



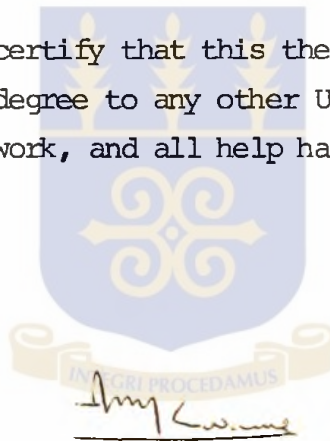
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ZOOLOGY DEPARTMENT
UNIVERSITY OF GHANA
LEGON
GHANA

This is to certify that this thesis has not been submitted for a degree to any other University. It is entirely my own work, and all help has been duly acknowledged.



(KWAME ADU-MENSAH)

ii.

BIOLOGY OF SOME OXYCARENUS SPECIES
(HETEROPTERA: LYGAEIDAE) IN
SOUTHERN GHANA

BY

KWAME ADU-MENSAH, B.Sc. (Hons)



A thesis submitted for the degree of Master of Science
at the University of Ghana, 1976.

JUNE 1976

iii.

To

My Uncle

KWAME AMOAH

"Esie ne kagya ni aseda".



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A B S T R A C T

The biology of three species of Oxycarenus found in Southern Ghana has been studied. Their host plants are listed and host preferences examined. The seasonal population changes of two species have been followed. The natural enemies and defensive mechanisms have been studied. A detailed description of the immature stages of the three Oxycarenus species has been given for the first time and keys furnished to distinguish all the larval stages as well as the adults. Growth patterns were studied and the relationship between measurements of successive instars is discussed.

1. GENERAL INTRODUCTION

The genus Oxycarenum Fieber, 1837 (Lygaeidae: Oxycareninae) consists of three sub genera which includes several species distributed throughout the world, except North America (Slater, 1964). Slater (1964) listed 39 species in his catalogue of the Lygaeidae of the world out of which 21 were recorded from Africa. Samy (1969) erected 2 sub genera within the genus and described 17 new species from Africa, making a total of 38 species now known from Africa. The African species are known to occupy a wide range of distribution from the Mediterranean North down to the Temperate South and across the Tropical Savanna, each sub-region having its own group of dominant species.

In Ghana, four species are known; these are Oxycarenum fieberi Stål; Oxycarenum dudgeoni Distant; Oxycarenum gossipinus Distant; and Oxycarenum hyalinipennis (Costa). The first three species occupy the Guinean forest block with extension into large clearings, while the fourth is a Guinea savanna species stretching into the coastal scrub belt of parts of the Central Region and into the dry savanna of the Accra plains (Leston, 1970). They are among 7 species that occur in the West African sub-region.

Oxycarenum sp. have been known for a long time as pests of cotton

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and other crops. Ballou (1919) stated that O. hyalinipennis was known in Egypt as early as 1860. In Australia, the name "Coon Bugs" first appeared in the literature in Froggatt (1901). In Africa, Theobald (1906) reported of Oxycarenum in bales of cotton from Uganda as well as their attack on cotton seeds in the field. Morstatt (1914) reported the occurrence of this genus from Tanganyika; Pomeroy (1921) from Nigeria; Vrijdagh (1930) from Belgian Congo; and Cotterell (1928) from Ghana.

Opinions differ, however, on the type and extent of damage done to cotton and whether to regard Oxycarenum species as major or minor pests. The first scientific description of the damage caused was credited to Sickenberger (1890) who made mention of the insects sucking sap from the bases of young pods and also from the blossom preventing their development. Damage to seeds with the resulting diminution of germinative strength was also mentioned. Many workers, notably, Peacock (1913) and Ballou (1919) studied the biology of Oxycarenum but did not describe the nature and extent of damage. While Rao (1921) and Anonymous (1922) regarded Oxycarenum as a minor pest, Vrijdagh (1930) reported average damage being done to cotton in Belgian Congo and Pomeroy (1921) regarded O. dudgeoni Distant as one of the major pests in Nigeria. The most important work on Oxycarenum to date is that of Kirkpatrick (1923) in Egypt. After an extensive study of O. hyalinipennis, he came to regard this species as

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a major pest of cotton and this was confirmed by Bedford (1923) in Sudan. Similar work by Morstatt (1914) in Tanganyika (Tanzania) failed to establish O. hyalinipennis as a pest but noted that the staining resulting from crushing the insects during ginning might prove a source of economic loss. Harris (1936) in Tanzania and Anderson (1927) in Kenya expressed similar views. However, from Uganda, Gowdey (1912) stated: "the Dysdercus species being large and conspicuous are generally considered to be the most prevalent and destructive but O. hyalinipennis is responsible for the greatest destruction". Forty-five years later, Odhiambo (1957) regarded Oxycarenus as a minor pest of cotton and that the major damage was in the lowering of germinating power of seeds.

Recent progress with the study of the various aspects of the biology, behaviour as well as the formulation of keys for identification of immature stages of Heteroptera has been remarkable. Prominent among these are the works of Butler (1923); Woodward (1952, 1949, 1962); Leston and Scudder (1956); Southwood (1956a and b); Pearson (1958); Puchkov (1958, 1959a and b); Sweet and Slater (1961), who suggested that the classification categories must in future be based in part on larval instars; Kennedy (1961); Decoursey and Esselbaugh (1962); Johnson (1963); Eyles (1963); Kumar (1966, 1967, 1969); Kumar and Ansari (1974). None of these workers, however, included the

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sub-family Oxycareninae in his studies. With the growing of cotton on large scale in Ghana, such a study assumes some importance.

Kirkpatrick (1923), Odhiambo (1957), Pearson (1958), Samy (1969) and Forsyth (1966) all have named some feral host plants of Oxycarenus but still more work is needed in this direction. It also remains to be established whether seeds are the prime item in the diet of these bugs and if so what preferences the various species have. Added to these are the lack of information on the details of colonial populations and how these fluctuate in size. Studies on parasites and predators are totally lacking, so also is a comprehensive key for separating the various instars of the species. This work may prove useful in these directions.

Samy's (1969) revision of the genus Oxycarenus Fieber is most timely as more malvaceous crops are being cultivated on a large scale in Ghana. The most important single project afoot is the irrigation of the Accra plains for the cultivation of crops like okro, cotton and kenaf. The monoculture situations that may arise, coupled with improved methods for high yields may only succeed in a shifting of both seed feeding and plant sucking insects from their feral host plants unto such introduced crops, a problem having already been encountered in the cocoa industry (Entwistle 1972). A general survey of poten-

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tial pests and the problems they could pose becomes essential. Little reliance can be placed on Samy's (1969) determinations, and records of Forsyth (1966) from Ghana are largely indeterminate. In all these respects, entomologists now recognize that a knowledge of the immature stages of the species involved often increases our understanding of current biological problems (Kumar and Ansari 1974).

The purpose of this project was to investigate some of the above mentioned aspects of the biology of Oxycarenus in Southern Ghana as well as the following: development of suitable methods of rearing instars in the laboratory which have enabled studies to be made of the basic features of biology such as oviposition, oviposition preferences, pre-oviposition period, mating behaviour, aggregation, moulting, morphology and morphometrics of all immature stages, growth patterns; formulation of keys for distinguishing larvae and adults; flight and dispersal; distribution of three species of Oxycarenus in Ghana; host preference, succession of hosts and the structure of Oxycarenus colonies.

Due to the time limit of one year, this project is necessarily incomplete. It remains a regret that it was not possible to study the fourth species of Oxycarenus which seems to be confined to Northern Ghana. However, the author hopes to pursue the project in the near future.

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2. ECOLOGY OF OXYCARENUS SPECIES IN SOUTHERN GHANA2.1 INTRODUCTION

Bugs of the genus Oxycarenus Fieber, 1837, are well known pests of cotton and other malvaceous crops in Africa and elsewhere in the world. However, studies on details of colonial populations and their fluctuations are totally lacking in this genus. Added to these are problems such as the occurrence of wild host plants, host plant succession as well as natural enemies. Studies on the flight activity and dispersal have never been made. With the cultivation of malvaceous crops such as cotton, okro and kenaf, now one of the priorities in Ghana, a knowledge of these aspects of the ecology of Oxycarenus in Ghana would, it is hoped, be of assistance in evolving long term control measures.

2.2 MATERIALS, LOCALITIES AND METHODS2.2.1 Materials

All the material was the writer's own collection. A stock culture was kept in the laboratory (see p. 63.)

2.2.2 Localities

In the savanna zone, surveys were done at Madina, Domi, Christian Village and Achimota, all near the

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University of Ghana, Legon; and in the forest zone areas at Obosomasi, Mampong, Mamfe, Akropong and Adukrom, all in the Eastern Region of Ghana; (Fig.2.1.)

2.2.3 Methods

2.2.3.1 Methods for host preference tests:

Thirty adult individuals (15 males and 15 females) of each species of Oxycarenus were collected from the field and starved for 24 hours. Equal quantities by volume of two species of seeds were presented. These were soaked for a few hours and heaped at the opposite corners of a perspex box measuring 220 mm long, 110 mm broad and 15 mm high. The thirty starved insects were dropped into the base from a hole in the centre of the cover so that they landed between the two heaps. After allowing the insects to get settled, the number feeding on each heap of seeds was recorded at fifteen minute intervals. This was repeated three times, disturbing the insects at the end of each recording. Each series of experiments was repeated four times, using fresh individuals and fresh seeds each time. The volumes of seeds used were measured with a perspex dish of diameter 50 mm and height 20 mm. This was filled to the brim and then levelled off.

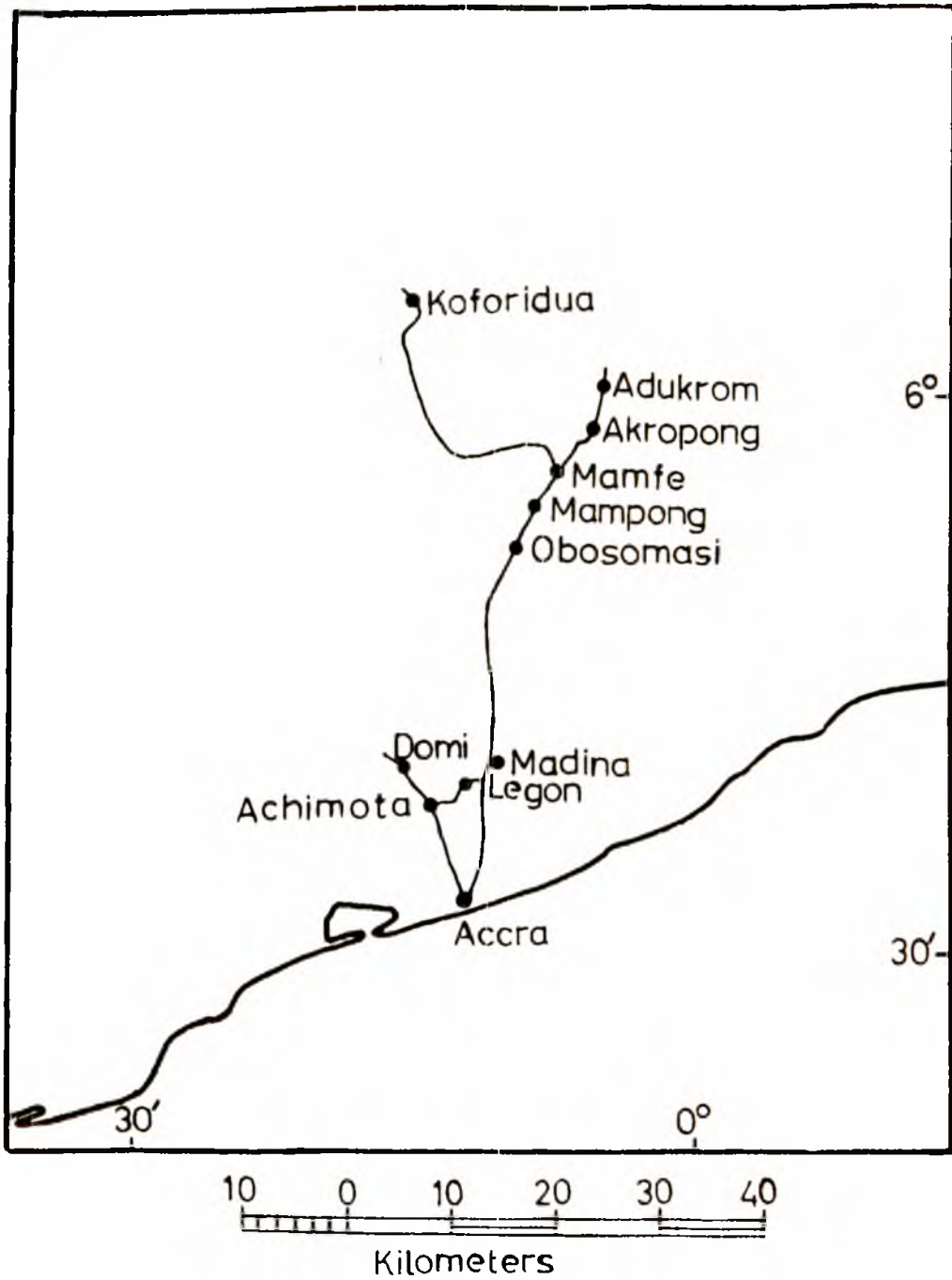


Fig. 2.1: Showing localities where sampling was done.

