extremity as in other Coccinellids.

Population studies of *Cheilomenes sexmaculata* F. and *Aphis crassivora* K. have been undertaken for a period of 48 weeks from 5-3-62 to 26-1-63. Weather data have been statistically correlated with both Coccinellid and Aphid populations. The association between the predator and prey has been studied. Among the weather factors wind velocity showed a negative correlation with aphid population while evening humidity and wind velocity have been found to be negatively correlated with the population of the Coccinellid. Population density of *Cheilomenes sexmaculata* F. has been found to be positively correlated with that of the aphid *Aphis crassivora* Koch. which is in general agreement with the biological principle that "the abundance of a predator is usually associated with the abundance of its prey".

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*Original not seen.

TABLES

TABLE V

Mean weekly Population of *Cheilomenes sexmaculata* F.(Coccinellidae) and *Aphis craccivora* Koch. (Aphididae) on *Gliricidia maculata* H.B and K.

S. No.	Date of observation	Population *Aphis craccivora* Koch.	 *Cheilomenes sexmaculata* F.
(1)	(2)	(3)	(4)
1	3-3-62	6486.50	0.83
2	10-3-62	4267.50	1.17
3	17-3-62	2464.67	1.50
4	24-3-62	1272.33	0.33
5	31-3-62	1249.00	1.17
6	7-4-62	675.83	0.50
7	14-4-62	1487.17	0.33
8	21-4-62	2085.67	1.00
9	28-4-62	1854.83	0.67
10	5-5-62	1459.17	0.17
11	12-5-62	226.83	0.67
12	19-5-62	455.00	0.50
13	26-5-62	485.00	0.17
14	2-6-62	1059.50	0.33
15	9-6-62	222.17	0.17
16	16-6-62	-	-
17	23-6-62	9.33	-
18	30-6-62	-	-
19	7-7-62	-	-

TABLE V (Contd.)

(1)	(2)	(3)	(4)
20	14-7-62	-	-
21	21-7-62	597.67	0.50
22	28-7-62	9.33	0.17
23	4-8-62	-	-
24	11-8-62	4.67	-
25	18-8-62	14.00	-
26	25-8-62	9.33	-
27	1-9-62	14.00	-
28	8-9-62	32.67	-
29	15-9-62	18.67	-
30	22-9-62	14.00	-
31	29-9-62	-	-
32	6-10-62	9.33	-
33	13-10-62	8851.83	0.50
34	20-10-62	5398.83	1.00
35	27-10-62	565.33	0.17
36	3-11-62	9.33	0.17
37	10-11-62	4.67	-
38	17-11-62	4.67	-
39	24-11-62	222.17	-
40	1-12-62	217.50	-
41	8-12-62	28.00	-
42	15-12-62	52.67	-
43	22-12-62	212.83	-
44	29-12-62	1431.67	0.17
45	5-1-63	2239.00	0.17
46	12-1-63	2840.33	-
47	19-1-63	3428.83	0.67
48	26-1-63	2400.00	0.33

TABLE VI

Meteorological data for the period from 3-3-62 to 26-1-63

(Absolute values for the preceding week)

Sl.No. (1)	Date of observation (2)	Temperature °F		Humidity Percent		Wind velocity-miles per hour (7)	Rainfall in inches (8)
		Minimum (3)	Maximum (4)	Morning (5)	Evening (6)		
1	3-3-62	63.9	92.9	93	57	5	–
2	10-3-62	66.9	94.9	68	42	4	–
3	17-3-62	61.4	95.7	87	44	5	–
4	24-3-62	62.6	95.9	93	61	3	0.75
5	31-3-62	64.5	96.5	90	51	4	0.12
6	7-4-62	67.4	96.7	88	64	4	–
7	14-4-62	71.9	98.4	95	48	2	0.09
8	21-4-62	68.2	95.1	93	46	1	1.25
9	28-4-62	72.3	96.8	90	45	2	–
10	5-5-62	70.4	98.3	93	54	2	1.35
11	12-5-62	72.1	95.6	95	60	3	0.56
12	19-5-62	70.1	94.2	99	97	2	2.19
13	26-5-62	71.8	91.0	86	71	6	–
14	2-6-62	71.3	94.1	95	65	4	–
15	9-6-62	72.5	92.1	84	65	7	–
16	16-6-62	70.6	90.1	91	63	10	0.02
17	23-6-62	69.4	94.0	88	53	5	–
18	30-6-62	68.5	94.2	92	68	13	0.32
19	7-7-62	70.6	92.5	88	73	10	0.80
20	14-7-62	69.5	88.2	90	84	13	3.14
21	21-7-62	71.2	89.5	92	75	7	0.13

TABLE VI (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
22	28-7-62	72.4	86.2	81	60	9	0.01
23	4-8-62	69.2	91.1	92	64	13	-
24	11-8-62	71.1	87.8	95	64	10	0.41
25	18-8-62	70.2	89.1	98	74	11	0.15
26	25-8-62	68.2	90.8	88	75	2	-
27	1-9-62	70.9	90.2	96	71	3	0.08
28	8-9-62	69.7	93.4	95	80	6	0.87
29	15-9-62	70.9	71.2	92	59	8	0.17
30	22-9-62	70.7	90.6	95	68	13	0.16
31	29-9-62	69.0	91.2	95	62	2	0.23
32	6-10-62	71.3	90.8	99	98	5	1.32
33	13-10-62	70.7	93.1	99	77	3	1.90
34	20-10-62	70.8	85.7	99	97	7	4.31
35	27-10-62	69.2	84.7	99	77	5	2.98
36	3-11-62	68.1	89.0	98	74	5	-
37.	10-11-62	67.2	90.1	97	98	5	1.20
38	17-11-62	60.0	86.2	95	56	4	-
39	24-11-62	63.3	87.0	90	68	6	0.02
40	1-12-62	62.7	86.9	97	94	4	0.41
41	8-12-62	63.2	87.4	97	94	2	1.57
42	15-12-62	61.2	84.8	97	69	4	-
43	22-12-62	64.1	84.0	98	64	5	-
44	29-12-62	65.7	85.0	95	70	5	-
45	5- 1-63	57.3	85.4	94	61	5	-

TABLE VI (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
46	12-1-65	67.0	84.7	98	97	4	0.19
47	19-1-65	60.7	85.0	97	69	5	0.13
48	26-1-65	57.2	85.7	95	57	5	-

TABLE VII

Measurement of the fourth instar grub and the pupa of *Cheilomenes sexmaculata* F.

(Average of 10 specimens in mm.)