2.2.3.2 Methods used in the study of population changes

Oxycarenus hyalinipennis on Abutilon mauritianum

(Jacq.) Medic. was sampled from October 1974 to October 1975 in the Guinea savanna localities near Legon in the Greater Accra Region. Two sampling sites were selected from Madina, one on either side of the main road leading to the town. One site was selected from each of the localities at Domi, Christian Village, and Achimota (Fig.2.1). Once a week, two dry flower heads were collected from each sampling site to make up a total of 10 heads. Collection was done in the morning, between 8.00 a.m. and 9.00 a.m. when the insects were still sheltering in the seed compartments. Ethyl acetate was used as the killing agent and data for the first to third instars were pooled together.

O. fieberi on Sida acuta Burm. was sampled from the Guinea savanna localities and forest zone. Sampling sites in the savanna zone were the same as for O. hyalinipennis. In the forest zone one site was selected each from Akropong, Obosomasi, Mampong, Mamfe and Adukrom (Fig.2.1).

From each site two stems of Sida acuta measuring 300 mm in height were collected into polythene bags. The stem was enveloped in the bag before the required length was cut. Adults were thus prevented from flying away

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and larvae from dropping to the ground. Material collected was treated as for O. hyalinipennis.

2.2.3.3 Methods for studying dispersal

50 young adults of O. dudgeoni, 25 males, 25 females, 1-2 days old, were marked on the pronotum and corium of wing and released on a branch of Ceiba pentandra in the University of Ghana Botanical Gardens. Within the following three days collection and examination of O. dudgeoni individuals was carried out in the surrounding areas to find out if any marked insects have been recaptured. Older adults, 8-10 days old, were similarly treated two weeks later. Similar experiments were carried out for O. hyalinipennis on Abutilon mauritianum.

2.2.3.4 Methods for studying flight in different age groups

30 adult females of O. dudgeoni in age groups 1-2 days, 3-4 days, 5-6 days, 7-8 days, 9-10 days, 11-12 days, 13-14 days, 15-16 days, and 17-18 days, were used. The insect was held suspended from the blunt end of a pin attached to a long thread and was lifted sharply from the substrate and moved through a gentle breeze from an electric ceiling fan. As the tarsi lost contact the insect spread its wings in some cases and flight commenced. Each insect so treated was lifted off the

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substrate on 10 occasions. Flight activity was scored when the wings were spread. The experiment was repeated with males.

2.2.3.5 Methods of studying parasites

Egg parasites

50 eggs each of O. dudgeoni and the same number of O. hyalinipennis were collected from the field every month. 25 eggs of O. fieberi were collected from the forest zone and the same number from the savanna zone every month. All eggs were kept in covered perspex dishes for the emergence of parasites. A total of about 500 eggs were examined for egg parasites of O. fieberi and O. hyalinipennis from October 1974 to October 1975, and about 150 of O. dudgeoni from February to April 1975.

Larval parasites

About 100 larvae of each of the third, fourth, and fifth instars of O. hyalinipennis and O. fieberi were collected from the field and reared in the laboratory from the period October 1974 to October 1975. The same number of O. dudgeoni was reared between February 1975 and April 1975. Since larval parasites usually emerge from adults, the larvae were reared to adulthood. Parasites that emerged, if any, were noted.

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Ectoparasites

Ectoparasitic mites were collected from the body and also the rearing dishes. These were sent to specialists for identification.

2.2.3.6 Methods for studying predators

Vertebrate predators

Visual observations were made to establish the identity of vertebrates such as birds, lizards and any others that might be preying on the bugs. Faecal pellets and stomach contents of five lizards were examined for various parts of Oxycarenus that might have been consumed as food.

A caged Agama agama^(L.) was presented with both larvae and adults of the three species to determine whether these were used as food.

Invertebrate predators

Insect predators of Oxycarenus were collected and identified. The predator-prey relationship was studied in the laboratory for some of the species collected.

Potted Sida acuta^{Burm.} plants were put in a cage. A number of young Oxycarenus adults or larvae were introduced into the cage together with an assassin bug (Heteroptera: Reduviidae) which had been starved

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for 24 hours. A control was set up without the predator to account for numbers which died from natural causes. Records were kept of the number of prey eaten in 24 hours. Five replicates were set up.

Preference tests

Equal numbers of two species of Oxycarenus were introduced into the cage. Two predators of the same species were also introduced. The total number of each species of prey eaten in 24 hours was recorded. A control and three replicates were set up.

2.3 RESULTS AND OBSERVATIONS

2.3.1 Distribution of the three species of Oxycarenus in Ghana

Locality records of Oxycarenus hyalinipennis, O. dudgeoni and O. fieberi in Ghana are based on the present work and Leston (1970). These records indicate O. hyalinipennis to be a species of the Guinea savanna vegetation of the North and also ranges along the coastal forest-savanna mosaic (scrubland) belt of the Central Region and in the dry savanna of the Accra plains. However, old extensive clearings in the forest zone have also been colonized because of the growth of Abutilon^{sp.} and Sida cordifolia Linn. which thrive in the open habitat. This was seen at Kumasi,

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Bekwai, Aburi, Keta, Kpedzi and Fomena (Fig.2.2).

The range of O. dudgeoni in Ghana extends in the forest zone. Leston's (1970) interpretation of Samy's (1969) data on O. dudgeoni is that the range is co-extensive with that of the tropical African forest, covering both the Guinean and Congo blocks (see Keay's (1959) map). This range and the distribution in Ghana dovetail neatly. Samy (1969) listed kapok or silk cotton under the name Eriodendron and placed it in Malvaceae but it is now regarded as a single species (Ceiba pentandra Gaertn.) of Bombacaceae in Africa, (Institut National pour L'Etude Agronomique du Congo 1963; Hutchinson and Dalziel 1958). Ceiba pentandra is the principal feral host plant in Ghana and this is a forest plant variety. It seems from records that O. dudgeoni cannot survive outside the forest zone (Leston 1970). Its occurrence in the forest-savanna interface is largely due to the presence of Ceiba pentandra, for example at Legon which has a mixed forest-savanna fauna exemplified by such diverse groups as birds and mantids. Cotton cultivation in Ghana, until recently, was confined to the savanna and the absence of the bugs from the cotton plots in Northern Ghana is a significant indication of

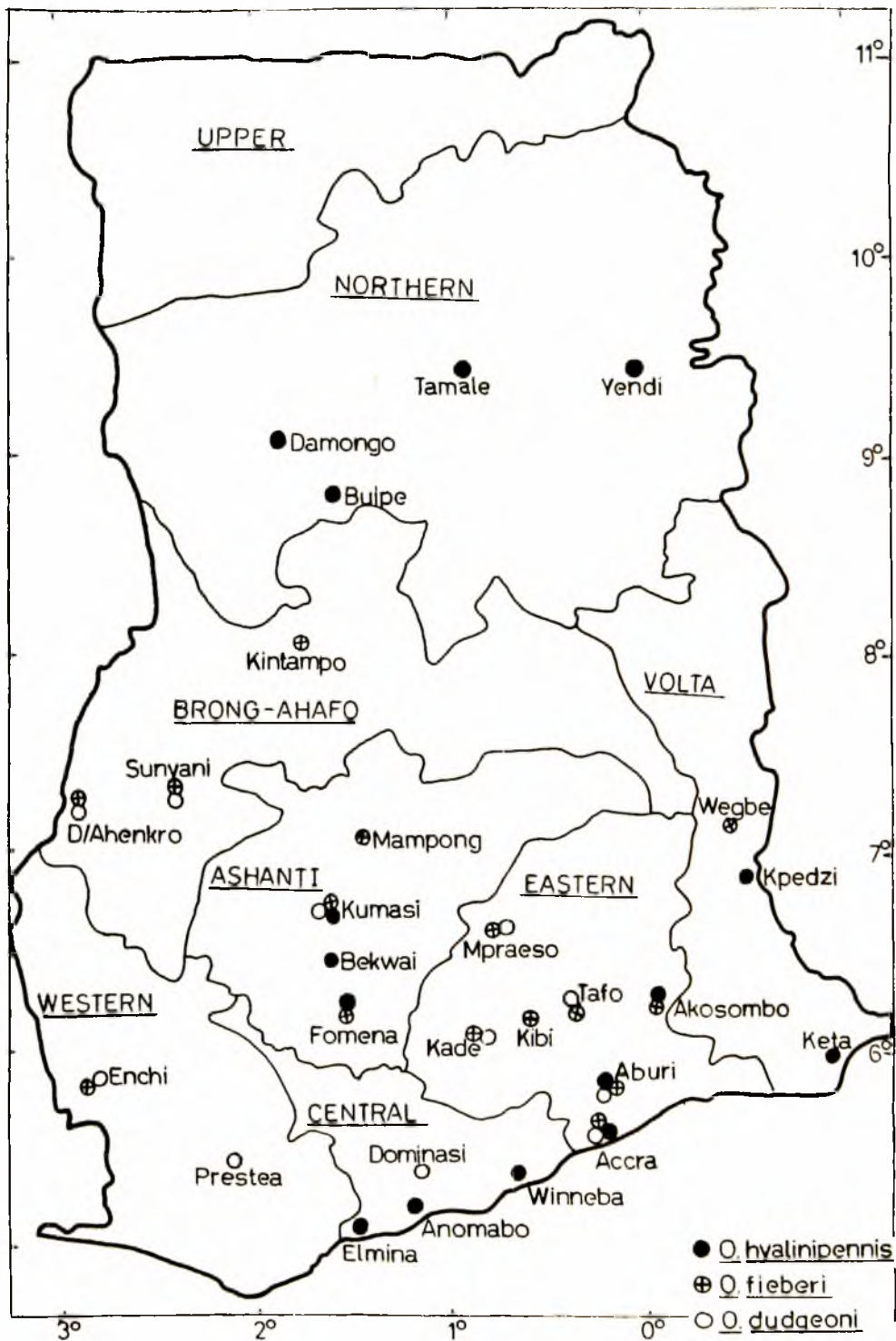


Fig. 2.2: Map of Ghana showing the distribution of the three *Oxycaenus* species studied in the present work.

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the unimportance of these bugs there.

The main feral host plants of O. fieberi in Ghana are varieties of Sida, notably, S. acuta and S. rhombifolia. These perennials grow at the isolated margins of cocoa farms, on paths in food farms and farm bush as well as around weedy lanes and backyards of towns and villages. The distribution indicates it as a common bug of clearings in the forest zone and the derived savanna areas which once were forest. This fits the overall pattern in West Africa by Samy (1969).

Mapping of this nature is important since it delimits areas where feral host plants support indigenous populations which can serve as the only source of infestation of introduced crops. Once such areas are clearly known, they can be avoided during the selection of areas for agricultural projects.

2.3.2 Host plants

Bugs of the family Lygaeidae have rather varied feeding habits (Pearson, 1958). While some genera such as Geocoris are predatory, others attack the vegetative parts of plants and several others feed on fruits and seeds in various stages of development. The genus Oxycarenus Fieber is particularly associated

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with the ripe seeds of cotton, Gossypium spp., and other Malvaceous plants, hence the various species being known collectively as "COTTON SEED BUGS". Both adults and larvae suck oil from mature seeds (Vayssiere and Mimeur 1923) and will also suck juice from leaves and young stems to secure moisture (Odhiambo 1957). While studying the life history of O. hyalinipennis in Egypt, Kirkpatrick (1923) showed that prior feeding on seeds of various malvaceous plants such as Gossypium, Hibiscus, Althaea and other closely related plants was essential for breeding to take place.