S.No. (1)	Parts (2)	Minimum Length (3)	Minimum Breadth (4)	Maximum Length (5)	Maximum Breadth (6)	Average Length (7)	Average Breadth (8)
A.	GRUB						
1	Total length	6.461	-	7.100	-	6.612	-
2	Max. breadth	-	1.988	-	2.414	-	2.187
3	Head	3.692	3.621	4.402	4.260	4.109	3.962
4	Antenna	0.284	-	0.497	-	0.383	-
5	Prothorax	0.852	1.420	1.065	1.775	1.008	1.565
6	Mesothorax	0.710	1.846	1.065	2.627	0.851	2.045
7	Metathorax	0.710	1.988	0.852	2.414	0.774	2.187
8	Abdomen	4.402	1.917	5.183	2.414	4.779	2.109
9	Foreleg: Coxa	0.213	0.426	0.355	0.568	0.270	0.476
10	Trochanter	0.284	0.142	0.355	0.213	0.305	0.202
11	Femur	0.710	0.142	0.852	0.213	0.817	0.208
12	Tibia	0.852	0.107	1.136	0.142	1.051	0.138
13	Middle leg: Coxa	0.213	0.497	0.284	0.568	0.277	0.545
14	Trochanter	0.284	0.142	0.355	0.123	0.341	0.199
15	Femur	0.710	0.213	0.852	0.213	0.774	0.213
16	Tibia	0.923	0.142	1.136	0.213	0.987	0.156

TABLE VII (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
17	Hind legs Coxa	0.234	0.497	0.355	0.639	0.518	0.581
18	Trochanter	0.284	0.178	0.355	0.213	0.341	0.202
19	Femur	0.710	0.213	0.923	0.213	0.777	0.213
20	Tibia	0.923	0.142	1.207	0.178	1.016	0.148
B.	PUPA						
21	Total length	4.144	-	4.810	-	4.477	-
2	Maximum breadth	-	2.886	-	3.404	-	3.115
3	Prothorax	1.110	2.516	1.628	2.812	1.456	2.664
4	Mesothorax	0.444	2.442	0.740	2.886	0.540	2.590
5	Metathorax	0.592	2.738	0.740	3.258	0.681	3.004
6	Abdomen	2.664	2.886	3.330	3.404	2.967	3.115

TABLE VIII

Measurements of the adult (male) of <u>Cheilomenes</u> <u>sexmaculata</u> F.

(Average of ten specimens in mm.)

S. No.	Parts	Minimum		Maximum		Average	
		Length	Breadth	Length	Breadth	Length	Breadth
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Head	0.781	0.994	1.065	1.307	0.930	1.140
2	Distance between the eyes	0.497	-	0.639	-	0.572	-
3	Antenna: Scape	0.135	-	0.150	-	0.143	-
4	Pedicel	0.060	-	0.075	-	0.071	-
5	Funicle	0.205	-	0.240	-	0.212	-
6	Club	0.135	-	0.235	-	0.184	-
7	Prothorax	0.852	1.917	1.207	2.414	1.078	2.251
8	Pterothorax: dorsal	1.065	-	1.562	-	1.335	-
9	" ventral	0.994	-	1.278	-	1.179	-
10	Maximum breadth	-	2.272	-	3.053	-	2.641
11	Abdomen: dorsal	2.130	-	2.769	-	2.549	-
12	" ventral	1.491	-	2.130	-	1.818	-
13	Max. breadth	-	2.130	-	2.769	-	2.398
14	Foreleg: Coxa	0.213	0.714	0.213	0.994	0.213	0.895
15	" Trochanter	0.142	0.284	0.213	0.355	0.156	0.358
16	" Femur	0.852	0.426	1.065	0.497	0.937	0.433
17	" Tibia	0.714	0.142	0.923	0.213	0.852	1.182
18	" Tarsus	0.497	0.071	0.714	0.142	0.618	0.135

TABLE VIII (Contd.)

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
20	Middle leg:Coxa		0.142	0.426	0.426	0.568	0.327	0.525
21	"	Trochanter	0.142	0.213	0.213	0.355	0.195	0.327
21	"	Femur	0.923	0.284	1.065	0.391	1.008	0.351
22	"	Tibia	0.781	0.142	0.994	0.284	0.923	0.213
23	"	Tarsus	0.568	0.071	0.714	0.142	0.646	0.151
24	Hind leg:Coxa		0.213	0.568	0.284	0.714	0.255	0.602
25	"	Trochanter	0.213	0.213	0.284	0.355	0.213	0.298
26	"	Femur	0.933	0.355	0.135	0.497	1.044	0.412
27	"	Tibia	0.852	0.142	1.287	0.213	0.830	0.199
28	"	Tarsus	0.497	0.071	0.714	0.142	0.632	0.151
29	Elytron		2.840	1.633	3.408	2.414	3.091	2.016
30	Hind wing		5.278	1.729	6.034	2.065	5.651	1.820
31	Total length of the beetle		5.005	-	5.460	-	5.214	—
32	Maximum breadth		-	3.823	-	4.550	-	4.241

TABLE IX

Measurements of the adult (female) of Cheilomenes sexmaculata F.

(Average of ten specimensin mm.)

S.No.	Parts	Minimum		Maximum		Average	
		Length	Breadth	Length	Breadth	Length	Breadth
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Head	1.025	1.197	1.235	1.567	1.108	1.515
2	Distance between the eyes	0.608	-	0.634	-	0.648	-
3	Antenna-Scape	0.095	-	0.152	-	0.131	-
4	" Pedicel	0.057	-	0.076	-	0.072	-
5	" Funicle	0.190	-	0.247	-	0.211	-
6	" Club	0.180	-	0.228	-	0.198	-
7	Prothorax	1.065	2.201	1.549	2.367	1.264	2.465
8	Pterothorax-dorsal	1.591	-	1.917	-	1.685	-
9	" ventral	1.278	-	1.633	-	1.426	-
10	Maximum breadth	-	2.526	-	4.765	-	3.202
11	Abdomen-dorsal	2.698	-	3.550	-	3.202	-
12	" ventral	2.059	-	2.698	-	2.495	-
13	Max. Breadth	-	2.556	-	3.266	-	3.052
14	Foreleg Coxa	0.213	0.781	0.284	0.994	0.256	0.888
15	" Trochanter	0.142	0.284	0.213	0.426	0.185	0.362
16	" Femur	0.852	0.355	1.136	0.508	1.056	0.452
17	" Tibia	0.781	0.142	1.065	0.213	0.857	0.199
18	" Tarsus	0.568	0.142	0.781	0.142	0.710	0.142

TABLE IX (Contd.)

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
19	Middle leg	Coxa	0.284	0.497	0.426	0.639	0.355	0.604
20	"	Trochanter	0.213	0.355	0-213	0.426	0.213	0.381
21	"	Femur	0.994	0.355	1.126	0.426	1.101	0.398
22	"	Tibia	0.923	0.213	1.065	0.213	1.025	0.213
23	"	Tarsus	0.639	0.107	0.781	0.142	0.710	0.138
24	Hind leg	Coxa	0.284	0.710	0.355	0.852	0.502	0.802
25	"	Trochanter	0.213	0.284	0.284	0.355	0.270	0.348
26	"	Femur	1.065	0.426	1.278	0.497	1.186	0.444
27	"	Tibia	1.065	0.213	1.278	0.213	1.186	0.213
28	"	Tarsus	0.710	0.142	0.852	0.142	0.767	0.142
29	Elytron		3.550	2.272	4.260	2.840	3.990	2.613
30	Hind wing		6.188	2.095	7.009	2.457	6.618	2.211
31	Total length of the beetle		5.551	-	7.109	-	6.206	4.914
32	Maximum breadth		-	4.550	-	3.869	6.205	-

PLATES

PLATE I

External characters of the adults of *Cheilomenes sexmaculata* F.

Fig. 1. Female

2. Male

* * *

Ely - Elytron

H - Head

Pn - Pronotum

Scl - Scutellum

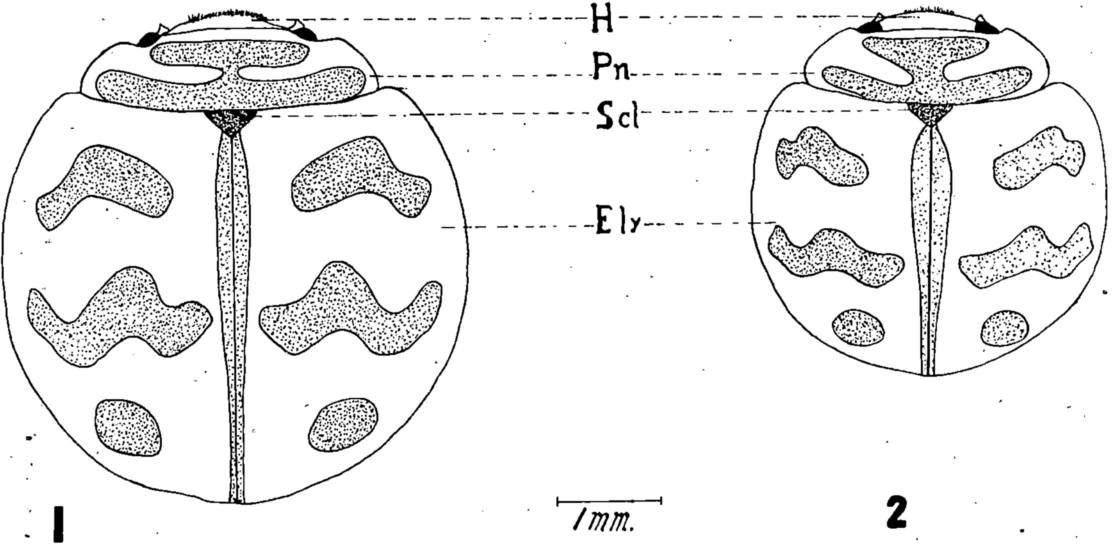


PLATE I

PLATE II

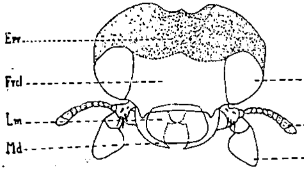
Structures of the head and mouth parts in *Cheilomenes sexmaculata* F.

Fig. 1. Head - dorsal view
2. Head - ventral view
3. Head - dorsal view (Labrum and fronto-clypeal region removed
4. Antenna
5. Labrum
6. Mandible
7. Epiphraynx
8. Torma
9. Hypopharynx
10. Labium
11. Maxilla

...

Aclp - Anteclypeus
Ant - Antenna
Bga - Basigalea
Cd - Cardo
Cdg - Cardogroove
Cdp - Cardoprocess
Cl - Club
E - Eye
Ephy - Epipharynx
Epr - Epicranium
Est - Eustipes
Fn - Funicle
Frcl - Fronto-clypeus
Ga - Galea
Gu - Gula
Gus - Gular suture
Hph - Hypopharynx
Hs - Hypopharyngeal suspensorium
Dga - Distigalea

Lb - Labium
Lc - Lacinia
Lbp - Labial palpus
Lig - Ligula
Lm - Labrum
Md - Mandible
Mo - Mola
Mx - Maxilla
Mxp - Maxillary palpus
Mt - Mentum
Pdc - Pedicel
Pfr - Palpifer
Prmt - Prementum
Pt - Posterior tentorial pit
Scp - Scape
Sga - Subgalea
Smt - Submentum
St - Stipes
Sgr - Subgenal ridge
T - Torma



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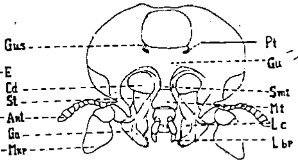

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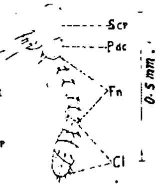

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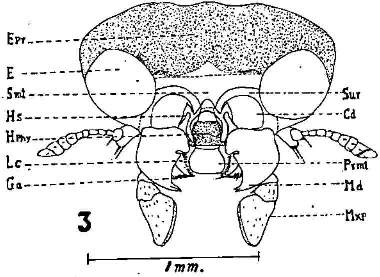

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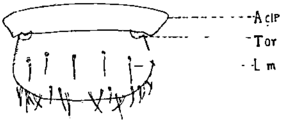

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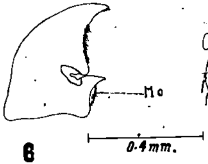

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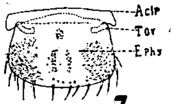

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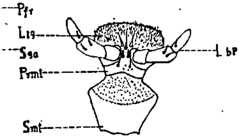

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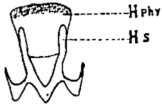


9

PLATE II

PLATE III

Thoracic sclerites in *Cheilomenes sexmaculata* F.

Fig. 1. Prothorax - dorsal view
2. Prothorax - ventral view
3. Mesonotum
4. Meso sternum and meso-pleura
5. Meta notum
6. Metasternum and metapleura
7. Metasternum - Internal aspect

***

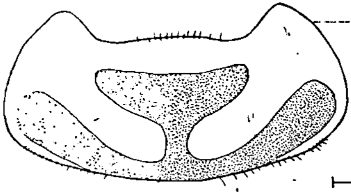
A - Anal vein
Aem - Anepimeron
Aes - Anepisternum
Anp - Anterior notal wing process
Aph - Anterior phragma
1 Ax - First axillary
2 Ax - Second axillary
3 Ax - Third axillary
Axc - Axillary cord
Bs - Basisternum

C - Costa
Co - Coxal cavity
Chl - Chitinized lobe
Cu - Cubitus
Cx - Coxa
Epm - Epimeron
Eps - Episternum
Fp - Furcal pit
Fu1 - Pro-furca
Fu2 - Meso-furca
Fu3 - Meta-furca

PLATE III (Contd.)

Fua - Furcal arm
Fum - Furca sternum
Hc - Humeral carina
Kem - Katepimeron
Kes - Katepisternum
Mes - Median suture
Mg - Median groove
Mp - Median plate
Mu - Muscle disc
Pa - Post alare
Pas - Para scutellum
Pc - Pronotal carina
Pcx - Post coxale
Pes - Preepisternum
Pl - Prosternal lobe
Pls - Pleural suture
Pn - Pronotum
Pnp - Posterior notal wing process

Pph - Posterior phragma
Pra - Prealare
Prc - Precoxale
Prf - Precoxal fold
Prsc - Prescutum
Ps - Pleural suture
Pscl - Post scutellum
R - Radius
Sc - Subcosta
Scl - Scutellum
Sct - Scutum
Scu - Scuto-scutellar suture
Sp - Spiracle
Sr - Sclerotic rod
Os - Oblique suture
Wp - Pleural wing process



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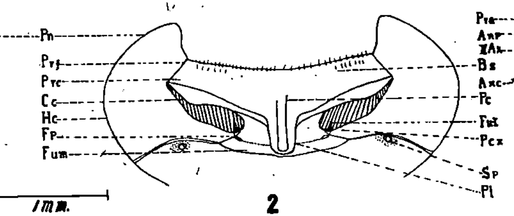

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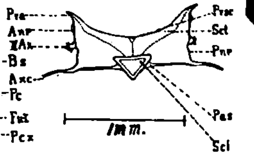

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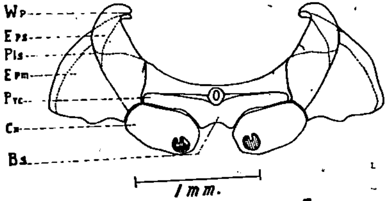

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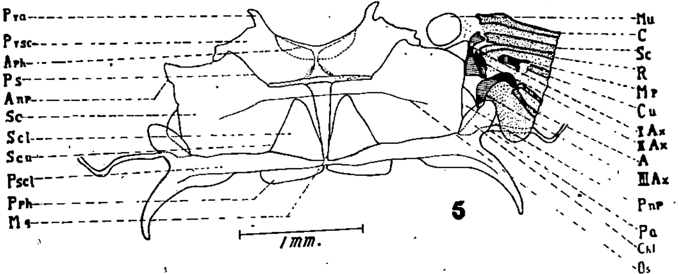

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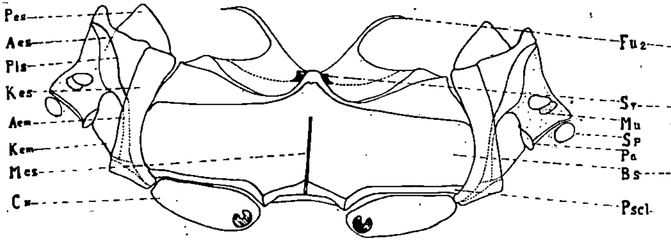

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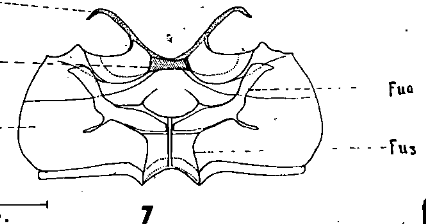

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PLATE III

PLATE IV

Structural details of the legs and wings in

Cheilomenes sexmaculata F.