There are other plants outside the Malvaceae on which various species of Oxycarenus have been found at one time or another. Results from pyrethrum knockdowns are largely indeterminate, so it seems unlikely that Oxycarenus feeds on many of the host plants cited by various authors and collectors. For example, the presence of O. dudgeoni in pyrethrum knockdowns from cocoa (Theobroma cacao L.) Leston 1970); on Spondias mangifera Willd seedling (Forsyth 1966) and of O. hyalinipennis on mango (Mangifera indica), guava (Psidium guajava) and citrus trees (Samy 1969). Their presence on such plants, especially during the resting stage is only accidental and temporary (Samy 1969). Neither feeding nor breeding

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takes place on such "hosts" which can be recognised by the undamaged condition of the plants when the insects are shaken off. Even if some damage were done, it could be argued that it was in respect of search for moisture. In addition, species with wide powers of dispersal, for example, O. dudgeoni in kapok are inadvertently transported to plants which are not host plants and are not colonized.

While some host plants flower throughout the year, others do so periodically and in this case colonization occurs at the particular period when dry seeds are present. It is to be expected that bugs will abandon old habitats in search of new ones as seeds diminish in quality and/or quantity, and new ones become available. With migration between a succession of host plants throughout the year, the population of particular host plants will wax and wane. Potential host plants without mature seeds or even those with developing fruits have been found without bugs, even when the plants have been colonized before.

The host plants of the three species, Oxycarenus dudgeoni, Oxycarenus fieberi and Oxycarenus hyalinipennis, are listed in Table 2.1.

19.

Table 2.1: HOST PLANTS OF OXYCARENUS IN GHANA
(Localities are given in brackets)

HOST PLANTS	Dudgeoni	Fieberi	Hyalinipennis
<u>MALVACEAE</u>			
<u>Hibiscus micranthus</u> Linn. (Achimota, Akwapim-Mampong, Legon, Madina)	A		A
<u>Hibiscus tiliaceus</u> Linn. (Legon, Achimota)	A		A
<u>Hibiscus sabdariffa</u> Linn. (Mampong-Ashanti, Kwadaso)			A DL
<u>Hibiscus esculentus</u> Linn. (Keta, Tegbui, Avume, Elmina, Sunyani, Kpedzi, Legon, Achimota, Shai Hills)	A		A
<u>Hibiscus cannabinus</u> Linn. (Mampong-Ashanti, Kwadaso, Ejura)			A
<u>Abutilon guineense</u> (Schum. & Thonn.) (Madina, Legon, Achimota)	A F	A	A F
<u>Abutilon mauritianum</u> (Jacq.) Medic. (Achimota, Madina, Legon, Elmina, Aburi)	A F	A	A DL
<u>Sida cordifolia</u> Linn. (Legon, Achimota, Madina, Nungua)	A	A DL	A DL
<u>Sida acuta</u> Burm. (Elmina, Kankan, Kintampo, Fomena, Kumasi, Enchi, Abeadzi-Dominasi, Akosombo, Begoro, Mampong-Akwapim, Sagyasi, Mpraeso, Tafo, Legon, Achimota, Aburi, Wegbe, Sunyani, Dormaa-Ahenkro, Atebubu).	A	A DL	A DL

20.

HOST PLANTS	Dudgeoni	Fieberi	Hyalinipennis
<u>Sida rhombifolia</u> Linn. (Mampong-Akwapim, Akropong, Mampong-Ashanti, Kintampo, Sunyani, Dormaa-Ahenkro, Fomena, Legon, Cape Coast, Tafo, Aburi, Kumasi, Akosombo)	A	A DL	A
<u>Gossypium hirsutum</u> Linn. (Nungua, Ohawu, Pomadzi, Yendi, Kwadaso, Anomabu, Biriwa)	A DL F		A DL
<u>Urena lobata</u> Linn. (Mampong-Ashanti, Madina, Nungua)	A		A
<u>Malvastrum</u> sp. (Madina, Elmina, Kumasi, Odumasi-Sunyani)			A
<u>Wissedula amplissima</u> (Schum. & Thonn.) (Madina, Elmina, Legon, Achimota, Aburi)			A
<u>Cochorus</u> sp. (Mampong-Ashanti)			A
<u>BOMBACACEAE</u>			
<u>Ceiba pentandra</u> Gaertn. (Kumasi, Prestea, Aburi, Amanforo, Nkwanta, Tafo, Legon, Odumasi-Sunyani, Abandzi, Anomabu, Mampong-Ashanti)	A DL		
<u>Ochroma lagopus</u> SW. (Legon)	A		
<u>STERCULIACEAE</u>			
<u>Sterculia foetida</u> Linn. (Legon)	A		

21.

HOST PLANTS	Dudgeoni	Fieberi	Hyalinipennis
<u>OTHERS</u>			
<u>Asclepias</u> sp. (Locality names not available)			DL
<u>Spondias mangifera</u> Willd. (Locality names not available)			F
<u>Ricinus communis</u> Linn. (Nyankpala, Kumasi, Adukrom, Elmina, Akropong)			F

KEY: A - This study
 DL - Leston (1970)
 F - Forsyth (1969)

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The main feral host plants of Oxycarenus are limited to the Malvales which include the families Malvaceae, Sterculiaceae and Bombacaceae. These together form the natural order Columniferae. Seeds of Malvaceae become available as and when they mature whereas pods of Bombacaceae and Sterculiaceae must dehisce before their seeds become accessible. Malvaceous species normally do not shed their seeds, unlike Sterculiaceae and Bombacaceae, which drop their seed laden pods when these ripen and dehisce. These differences are reflected in feeding behaviour of the Oxycarenus species that colonize them and also explains why Sterculiaceae and Bombacaceae are colonized only at the particular periods when dry dehisced fruits are available. Thus, while colonization always occurs on the malvaceous plants, seeds of the other two families may be colonized both on the trees and on the ground.

The malvaceous species flower throughout the year, unlike Sterculiaceae and Bombacaceae, which do so periodically. The latter situation calls for succession of colonization by the bugs to ensure food all the year round. Preference for particular species of seeds may also account for succession. In this case, the bugs abandon already colonized host plants and move onto new ones which are preferred when these come around although in quality and quantity, the food of the first host

plant may not have been exhausted. Generally, however, heavily colonized seeds tend to diminish in quality and/or quantity.

The feral host plants of O. fieberi and O. hyalinipennis are limited to the Malvaceae. Sida rhombifolia, S. acuta and S. cordifolia constitute the main feral host plants of O. fieberi in Ghana. Sida species are widespread in the tropics and are important perennial weeds of many plantation crops. Elsewhere in Africa, in Uganda, in addition to Sida sp., Odhiambo (1957) reported Hibiscus sabdariffa, Abutilon mauritianum and A. guineense to support populations of O. fieberi. Hibiscus sabdariffa is widely cultivated in the tropics and varies in form and size.

Colonization by O. hyalinipennis occurs on a wider range of host plants in Ghana. Isolated individuals occur on all the species of Sida listed above for O. fieberi in addition to several species of Hibiscus which support small populations and can build up to large sizes at particular periods of the year. Such periods are of maximum seed production. Hibiscus micranthus, H. tiliaceus, H. esculentus in addition to H. sabdariffa and H. cannabinus constitute the major Hibiscus species.

The largest populations of O. hyalinipennis were found to occur on Abutilon mauritianum and A. guineense. Other impor-

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tant malvaceous host plants include Gossypium sp., Wissedula amplissima and Urena lobata.

Of much less significance was Malvastrum corchorifolium and M. coromandelianum. These plants are native to America and have in recent times been spread to tropical Africa.

2.3.3 Host preference

It is a common observation in the field that seed feeding bugs show a preference for certain species of seeds. In an abandoned cassava farm where Abutilon mauritianum grew together with Sida acuta and Hibiscus esculentus, more of Oxycarenus hyalinipennis were observed on Abutilon, followed by H. esculentus and only a few on Sida. At the same time, O. fieberi was abundant on Sida but there were none on either Abutilon or H. esculentus. Where Sida grew alone, 100 sweeps taken 10 at a time returned numbers in the ratio 1,271 O. fieberi to only 43 of O. hyalinipennis, and 9 of O. dudgeoni. A similar observation was made by Odhiambo (1957) at Serere (Uganda) where O. fieberi was more prevalent on Sida; O. dudgeoni on cotton; and a third species, O. rufiventris was almost exclusively confined to Hibiscus cannabinus. Therefore, although species of

25.

Oxycarenus are polyphagous, they show a differential preference for particular host plants. It is, however, not known how this selection is brought about, but it may not be solely nutritive (Dethier 1954).

2.3.3.1 Host preference tests

Tests were carried out in the laboratory to investigate the basis of these observations and to determine which seeds were preferred.

The data obtained were analysed. The observed distribution was compared with the expectation that they would feed equally on the two species of seeds, and chi-squared values were calculated. The results are tabulated in Tables 2.2 - 2.4.

26.

Table 2.2: HOST PREFERENCE TESTS FOR O. HYALINIPENNIS

Species of seed	Numbers of individuals feeding at 15 minute intervals				Total Expectation	
	a	b	c	d		
(A) Cotton seeds	14	10	9	14	47	28.5
<u>Abutilon mauritianum</u>	2	4	1	3	10	28.5
Totals	16	14	10	17	57	
	$\chi^2_{(1)} = 12.54, P < 0.001.$					
(B) Cotton	21	15	10	18	64	35.0
<u>Sida acuta</u>	3	1	2	0	6	35.0
Totals	24	16	12	18	70	
	$\chi^2_{(1)} = 22.49, P < 0.001.$					
(C) <u>Sida acuta</u>	15	7	6	6	34	39.5
<u>Abutilon mauritianum</u>	11	12	9	13	45	39.5
Totals	26	19	15	19	79	
	$\chi^2_{(1)} = 2.56, P, \text{ not significant.}$					
(D) Cotton	4	13	11	4	32	33.5
Kenaf	9	7	8	11	35	33.5
Totals	13	20	19	15	67	
	$\chi^2 = 3.73, P, \text{ not significant.}$					

27.

Species of seed	Numbers of individuals feeding at 15 minute intervals				Total Expectation	
	a	b	c	d		
(E) Kenaf	9	11	6	14	40	38.5
<u>Abutilon mauritianum</u>	8	9	9	11	37	38.5
Totals	17	20	15	25	77	
	$X^2_{(1)} = 0.84, P, \text{ not significant}$					
(F) Kenaf	17	10	17	13	57	36.5
<u>Sida acuta</u>	4	7	2	3	16	36.5
Totals	21	17	19	16	73	
	$X^2_{(1)} = 13.54, P < 0.001.$					

The analysis for O. hyalinipennis shows that Cotton seeds are preferred to the principal feral host plant, Abutilon mauritianum (Jacq.) Medic. Cotton is again preferred to Sida acuta. There is no choice between Sida and Abutilon, and also between Cotton and Kenaf. Kenaf is preferred to Sida acuta.

28.

Table 2.3: HOST PREFERENCE TESTS FOR OXYCARENUS DUDGEONI

Species of seed	Numbers of individuals feeding at 15 minute intervals				Total Expectation	
	a	b	c	d		
(A) Cotton	7	8	9	8	32	31.5
<u>Ceiba pentandra</u>	9	7	7	8	31	31.5
Totals	16	15	16	16	63	
	$\chi^2_{(1)} = 0.28$ P, not significant					
(B) Cotton	7	7	8	7	29	24.5
<u>Abutilon mauritianum</u>	5	5	4	6	20	24.5
Totals	12	12	12	13	49	
	$\chi^2_{(1)} = 4.40$ P, not significant					
(C) Cotton	7	9	9	11	36	20.0
<u>Sida acuta</u>	2	1	0	1	4	20.0
Totals	9	10	9	12	40	
	$\chi^2_{(1)} = 13.26$ P < 0.001					
(D) <u>Ceiba pentandra</u>	12	14	8	8	42	29.0
<u>Abutilon mauritianum</u>	5	5	3	3	16	29.0
Totals	17	19	11	11	58	
	$\chi^2_{(1)} = 5.85$ 0.01 < P < 0.1					

29.