Fig. 1. Foreleg

2. Middle leg

3. Hind leg

4. Fore coxa

5. Trochanter

6. Tarsus and Pretarsus

7. Pretarsus

8. Elytron – Dorsal view

9. Elytron – Ventral view

10. Hind wing – Folded

11. Hind wing – showing areas of the folds

12. Hind wing – Venation

***

A – Anal vein

Ap – Apophysis

Art – Articular surface

C – Costa

Con – Condyle

Cu – Cubitus

Cx – Coxa

Epl – Epipleura

Fm – Femur

M1 – First branch of media

Mr – Median recurrent

M4 + Cu – Fourth branch of Media and Cubitus

Ptar – Pretarsus

R – Radius

R1 – First branch of Radius

R3 – Third branch of Radius

Rr – Radial recurrent

Sc – Subcosta

Scm – Scutellar margin

Sum – Sutural margin

Tar – Tarsus

Tb – Tibia

Tbs – Tibial spur

Tr – Trochanter

Tra – Trachea

Un – Ungues

Utr – Unguitractor

X – Retractor of Claws (Tendon)

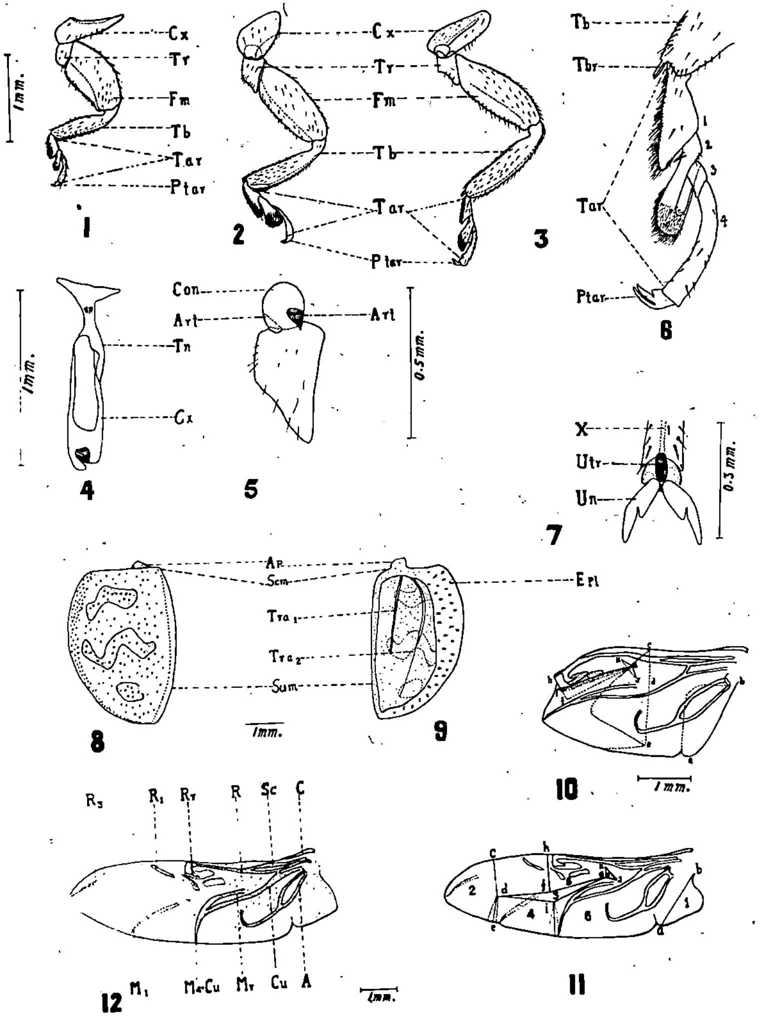

Cx
Tr
Fm
Tb
Tar
Ptar
1mm.
1
2
3
Tb
Tbr
1
2
3
4
Tar
Ptar
1mm.
6
Con
Art
Art
Tn
Cx
1mm.
0.5mm.
4
5
X
Utr
Un
0.3 mm.
7
Ap
Scm
Epl
Tra1
Tra2
Sum
1mm.
8
9
10
1mm.
R3
R1
Rr
R
Sc
C
M1
M+Cu
Mr
Cu
A
12
1mm.
c
h
d
e
a
b
1
2
4
6
11

PLATE IV

PLATE V

Structural characters of the abdomen and female genitalia in *Cheilomenes sexmaculata* F.

Fig. 1. Tergites

2. Sternites

3. Female genitalia - dorsal view

4. Female genitalia - ventral view

...