Species of seed	Numbers of individuals feeding at 15 minute intervals				Total Expectation	
	a	b	c	d		
(E) <u>Ceiba pentandra</u>	11	10	10	7	38	19.5
<u>Sida acuta</u>	0	1	0	0	1	19.5
Totals	11	11	10	7	39	
	$\chi^2_{(1)} = 17.68, \quad P < 0.001$					
(F) <u>Sida acuta</u>	7	9	4	3	23	23.0
<u>Abutilon mauritianum</u>	5	5	7	6	23	23.0
Totals	12	14	11	13	46	
	$\chi^2_{(1)} = 3.03$ P Not significant					

The results show that for O. dudgeoni, cotton and Ceiba pentandra enjoy similar preference while Sida acuta and Abutilon mauritianum are also equally preferred. Cotton is preferred to Sida acuta, and Ceiba pentandra is preferred to Sida acuta.

30.

Table 2.4: HOST PREFERENCE TESTS FOR O. FIEBERI

Species of seed	Numbers of individuals feeding at 15 minute intervals				Totals	
	a	b	c	d	Expectation	
(A) <u>Sida acuta</u>	14	7	8	10	39	40.0
Cotton	9	7	11	14	41	40.0
Totals	23	14	19	24	80	
	$\chi^2_{(1)} = 1.11$ P, not significant					
(B) <u>Sida acuta</u>	13	17	12	13	55	48.5
<u>Ceiba pentandra</u>	9	9	13	11	42	48.5
Totals	22	26	25	24	97	
	$\chi^2_{(1)} = 1.70$ P, not significant					
(C) <u>Sida acuta</u>	18	17	12	14	61	38.5
<u>Abutilon mauritianum</u>	5	8	3	2	18	38.5
Totals	23	25	15	16	79	
	$\chi^2_{(1)} = 12.44$ P < 0.001					
(D) <u>Ceiba pentandra</u>	8	9	7	5	29	25.5
Cotton	10	7	4	1	22	25.5
Totals	18	16	11	6	51	
	$\chi^2_{(1)} = 1.98$ P, not significant					

31.

Species of seed	Numbers of individuals feeding at 15 minute intervals				Totals Expectation	
	a	b	c	d		
(E) <u>Abutilon mauritianum</u>	4	3	2	2	11	29.5
Cotton	5	13	14	16	48	29.5
Totals	9	16	16	18	59	
	$\chi^2_{(1)} = 13.12 \quad P < 0.001$					
(F) <u>Ceiba pentandra</u>	2	3	4	3	12	20.5
<u>Abutilon mauritianum</u>	5	10	8	6	29	20.5
Totals	7	13	12	9	41	
	$\chi^2_{(1)} = 5.36 \quad P < 0.1$					

For O. fieberi, cotton and Sida acuta enjoy equal preference. Ceiba pentandra and cotton are also equally preferred. However, cotton is preferred to Abutilon mauritianum and Sida is also preferred to Abutilon, which is itself preferred to Ceiba.

2.3.3.2

DISCUSSION

Seeds are a principal item in the diet of all the three species, which can be reared through the complete life cycle on them alone. However, seed reared adults do not mate. In a similar study, Eyles (1964) working with some Rhyparochrominae (Heteroptera : Lygaeidae) found that all the five species of Scolopostethus could be reared on seeds alone. Earlier workers, notably, Lea and Niswander (1950), Frings and Piessner (1952), Frings et al (1957), found that O. fasciatus developed on seeds substituted for its natural food, milkweed seeds, (although survival and viability were reduced) but in all cases the seed coat was removed or cracked.

In feeding trials with Rhyparochromines on sunflower seeds, Sweet (1960) also hulled the seeds "to provide easier feeding". It is possible, however, that these results do not represent the response the species would have made to the food if it had been provided as found in nature. In the present study, foods were presented in their natural forms and so the results are applicable to the insect - host relationship in the field.

Before an insect will feed, the food must provide the stimuli that induce a feeding response that is not inhibited by any other properties or constituents of the food, (Thors- teinson 1960). Some important factors involved in food selection are the physical and chemical nature of the seed

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coat, the constituents of the seed, and the nutritional requirements of the insects (Eyles 1964). The roughness or smoothness, presence or absence of hairs or spines and their size, and the thickness and toughness of the seed coat may be important. However, Eyles (1964) reared Stygnocoris fuliginus Geoffroy on various seeds with a variety of coats and this is suggestive of the unimportance of seed coats in food selection. More intensive studies are required into the texture of seed coats to establish whether there is a relationship between seed coat and seed preference. Thorsteinson (1960) has shown that whereas insect resistance in plants has been attributed to the nature of the exterior, sensory and nutritional factors are also involved. Beck et al (1958) showed that milkweed seed husk wrapped round a purified diet stimulated the normal pattern of feeding in O. fasciatus and growth was good, whereas on the purified diet alone growth was poor because the duration of feeding was greatly reduced. This shows that the nature of the seed coat may play an important role in providing a chemotactic feeding stimulus.

In as much the same way as seeds differ in their constituents, insects' nutritional requirements also differ. This is presumed to be the basis of the differences in food preferences reported above and the reason for host plant selection could be gustatory (Eyles 1964). Thorsteinson (1960) has reported

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that insects possess unsuspected powers of discrimination resulting from very sensitive chemoreceptors which would enable precise selection between seeds having the same constituents but in different concentrations. O. dudgeoni can, therefore, be regarded as responding to a wider range of concentrations than the other two species. Fraenkel (1959) has suggested that secondary plant substances such as essential oils, glycosides and alkaloids may play an important part in host plant selection by insects. Although they are of no nutritional value, it is possible that these substances may act as releasers or inhibitors of the feeding response.

Results of the host preference tests confirm field observations in the choice between the two feral host plants, Abutilon mauritianum and Sida acuta by Oxycarenus fieberi; however, no significant difference was noted for O. hyalinipennis. While O. fieberi prefers Sida acuta to Abutilon mauritianum in the field, the reverse holds true for O. hyalinipennis. In all the three species, there were not much differences in the choice between cotton and the principal feral host plants. As has been pointed out elsewhere, this situation can result in a shift from the feral host plants to cotton cultivations which are usually of improved seed qualities and cultural practices.

2.3.4 Succession of host plants

The mechanism of host plant selection and succession in Oxycarenus is governed by host preference and seasonal differences in host plant fruiting. The herbaceous species flower throughout the year and are a source of mature seeds for colonization all the year round. All varieties of Sida support populations of O. fieberi and serve as the only wild host plants in Ghana. However, where Sida grows together with Abutilon, the latter has been found to support isolated individuals of O. fieberi. Occurring with O. fieberi on Sida by the same reason are isolated individuals of O. hyalinipennis.

The quantity of dry seed at any period is dependent upon prevailing conditions of rainfall. The first rainy season in 1975 began in February and March in the savanna and forest zones, respectively. Rainfall (monthly) recordings for these months after the 1974 - 1975 dry spell were 3.0 cm. and 11.4 cm. at Legon and Akropong, respectively. Much vegetative growth ensued, resulting in abundant seed production from April in the savanna localities and May in the forest zones. Seed production was continuous with a slight increase in September and November in the savanna and forest regions, respectively. Maximum seed production was accompanied by leaf loss with a general bare appearance. No other host plants were recorded for O. fieberi during the period of this work. This suggested

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a lack of succession of hosts outside Sida varieties. Differences in quantity and/or quality of Sida seeds between areas were brought about by differences in soil quality. While some areas bore freshly matured seeds, other patches were still flowering and still others had old dry seeds of low quality. Appetitive short flights or "flits" and/or walking were employed in moving from one area to the other. In this respect, females were most expected to be active, especially during the search for suitable breeding sites.

The other major feral host plants, Abutilon mauritianum and A. guineense, possessed similar fruiting cycles. These two varieties supported populations of O. hyalinipennis. Maximum seed production occurred from August to October, and around January - February. During the other lean periods, the populations on the other Malvaceous varieties increased. Urena lobata assumed importance in late October at a period when most of the dry fruit heads of Abutilon had become too dry, light in weight, and of little food value. In such a state, the seed chambers split open and the seeds were dropped to the ground. Other Malvaceous species that came into focus during this period were wild varieties of Hibiscus, mainly H. micranthus and Wissedula amplissima. Like many other Malvaceous varieties, these are herbaceous plants and produce seeds throughout the year. Populations of O. hyalinipennis

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existed on these all the year round. The period from October was, however, the main period of increased O. hyalinipennis activity on them. H. esculentus (okro) is a cultivated vegetable crop which is usually harvested while the fruits are still young and fresh. In abandoned farms, the pods were left to dry to provide seeds for the following season sowing. Dry pods were available for colonization by O. hyalinipennis in the period October, November and early December. By December, however, food value would have decreased and on most occasions, the stems were attacked by termites. The picture was similar in seed multiplication farms of Hibiscus cannabinus, H. sabdariffa and Cochorus capsularis as well as cultivated Urena lobata. Seed harvesting was done before seed feeding Lygaeidae as well as Dysdercus (Pyrrhocoridae) increased their activity. This meant that given the chance, there would be a shift of emphasis from the feral host plants to these recently introduced cultivated varieties during the periods of October, November and December.

Ceiba pentandra flowered around November and by late January, fruits had matured. Seeds inside kapok from dehisced fruits were available for colonization by O. dudgeoni from late February. Colonization of the trees began long before dehisced fruits dropped to the ground. Seething masses of all developmental stages of Oxycarenus formed large colonies on the ground,

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on the tree trunks and branches. At this time, Sterculia foetida was flowering.

The onset of the rainy season resulted in mass destruction of well established O. dudgeoni colonies both on the trees and on the ground. The direct effect of drowning of large numbers of all instar stages together with some adults occurred. The winds which accompany the beginning of the first rainy season succeeded in blowing together masses of kapok and the associated developmental stages^{of O. dudgeoni}, many of which were unable to colonize their new environments. Seeds began to germinate and became unsuitable for food. Termite activity increased in wet conditions, resulting in premature destruction of the seeds. The effect of rain was more pronounced in the forest zones. By the end of May, only small colonies were left; those on the remnants of dehisced fruits still hanging from the trees, and smaller colonies on kapok which had blown to dry environments such as high grounds or tall grass.

During this period (May - June), Sterculia foetida bore mature fruits, some of which were dehisced. The latter were usually hanging on the tree without dropping readily. A sudden population explosion of adults occurred on S. foetida by the beginning of May.

Larval numbers were very low in May, a situation which persisted for the whole period that the bugs remained on

Sterculia. The bugs obtained food by sucking juices from the mature green pods in addition to the seeds.

Malvaceous host plants of O. dudgeoni flowered all the year round (vide supra) and were colonized by isolated individuals. Small numbers were usually returned together with large populations of O. fieberi and O. hyalinipennis during the sampling. Larger numbers were obtained during the period immediately before the start of the rainy season. This could be explained by the characteristic winds during this period with the consequent explosive dispersal from the floss of Ceiba pentandra (vide supra). A similar period of explosive dispersal has been noted for other seed feeding Lygaeidae in Ghana (Gibbs and Leston 1970). While some individuals were able to establish themselves, many such dispersants died. Those that were established maintained small ephemeral populations, especially on Sida, Abutilon and varieties of Hibiscus and Gossypium.

It is worth stressing here that although Sterculia foetida forms an important link in host plant succession for O. dudgeoni, there is little reproductive activity on this plant. It seems that fertilized females dispersed from Ceiba pentandra lay eggs but no fresh matings take place on S. foetida. Large populations occur on S. foetida after the explosive dispersal and

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their numbers gradually decline. I am of the opinion that these populations pass the rest of the rainy season on Sterculia and then, owing to lack of other suitable hosts, fall into a period of dormancy which begins from the end of the second rainy season and lasts till the appearance of mature fruits of Ceiba pentandra. In Egypt, Kirkpatrick (1923) found that "resting period" of Oxycarenus begins from November and ends in May or June during which neither breeding nor feeding takes place. He also listed the following places as favourite sites for "resting" - (correctly dormant) bugs: tree trunks, underside of leaves of trees, pods of leguminous plants, dried flower heads, roots of grasses, under sheath of leaves of maize and sugar cane, cracks in telegraph poles or wooden posts, old nests of Polistes and the crevices between strands of barbed wire. In Ghana, hiding places for dormant bugs were found to include dry pods of fruits, undersides of barks of trees, between planks of wooden structures, dry grass and leaf litter.

Obviously, the host succession in O. dudgeoni, in particular its dormant period, warrants further study. The limitation of one year on the present project prevented the observations to be pursued further. Suggestions for further study include inducing the dormant insects to feed in captivity, changes in the sex ratio to establish the proportion of males or females that survive the resting period, and whether fertilization has

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occurred prior to "resting".

2.3.5 Population Studies

Numbers that were returned during sampling of adults and larvae in both the forest and savanna localities in southern Ghana are shown in appendix Table 1. Graphical representation of the population fluctuations for the same period are shown in the forest and savanna zones in Figures 2.3, 2.4, and 2.5, 2.6, respectively for O. fieberi; and in Figures 2.7, 2.8 for O. hyalinipennis in the savanna locality.

2.3.5.1 Population Changes

Oxycarenum fieberi in the savanna locality showed adult population with two peaks occurring in April and September. The first rainy season which occurred at the end of February was the cause of the marked decrease in larval populations, especially the first to third instars. From April to June, there was a high potential for population increase as a result of abundance of dry seeds for food, following much vegetative growth at the beginning of the rains. However, heavy rain during this period put a check on further population increase notwithstanding the abundance of food. The short break in rainfall in August - September, saw numbers rising again only to be held in check once more by the second rainy regime in

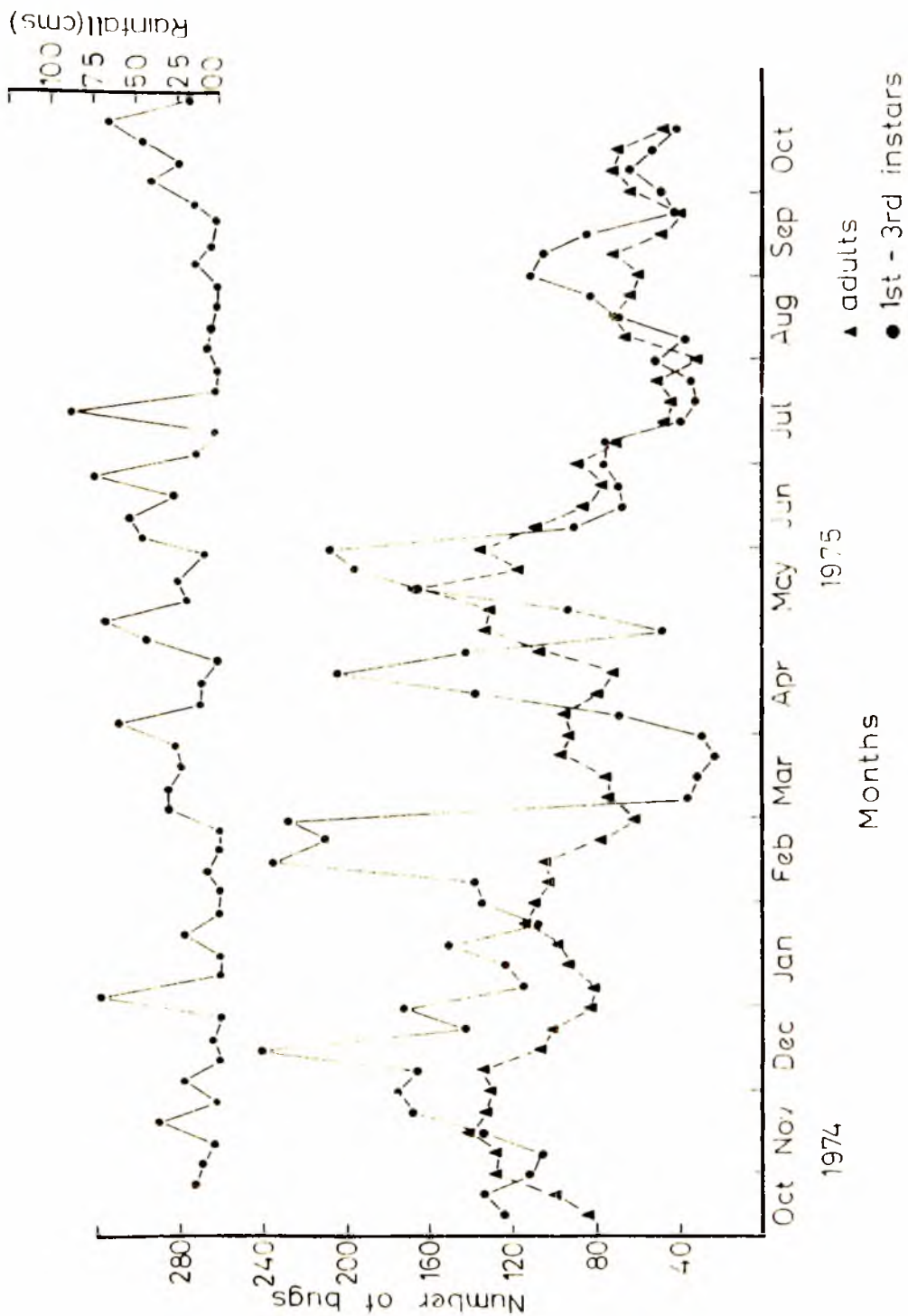


Fig. 2.3: Population changes in adults and instars 1 - 3 of O. fieberii in the forest locality.

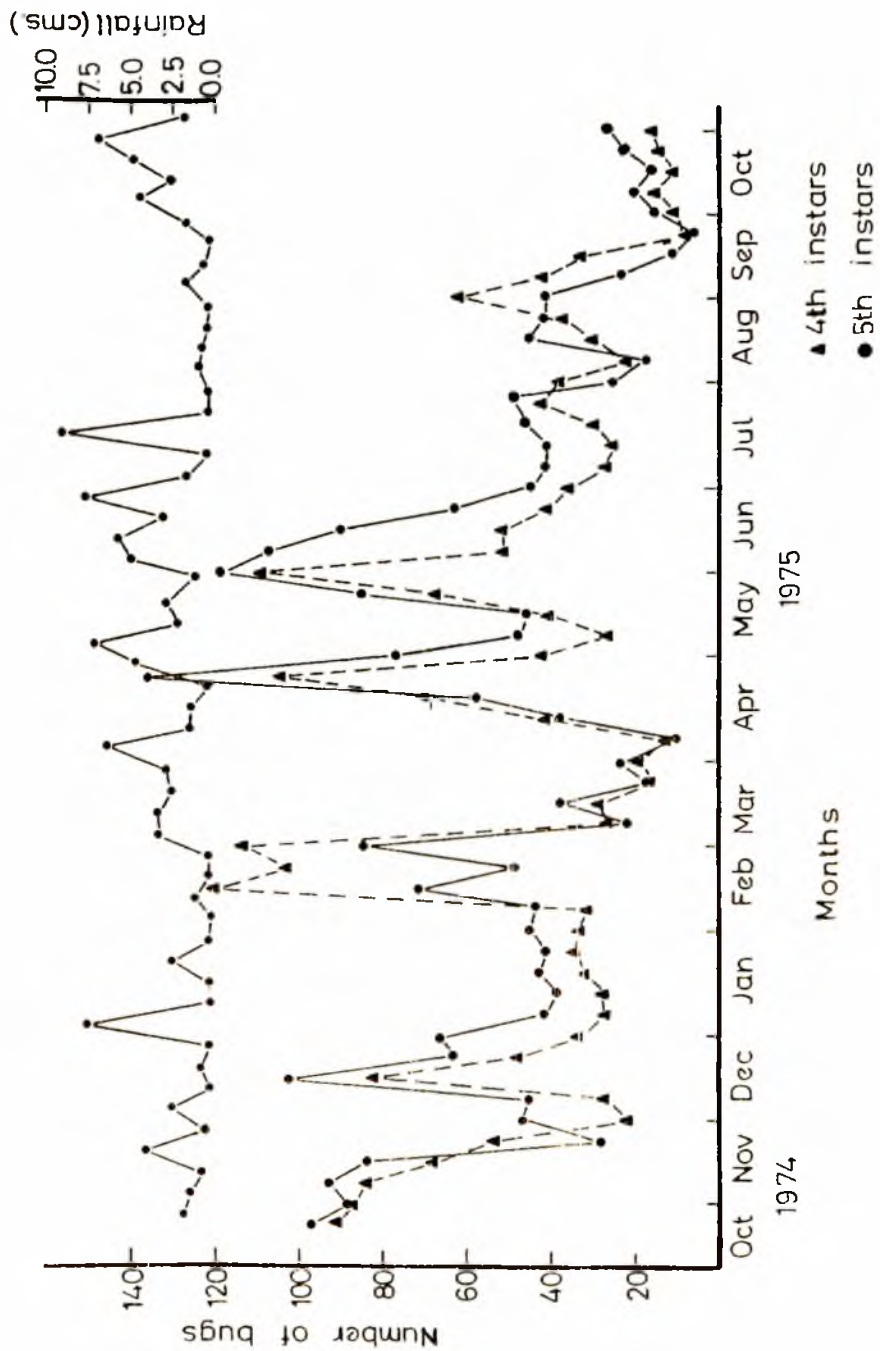


Fig. 2.4: Population changes in instars 4 and 5 of O. fieberii in the forest locality.

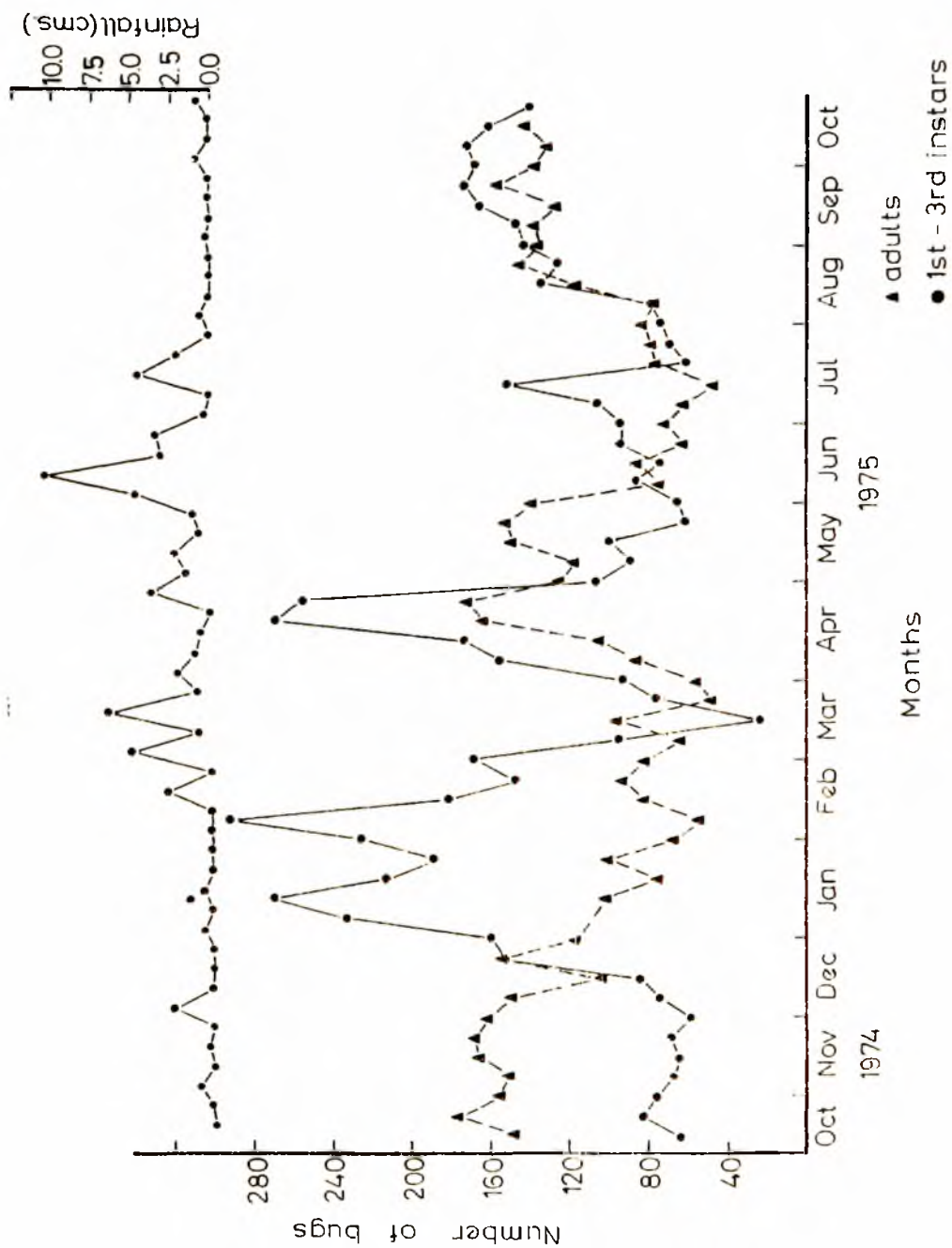


Fig. 2.5: Population changes in adults and instars 1 - 3 of U. fieberii in the savanna locality.