Abpl - Abdominal plate

An - Anus

Co - Coxites

Gpr - Gonopore

P - Pleural region

Pr - Proctiger

SpI - SpVII - Spiracles

Ss - Surstylus

StII- StVIII - Second to eighth sternites

Sty - Stylus

T I - T VIII - First to eighth tergites

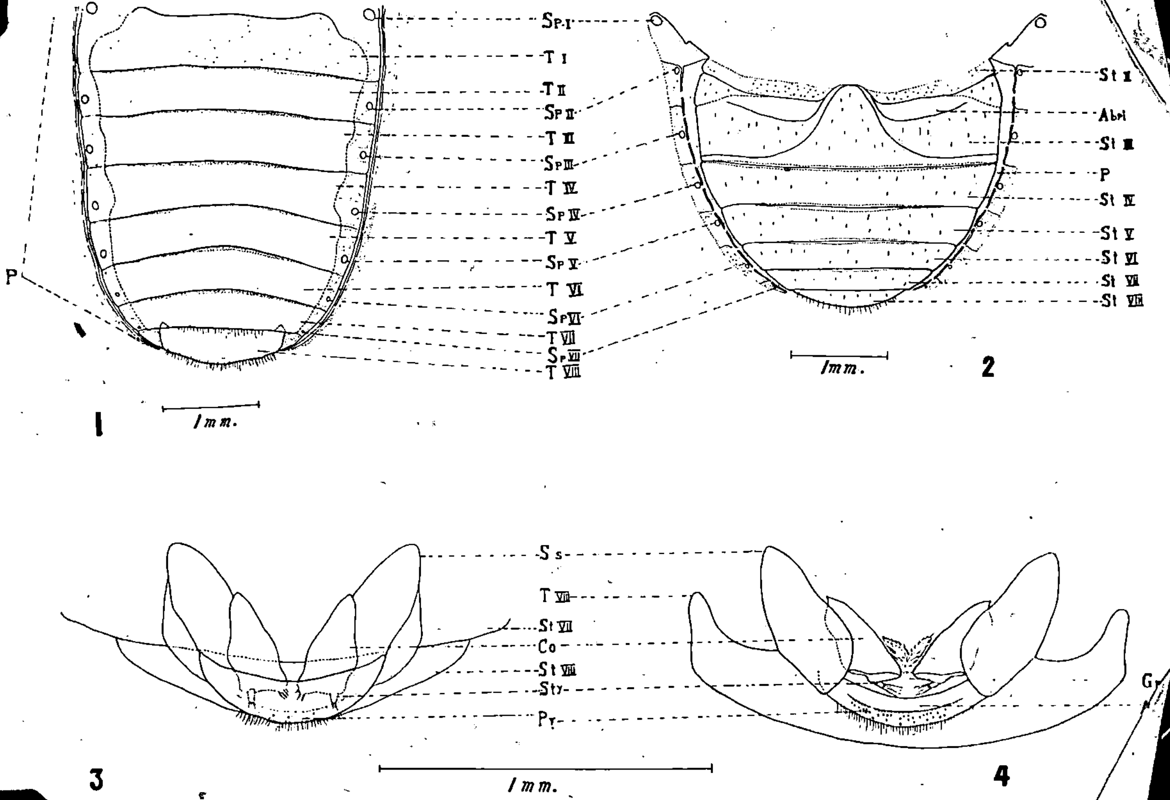

Sp I
T I
T II
Sp II
T III
Sp III
T IV
Sp IV
T V
Sp V
T VI
Sp VI
T VII
Sp VII
T VIII
P
1mm.
1
St II
Ab pl
St III
P
St IV
St V
St VI
St VII
St VIII
1mm.
2
Ss
T VII
St VII
Co
St VIII
Sty
Py
Gr
1mm.
3
4

PLATE V

PLATE VI

Structural details of male genitalia in

Cheilomenes sexmaculata F.

Fig. 1. Last abdominal segments (dorsal view)

2. Last abdominal segments (ventral view)

3. Tegmen

4. Male genital tube

5. Median lobe

6. Basal piece

7. Siphonal capsule

8. Lateral lobe

...

An - Anus

Bl - Basal lobe

BsAp - Basal apophysis

BsPc - Basal piece

Cm I - First connecting membrane

Ej - Ejaculatory duct

Gpr - Gonopore

Ll - Lateral lobe

Mg - Median groove

Mdlb - Median lobe

Mdst - Median strut

Spv - Spicula ventralis

IX T, X T - Nineth and tenth tergites

V - Virga

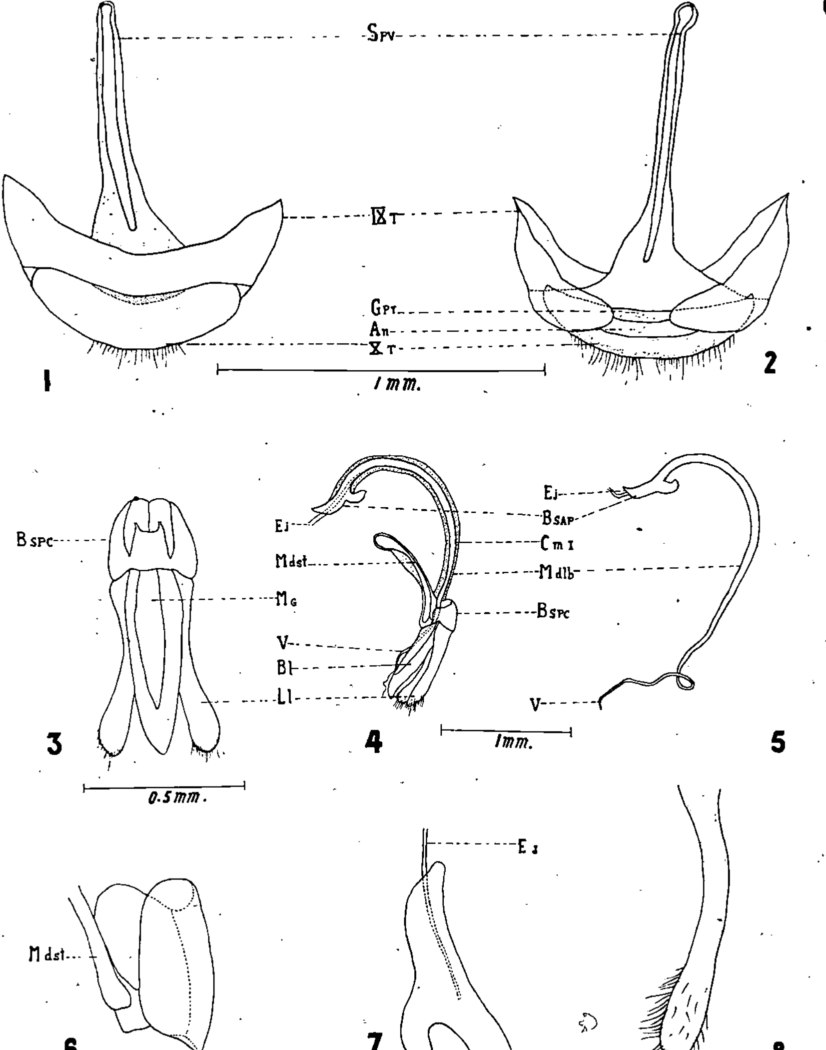

Spv
IX T
Gpt
An
X T
1
2
1 mm.
Bspc
Mg
V
Bl
Ll
3
0.5 mm.
Ej
Mdst
Bsap
Cm I
Mdlb
Bspc
4
1mm.
Ej
V
5
Mdst
6
Ej
7
8
0.6 mm.

PLATE VI

PLATE VII

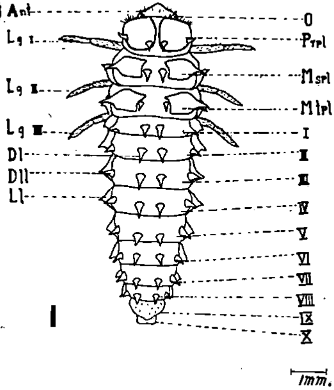
Structural characters of the 4th instar grub of *Cheilomenes sexmaculata* F.

Fig. 1. Dorsal view of the grub
2. Lateral view of the grub
3. Head - dorsal view
4. Head - ventral view
5. Antenna
6. Hypopharynx

* * *

Absp - Abdominal spiracle
Ant - Antenna
Bmb - Basal membrane
Cdst - Cardo and stipes (fused)
Dl - Dorsal spine
Dll - Dorso lateral spine
For - Foramen magnum
Frcl - Fronto-clypeal area
Fs - Frontal suture
Gms - Gulamental suture
Gs - Gular suture
Gu - Gula
Hphb - Chitinised bar of Hypopharynx
Hphs - Hypopharyngeal sclerome
Hphy - Hypopharynx
Lbp - Labial palpus
Lg1 - Prothoracic leg
Lg2 - Mesothoracic leg
Lg3 - Metathoracic leg

Lig - Ligula
Ll - Lateral spine
Lm - Labrum
Lsr - Lateral sclerotic rod
Ms - Ms
Md - Mandible
Msp - Mesothoracic spiracle
Mspl - Mesothoracic plate
Mtpl - Metathoracic plate
Mxp - Maxillary palpus
O - Lateral ocelli
Pmt - Postmentum
Prmt - Prementum
Prpl - Prothoracic plate
SeAp - Sensorial appendage
Scs - Semicircular sclerite
Suk - Sucker
Ve - Verrucae
I - X - Abdominal segments
1 - 3 - Antennal segments



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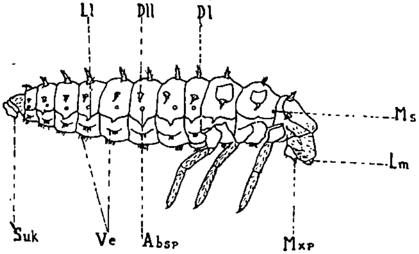

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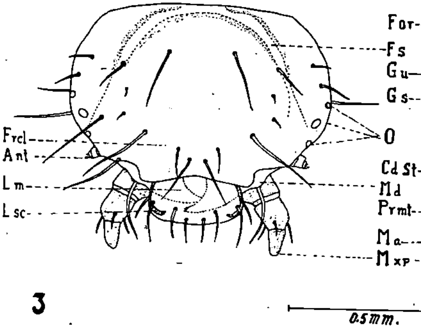

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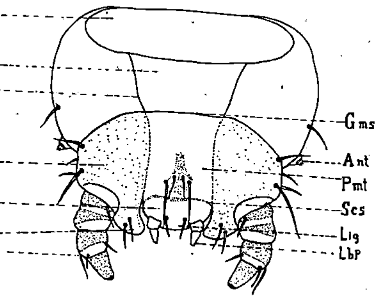

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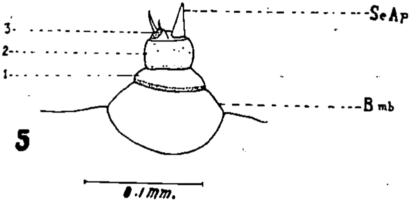

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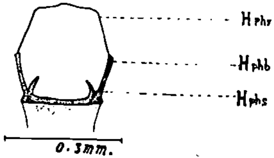

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PLATE VII

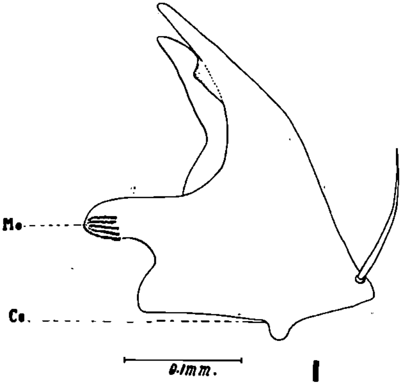
PLATE VIII

Structural details of the 4th instar grub (contd.) and pupa of *Cheilomenes sexmaculata* F.

Fig. 1. Mandible
2. Leg
3. Pretarsus
4. Terminal abdominal segments of the grub
5. Pupa - dorsal view
6. Pupa - ventral view

***

Ab - Abdomen
Abp - Abdominal pleuron
Absp - Abdominal spiracle
An - Anus
Cl - Claw
Co - Condyle
Cx - Coxa
E - Elytron
Fe - Femur
Fe1 - Femur of the foreleg
Fe2 - Femur mesothoracic leg
H - Head
Hw - Hind wing
Lm - Labrum
Ls - Larval skin
Msn - Mesonotum
Mssp - Mesothoracic spiracle
Mo - Mola
Mtn - Metanotum
Mxp - Maxillary palpus
Pn - Pronotum
Ptar - Pretarsus
Stn - Sternum
Suk - Sucker
Tar1 - Tarsus of the foreleg
Tar3 - Tarsus of the hind leg
Tbts - Tibiotarsus
Tr - Trochanter



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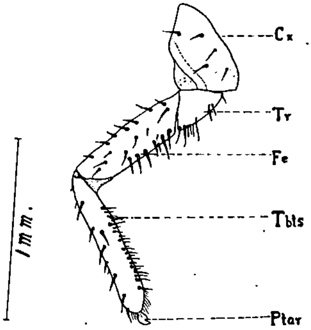

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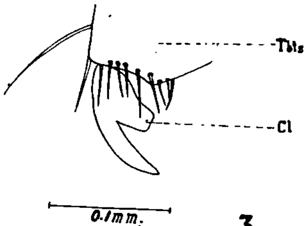

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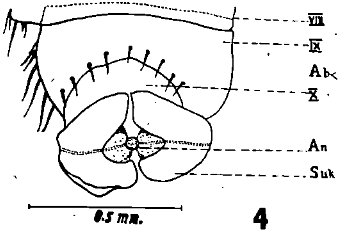

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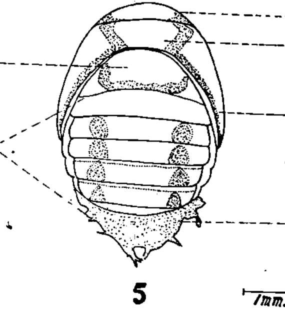

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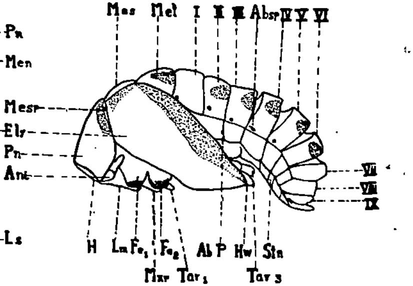

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PLATE VIII

PLATE IX

Glass cage used as oviposition
chamber

PLATE X

Gliricidia branch showing the unit area adopted
for counting the aphids and Coccinellids.

PLATE IX

PLATE X

PLATE XI

Graph showing the population of *Aphis craccivora* K. and *Cheilomenes sexmaculata* F. on Gliricidia for the period from 3-3-62 to 26-1-63 in relation to weather factors.