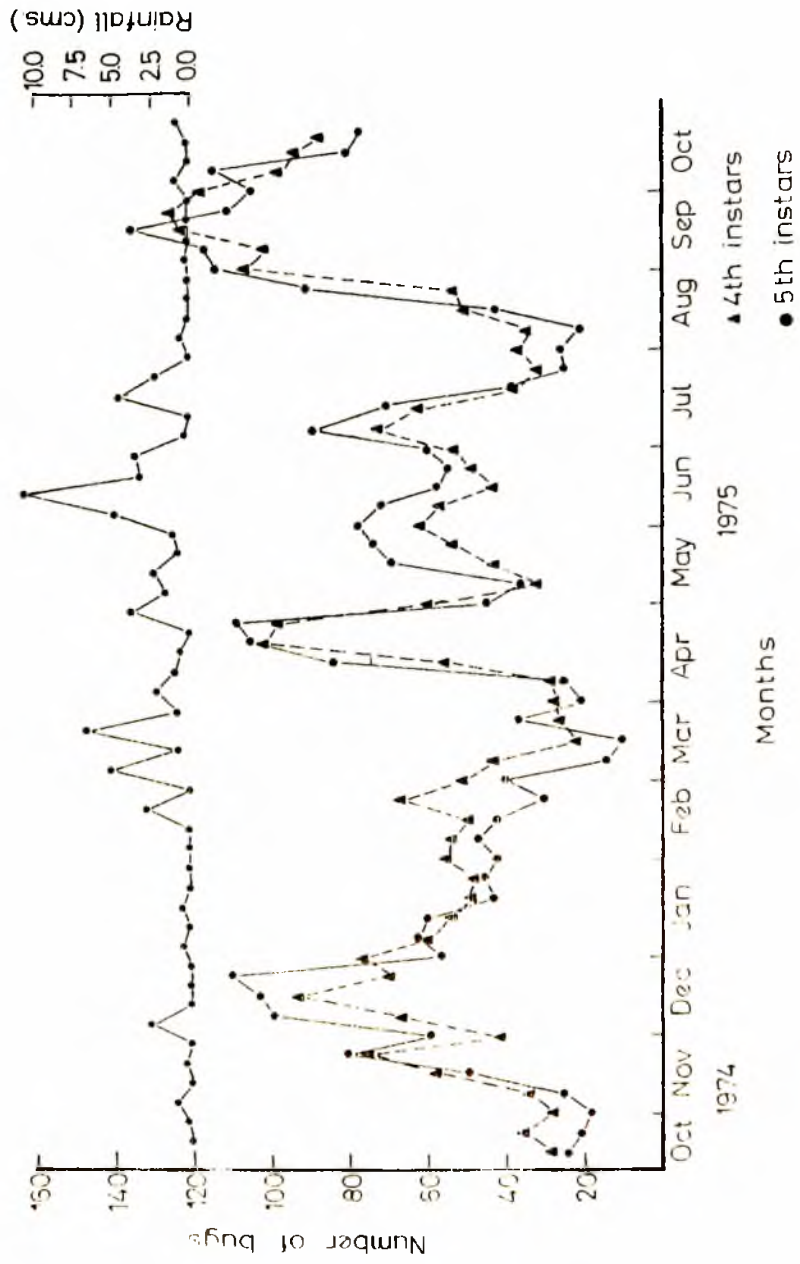


Fig. 2.6: Population changes in instars 4 and 5 of O. fieberii in the savanna locality.

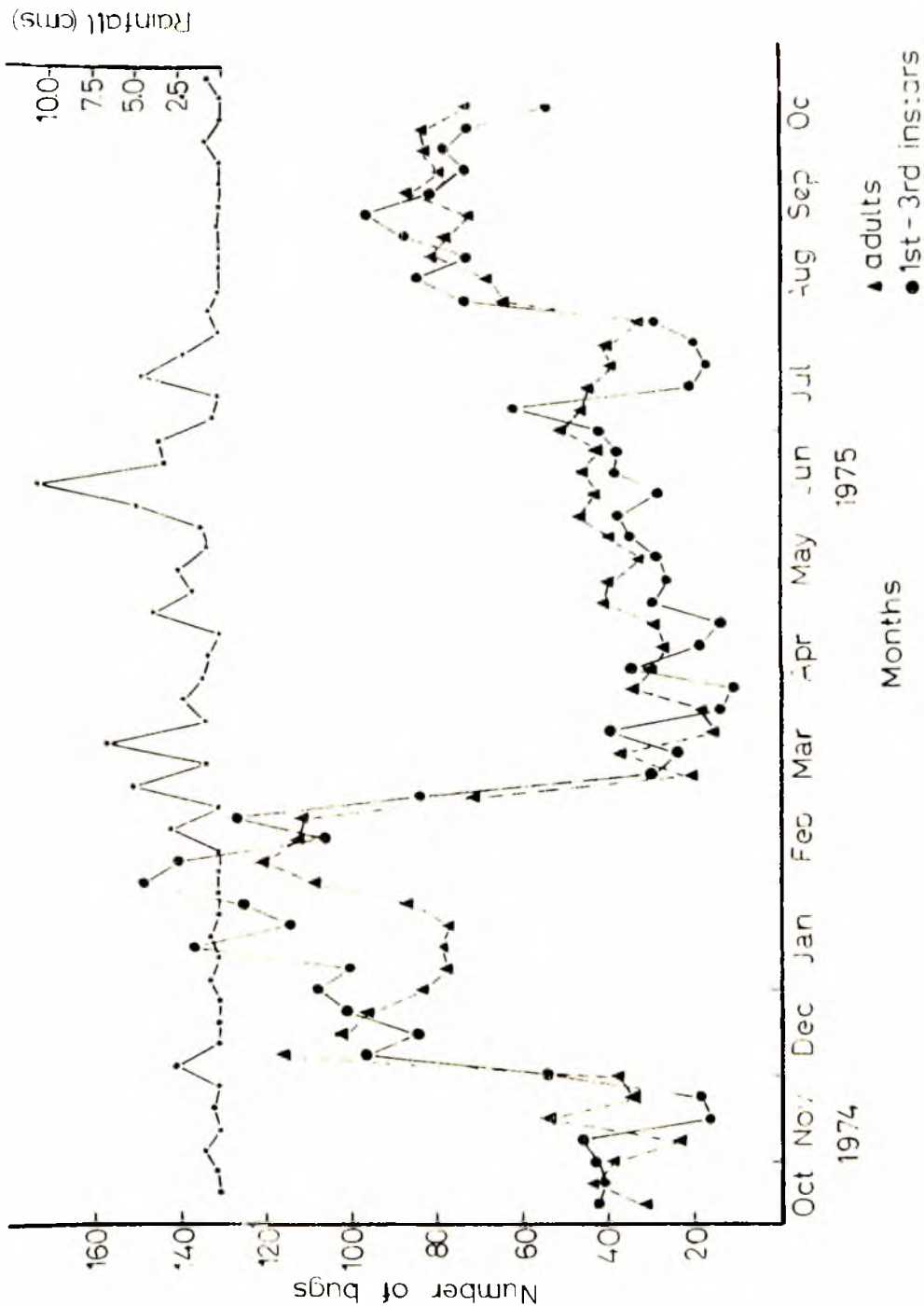


Fig. 2.7: Population changes in adults and instars 1 - 3 of O. hyalinipennis in the savanna locality.

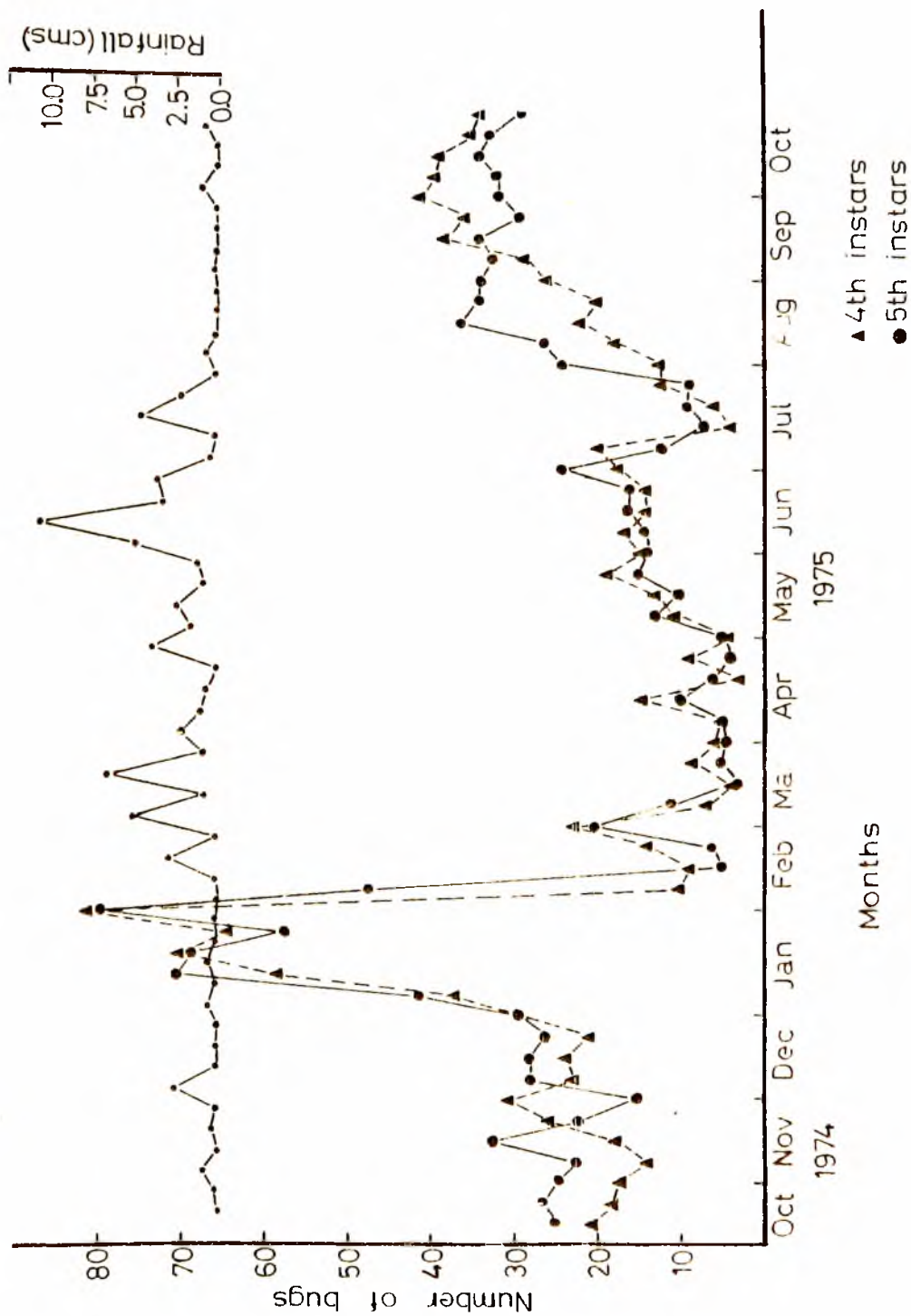


Fig. 2.8: Population changes in instars 4 and 5 of *O. hyalinipennis* in the savanna locality.

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October - November. Conditions of the major dry season started from late November through February. Food was abundant and the weather was dry. Population increases were as expected, especially of the first to third instars. Adult population decrease was related to intense reproductive activity with consequent high mortality of females after egg laying.

In the forest zone, adult population peaks that occurred were not very distinct. The first peak was in November, with a second higher one in May. Rainfall distribution appeared to be even with a slight break in July - August. The potential for increase in all instars at any period was suppressed by torrential rains, which also accounted for the sudden reduction in numbers after every rainfall.

The two-peak-pattern of population distribution throughout the year was very clearly exhibited by O. hyalinipennis on Abutilon mauritianum in the derived savanna locality of Southern Ghana (Legon). A major peak was reached in January, 1975. This period marked the major dry season. The second short break in rainfall in August - September resulted in a second peak less marked than the first. The onset of the first rainy season in a similar way was responsible for reduction in numbers that occurred at the end of February. The effect of the rains was more damaging because of the arrangement of the

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flower heads of Abutilon which collected water in the seed compartments. The singular effect was to cause drowning of more adults and larvae. Population levels were left low with a slight increase in June. The dip in July may be attributed to high humidity^(see appendix). High humidity had the effect of enhancing the damaging results of rainfall since water collected in recesses took longer to dry out.

2.3.5.2 Discussion

An analysis of the data showed that on the whole adult populations of Oxycarenus in both the forest and savanna regions showed bimodal population peaks. These were expected for seed feeding Lygaeidae (Gibbs and Leston 1970). Maximum population levels were reached in the period immediately following the second rainy season, with a smaller peak in the short break in rainfall that occurred from August - September. The onset of the first rainy season caused high mortalities, especially in larval populations. Population levels between the two peaks were held low by rainfall and availability of food.

The pattern of population fluctuations in Oxycarenus was governed by food as well as the prevailing weather conditions, mainly rainfall. The bimodal peaks clearly exhibited by

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adult populations as against the irregular fluctuations by the larvae resulted from the ability of the former to withstand to a greater extent sudden changes in weather conditions. Larval mortalities caused by drowning were high, particularly during rain, but to a less degree from dew. The effect of dew followed direct changes in relative humidity. High humidity was particularly prevalent from late July to early August. Rainfall was not particularly high but sunshine was low. It was a common observation to find young instars dead and piled together inside the bases of flower heads, as well as in flower buds.

Kirkpatrick (1923) believed that the weather directly or indirectly affects the population of O. hyalinipennis in Egypt. He singled out heavy rain as being responsible for considerable mortality. Willcocks and Baghart (1937) stated that such heavy mortality is not so much caused by heavy rains and winter cold as the sudden and marked changes in prevailing weather. Odhiambo (1957) observed at Serere that after every shower following a dry spell, there was always a reduction of Oxycarenius population in the field that can only be described as catastrophic and especially noticeable on Sida plants.

In the present study, no single factor appeared to be responsible for the changes in both adult and larval populations, although food and rainfall appeared to be the most

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important parameters. I believe also that changes in day and night temperature could assume importance as well as the physiological state of the host plant. In an open habitat, immigration and emmigration do occur and might account for some of the increases and decreases in population levels that cannot otherwise be explained by food, rainfall and other physical factors. For example, the drastic fall in numbers of fourth and fifth instars of O. hyalinipennis in early February cannot be explained by rainfall. Similarly, sudden increase in population cannot be accounted for by reproduction since a complete life cycle takes about one month. It should be noted that all larval stages were taken throughout the year. This is due to the relatively short life cycle of the bugs with an uninterrupted succession of generations.

2.3.6 Colony Structure

Studies of colony structure were made on three colonies of O. dudgeoni in the savanna, several colonies of O. hyalinipennis, also in savanna, and several O. fieberi colonies in both savanna and forest localities. Two colonies of O. dudgeoni in the University of Ghana Botanical Gardens were on Ceiba pentandra and about 300 meters apart. Studies were originally based on these but both soon died out or migrated elsewhere in late May, after the beginning of the

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rainy period. The sudden appearance of a colony of O. dudgeoni on Sterculia foetida in the vicinity of the original colony strongly suggested their migration or dispersal from the original colony on Ceiba pentandra. This was during the period of the explosive dispersal (vide supra) when winds might have played an important role by mechanical transport through kapok or in assisting the flying insect. Colonies of O. fieberi and O. hyalinipennis were studied weekly with sampling carried out between October 1974 and October 1975.

The size of colonies was variable, ranging from isolated individuals on Malvaceous herbaceous annuals to large colonies of several thousand O. dudgeoni on Ceiba pentandra and Sterculia foetida. Colonies on Ceiba consisted of members on kapok hanging on the branches (arboreal), those on the ground and members on the tree trunk. Whereas colonies on Ceiba pentandra and S. foetida consisted exclusively of O. dudgeoni, Abutilon mauritianum supported predominantly O. hyalinipennis while Sida acuta and S. rhombifolia colonies consisted predominantly of O. fieberi in close sympatric association with isolated individuals of O. hyalinipennis. During the period immediately following the explosive dispersal of O. dudgeoni, ephemeral mixed colonies became established on Abutilon sp., Sida sp. and several other malvaceous host plants. Within O. fieberi

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and O. hyalinipennis mixed colonies, inter specific matings were observed, although no fertile eggs were produced.

Forest colonies of O. fieberi were studied along foot paths, edges of cocoa and food farms, around towns and villages, along the main trunk road from Obosomasi to Adukrom in Eastern Ghana (Fig. 2.1). Forest population levels were usually lower than in the savanna. This could be due to heavier rainfall or lower temperatures, characteristic of those inland areas, or more vegetative growth at the expense of seed production.

O. hyalinipennis is not a forest species and O. dudgeoni is dispersed into tall trees in the closed canopy without getting down to the Sida undergrowth. Mixed colonies were, therefore, not observed, and quite unlike savanna colonies, forest colonies were not in any form of sympatric relationship.

In all colonies, there appeared to be competition between species of Oxycarenum and several other seed feeding Lygaeidae and Pyrrhocoridae. Several species of Dysdercus, notably D. melanoderes in the forest localities competed with Oxycarenum for food. The periods of population increase of D. melanoderes Karsch and D. voelkeri Schmidt on Ceiba pentandra and Sterculia foetida as reported by Fuseini and Kumar (1975) agree closely with O. dudgeoni on these host plants. A similar situation occurs on other malvaceous host plants. Colonization by D. voelkeri on Urena lobata and Hibiscus micranthus occurs in

October, when abundant dry seeds are present. This is the same period when species of Oxycarenus colonize these plants. The plants are then abandoned for the more preferred host, C. pentandra and S. foetida, when dry seeds of these are available. At several other periods, isolated individuals of Dysdercus sp. were found on Hibiscus cannabinus, H. esculentus, Abutilon sp., Sida sp. and Gossypium sp. in addition to many other malvaceous host plants.

Several species of Dieuches Dohrn, notably D. albostriatus Fabr., D. femoralis Dohrn. and D. proximus Dohrn. competed with Oxycarenus for seeds of Abutilon sp., Sida sp., Ceiba sp. and several other malvaceous plants.

2.3.7 Flight and Dispersal

Generally, in the Heteroptera, walking, not flying is the primary means of locomotion (Southwood and Johnson 1957), and therefore, in comparison with other groups of insects, for example, Diptera and Lepidoptera, a bug is likely to spend a relatively small amount of its life in flight. This is supported by a mean flight threshold which is higher in Heteroptera than that of most Lepidoptera and Diptera (Southwood 1960). Migration is considered to be a distinct behavioural and physiological syndrome (Kennedy 1961; Johnson 1963). In female insects, Johnson (1963) and Dingle (1972) have shown that migra-

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tion involves an "oogenesis-flight" syndrome and that most migrations take place prior to egg development and reproduction. Migration was, therefore, restricted to young adult females.

Results of mark-release-recapture experiments with O. hyalinipennis were not conclusive. However, with O. dudgeoni, the following results were obtained: 2 females were recaptured on nearby Hibiscus tiliaceus about 250 meters in the direction of the wind, and 4 (3 males and 1 female) on grass, ranging in distance from 17 meters to about 150 meters from the Ceiba pentandra tree. With older adults, 1 male was recaptured on an unidentified low shrub about 110 meters away and 2 females on the ground feeding on Ceiba pentandra seeds together with several unmarked ones at a distance of about 230 meters.

Results of flight experiments are given in Table 2.5, and plotted in Figure 2.9.

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Table 2.5: PERCENTAGE FLIGHT FOR DIFFERENT AGE GROUPS OF
OXYCARENUS DUDGEONI

Age group (days)	M A L E S		F E M A L E S	
	Number flying out of 30	Percentage	Number flying out of 30	Percentage
1 - 2	9	30	10	33
3 - 4	11	37	12	40
5 - 6	11	37	7	23
7 - 8	9	30	3	10
9 - 10	10	33	4	13
11 - 12	8	27	3	10
13 - 14	8	27	2	7
15 - 16	9	30	1	3
17 - 18	6	20	2	7

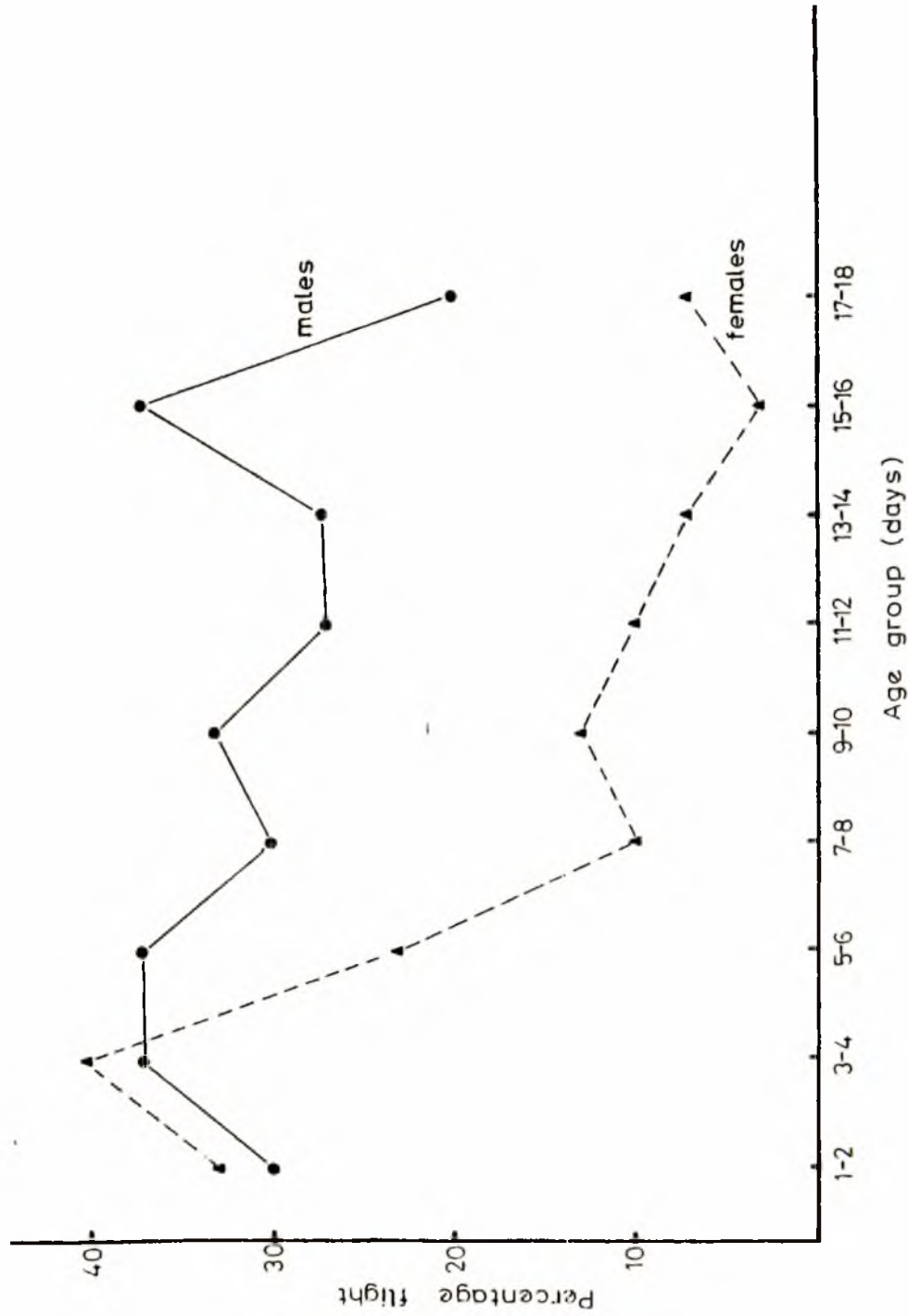


Fig. 2.9: *O. dudgeoni*: Percentage flight in different age groups of males and females.