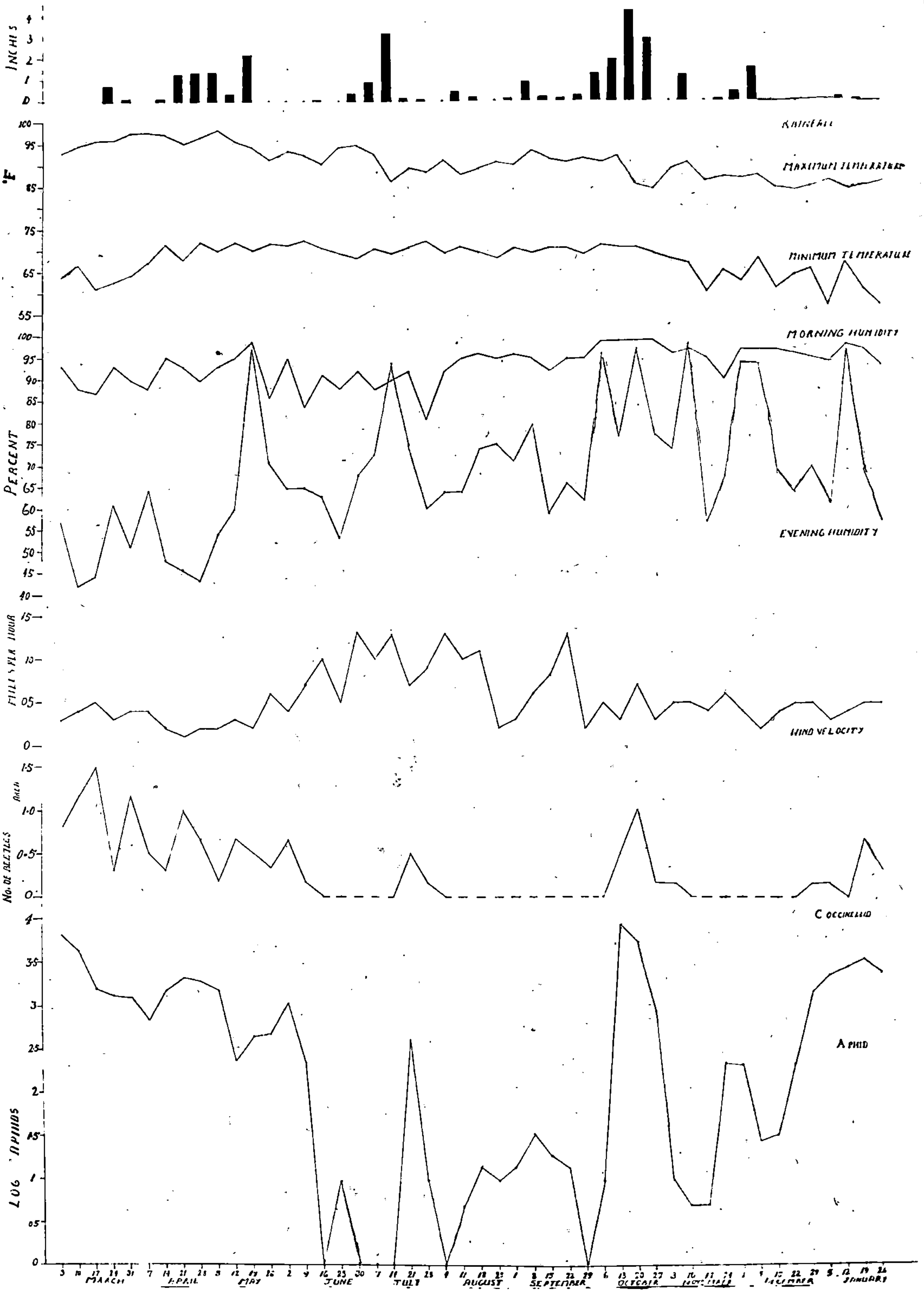

INCHES
0
1
2
3
4
RAINFALL
°F
100
95
85
75
65
55
MAXIMUM TEMPERATURE
MINIMUM TEMPERATURE
PERCENT
100
95
90
85
80
75
70
65
60
55
50
45
40
MORNING HUMIDITY
EVENING HUMIDITY
MILES PER HOUR
15
10
05
0
WIND VELOCITY
No. OF BEETLES EACH
1.5
1.0
0.5
0
COCCINELLID
LOG APHIDS
4
3.5
3
2.5
2
1.5
1
.05
0
APHID
3 10 17 24 31
MARCH
7 14 21 28
APRIL
5 12 19 26
MAY
2 9 16 23 30
JUNE
7 14 21 28
JULY
4 11 18 25
AUGUST
1 8 15 22 29
SEPTEMBER
6 13 20 27
OCTOBER
3 10 17 24
NOVEMBER
1 8 15 22 29
DECEMBER
5 12 19 26
JANUARY

PLATE XI

PLATE XII

Graph showing the population of *Aphis craccivora* K. and *Cheilomenes sexmaculata* F. in relation to wind velocity.

PLATE XII

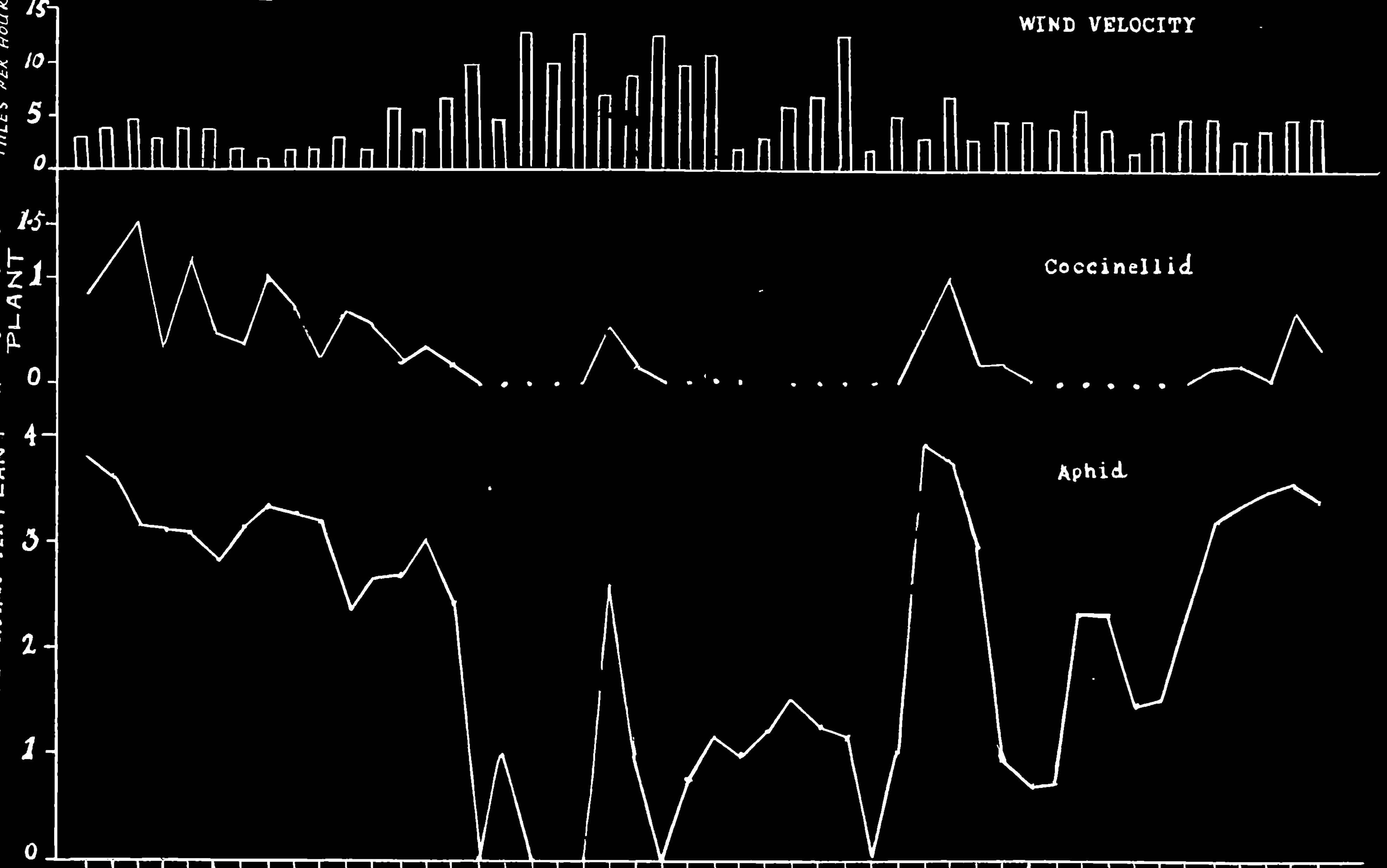
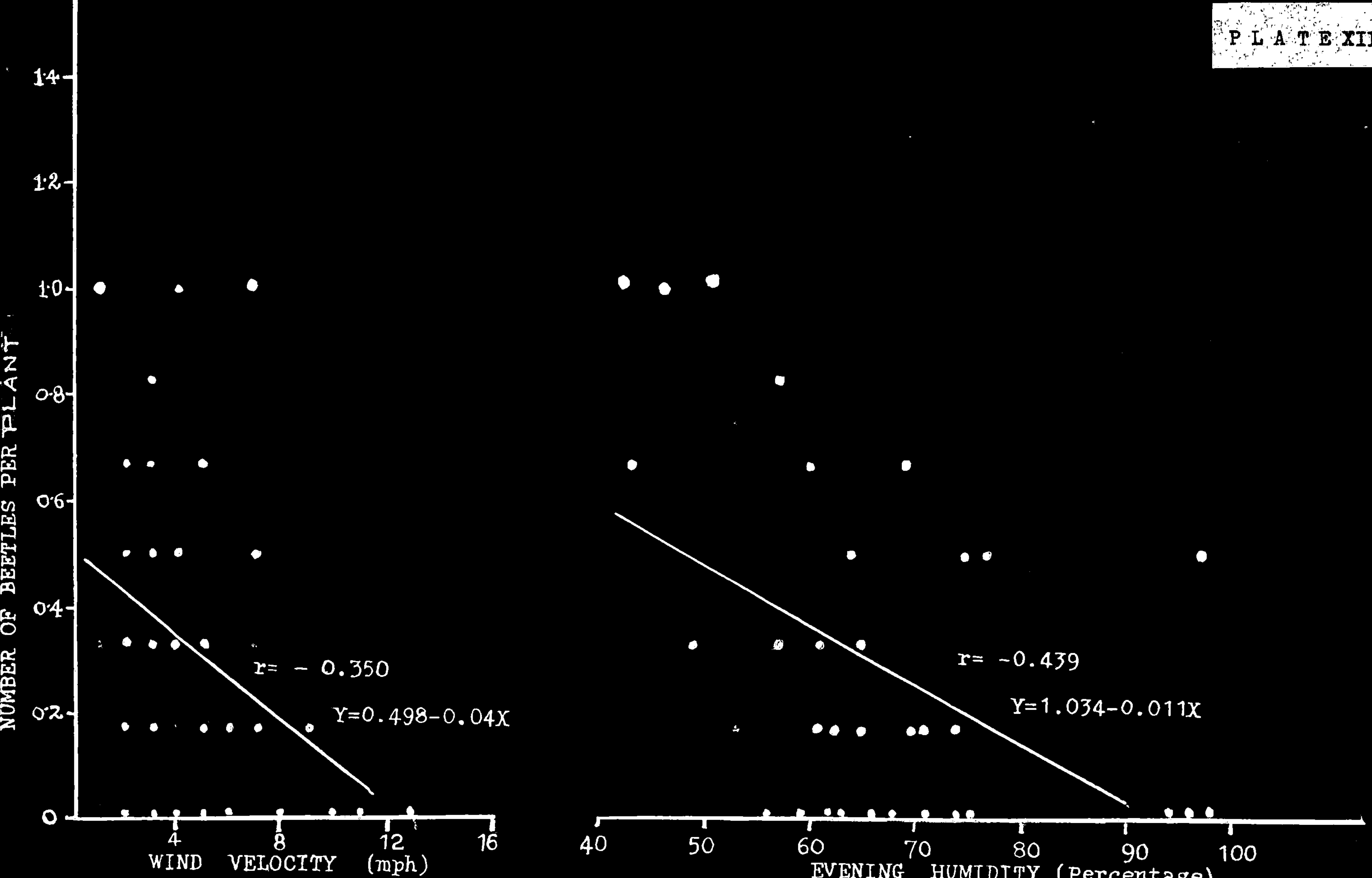

WIND VELOCITY
MILES PER HOUR
15
10
5
0
Coccinellid
PLANT
1·5
1
0
Aphid
4
3
2
1
0

PLATE XIII

RELATIONSHIP BETWEEN THE POPULATION OF *CHEILOMENES SEXMACULATA* F.
AND (i) WIND VELOCITY AND (ii) EVENING HUMIDITY



RELATIONSHIP BETWEEN THE POPULATION OF

APHIS CRACCIVORA K. AND *CHEILOMENES SEXMACULATA* F.

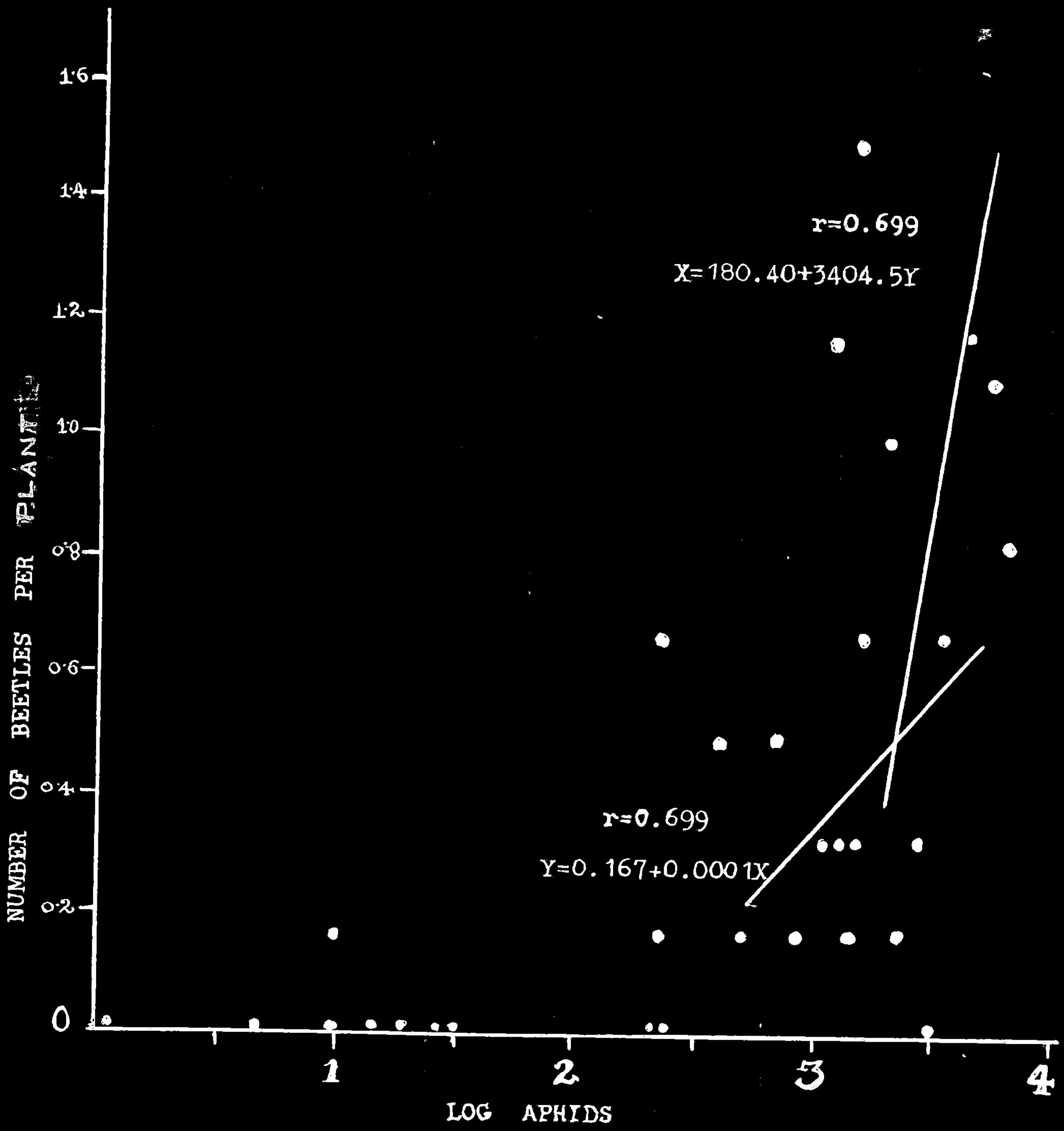


PLATE XIV