2.3.7.1

Discussion

The results indicate that flight behaviour is different in males and females of Oxycarenus species. Whereas males show no definite period of flight, females tend to fly more when young as shown by high flight percentages. Similar results were obtained by Kehat and Wyndham (1974) for Nysius vinitor Bergroth (Hemiptera : Lygaeidae). Furthermore, in older females flight activity was considerably reduced. These results for females also agree with Johnson's (1963) observation that migration in insects occurs soon after the moult to adulthood with decreasing flight durations as the insects grow older. Colony studies, however, show that a large proportion of newly emerged adults remain with the colony, especially when unfavourable conditions of food shortage and rainfall were not threatening the population. This observation was also reported in Dysdercus colonies in Southern Ghana (Fuseini and Kumar 1975). The colonization of new habitats with consequent aversion of ill-effects of unfavourable conditions of food shortage and weather are probably the main survival advantages of flight in Oxycarenus. In this connection, it must be stressed however that males and mature females, under adverse conditions may also vacate a habitat (Kehat and Wyndham 1973) but such flights are then dispersive and not migratory.

The duration of flight and its range are to some extent

different aspects of the same phenomenon (Southwood, 1960). An insect that flies for a long period at a time is more likely, other things being equal, to travel farther from its original habitat than one that flies for only a short period. An insect which flies voluntarily for a short distance may, of course, under certain circumstances, be carried much farther by air currents. In most Heteroptera flight range must be small and short flights in the immediate proximity of their host plants would be their commonest behaviour.

In the flight experiments it was observed that the flight duration was about 5.0 seconds for O. hyalinipennis and less than that for O. fieberi. Oxycarenum dudgeoni had a flight duration of about one minute. These results were, however, not conclusive. Nevertheless, an important area has been unearthed where further work needs to be done. For continued flight, an insect must not be inhibited from assuming the correct angle of flight. The wind speed must be ideal for flight, the thorax must not be inhibited from changes in shape associated with flight, and in addition, the insect must be allowed to carry its own weight. Furthermore, flight durations of this order can be considered extremely small and of little help in long range migration, considering the fact that the longest flight recorded for Sehirus bicolor L. (Hem.: Cydnidae)

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was 170 minutes and for Piesma maculatum (Costa) Het.: Piesmidæ) was 75 minutes. These two bugs are known to exhibit long range post-hibernation flights in England (Southwood 1960). In a typical flight behaviour of Oxycarenus the individual insect climbs to the highest point on the leaf, branch or terminal bud. For O. hyalinipennis and O. fieberi, a quick take off is immediately taken over by the wind which carries the insect to the nearest object in the wind direction. There is generally a loss of height with each short flight, which means that height must be regained before flight in these two species. Such flights are best described as "flits" and several of these taken successively will lead to dispersal and mixing of populations. While "flitting" occurs in all the three species of Oxycarenus, O. dudgeoni in addition undertakes sustained flight to some extent. Individuals have been observed on several occasions to fly from the host plant, Ceiba pentandra, and settle on small trees in the vicinity. In ^{my} attempts to collect kapok from a branch, several individuals took to flight and were observed to regain their positions after short periods of sustained flight.

On grounds of habitat, one would expect O. dudgeoni to be a better migrant than the other two species. This follows from Southwood's (1962) observation that insects breeding on temporary habitats are more apt to be migrants than those in perma-

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ment habitats. All varieties of Sida and Abutilon flower throughout the year and food is available all the year round. The only major problem that food poses to colonies of Oxycarenus that these varieties of host plants support is one of areal variations in food quantity and/or quality as has earlier been said. Short appetitive flights or "flits" and/or walking serve to put the various individuals in the preferred positions for a good supply of food. Inadvertently, dispersal of the species and mixing of populations are concomitant effects. During the course of this work, it has been difficult to induce individuals of O. hyalinipennis and even more difficult to get O. fieberi to take to flight. Odhiambo (1957) reported only 7 bugs which were seen to take to flight on 4 occasions during the whole of his study period. Unlike O. fieberi and O. hyalinipennis, flight in O. dudgeoni can easily be elicited in a gentle breeze from an electric fan helped by a slight standard stimulus: prodding with a fine brush.

Habitats of O. dudgeoni undergo very drastic changes which force whole colonies to move off in search of more favourable conditions. Ceiba pentandra flowers only once in a year, providing seeds for colonization for about only a third of the annual life cycle. Other sources of food must be found and these usually consist of host plants not in the vicinity. The fruiting cycle of Sterculia foetida and Ochroma lagopus are

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such as to be also considered temporary habitats and as with many other insects breeding in temporary habitats (Southwood 1960, 1962), O. dudgeoni proved to be highly mobile.

Dingle (1972) and others believe that the principal functions of migration are to escape from unfavourable conditions of the environment and to disperse and colonize all available habitats. While agreeing with Dingle (1972) it must also be stressed here that in seed feeding insects, preferences for particular types of seeds may also account for vacating of old habitats at a time when conditions of food appear favourable. Furthermore, in species of Oxycarenus which undergo migration, for example, O. dudgeoni, contrary to Dingle's (1972) observation, newly emerged adults stay in the colony and do not always undergo short periods of flight as he believes. This leads to large population build-ups that occur on colonized tree hosts such as Ceiba pentandra, and this would not have been possible if such mass flights of young potential reproductives occurred. I am of the opinion that it is only the adults which emerge at particular conditions of weather regimes which herald approaching adversity that tend to move away from the colony.

Of the three species of Oxycarenus studied, O. dudgeoni appears to be the only ^{active} migrant. This is supported by its ability to undertake sustained flight quite unlike the other

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two species. A lower flight threshold shown by the relative ease with which O. dudgeoni is induced to take to flight lends further support to this assertion. On a priori grounds, it might be expected that the amount of flight activity of the type likely to lead to dispersal (not flights) in a given species would be related to the frequency with which the individuals are compelled to find a new place to live (Southwood 1960). The work of Southwood and Scudder (1957) on the thistle lace bugs, Tingis cardui L. and T. ampliata (H-S.), established that the former, attached to a biennial host, shows more flight activity than the latter whose host plant is a perennial. Similar ideas have been expressed by Haine (1955) on aphids, Brown (1951) on Corixidae and Kehat and Wyndham (1973) on the Rutherglen bug Nysius vinitor Bergroth. Flight distance in O. dudgeoni is further enhanced in view of the level at which take off occurs, namely, on top of such tree hosts^{as}, Ceiba pentandra, S. foetida and Ochroma lagopus. Detailed observations by Southwood (1960) on Stenodema laevigatum (L.) amongst rough grass on Rothamsted Farm suggested a positive correlation between level of take off and the flight distance. This, perhaps, explains the observations of positive phototactic response in all three species of Oxycarenus in the laboratory. The significance of this in the field is in bringing individuals to the top layers of vegetation before flight take off. In a similar way, a positive phototactic response dominates

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the exodus flights of aphids (Kennedy and Booth, 1963); also, the moths Spodoptera exempta Walker (Whellan, 1958) and Cydia pomonella L. (Geier, 1960); the psyllid Psylla pyri L. (Willie 1950 in Johnson 1969); and the scoliid beetle Dendroctonus ponderosae Hopkins (Shepherd, 1966) are all attracted to light prior to migration.

1.3.8 Natural Enemies

1.3.8.1 Parasites

Protozoa

Del Guercio (1918) found two species of sporozoa, namely, Possidocystia oxycarenidis Del G. and Valvicystia rhopaloides Del G., in the viscera of both larvae and adults of Oxycarenum hyalinipennis. These records can, however, be regarded as isolated cases and have not been confirmed by other workers. Ten attempts were made to confirm this finding in the present work but failed to reveal the presence of any living organisms in the gut. The gut contents of live adults and larvae were taken out into a watch glass and diluted with water. Portions were examined at a time under high optical magnification.

Mites

Throughout the duration of the present work, several hundred small white ectoparasitic mites (Order: Astigmata; Family: Acaridae) were collected from both laboratory colonies and field populations of all the three

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species of Oxycarenum. Attempts to get them identified were not successful, and the literature available to me at Legon was not helpful in assigning them names. It seems there are few specialists working on them. Rapid increases in mite population occurred especially in wet colonies. On several occasions, as many as five mites were found under the wings of one adult. This number was about the highest that the individual bugs could support at a time without any serious physiological consequences. On one occasion 17 mites were counted on one female Oxycarenum hyalinipennis. Movement of the bug was sluggish and death ensued. Odhiambo (1957) reported a Trombidium mite under one of the wings of an adult female Oxycarenum.

Egg parasites

The eggs were collected from the field and hatched in the laboratory. No parasites emerged from them.

Larval parasites

Larvae collected from the field were reared to adulthood. No parasites emerged from O. fieberi and O. hyalinipennis. However, dipterous parasites did emerge from female adults of O. dudgeoni. All the flies belonged to family Tachinidae: Alophora (Mormonomyia) sp. No Oxycarenum were reared from instars 1 - 3. These instars are tiny (dimensions of third instars: 1.90 - 2.49 mm., mean 2.24 mm.) compared with the adult parasite (dimensions 2.81 mm. - 3.13 mm.; mean 3.07 mm.)

and the insertion of the ovipositor by the latter is likely to kill the former. It is thus most unlikely that the parasite attacks Oxycarenus in instars 1 - 3. The dimensions of the fourth instar (2.75 mm. - 3.30 mm.; mean 3.10mm.) are comparable to the parasite, and it is likely that parasitization by Alophora sp. occurs during this stage.

Parasitization was extremely low. Percentage parasitization was 4.0% (6 in 150) in a savanna locality at Legon and less than 1.0% (1 in 110) in a forest locality at Mampong in Eastern Ghana (Fig.2.1). With such low incidence of parasitization, it is doubtful whether these parasites can exert any significant degree of control over Oxycarenus in Ghana.

2.3.8.2 Predators

Invertebrate predators

1. Reduviidae (Heteroptera): A wide variety of assassin bugs were observed in the field preying on adult Oxycarenus species. They impale the victims on their rostrum and suck them dry. Species of Rhinocoris, Vestula and Nagusta appeared to be the most important predators. Odhiambo (1957) observed Nagusta sp. feeding on both adults and larvae of Oxycarenus species. Some predators would not feed on Oxycarenus in captivity, consequently, it was not possible to assess the probable effect of their predation.

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Of the three families of Reduviidae, species of genus? Rhinocoris were the most important predators. They included the three colour forms of Rhinocoris bicolor (Fabricius), (yellow, red, white forms), R. loratus (Stål), R. carmelita (Stål) and R. albopilosus^(Signoret). A single species of Vestula, V. lineaticeps (Signoret) and a single species of Nagusta, N. puncticollis (Stål) were also identified. Results of predator-prey relationship experiments with R. bicolor (yellow form) are given in Tables 2.6 and 2.7.

Table 2.6: Total Number of Prey Consumed by one R. bicolor (yellow form) in 24 Hours

Replicates	a	b	c	d	e	Average
Number of bugs consumed in the 1st hour	3	5	4	4	3	4
Total number of bugs consumed in 24 hours	16	9	11	8	13	11

The results indicate that if sufficiently starved, R. bicolor is able to kill about 4 bugs in the first hour and about 11 bugs in a day.

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Table 2.7: Prey Preference Tests for R. bicolor (yellow form)

Species of prey	No. presented	No. consumed			Totals	Expectation
		a	b	c		
1. <u>O. dudgeoni</u>	15	5	6	10	21	24.5
<u>O. fieberi</u>	15	8	6	14	28	24.5
Totals	30	13	12	24	49	
$\chi^2_{(1)} = 0.50, P = \text{not significant}$						
2. <u>O. dudgeoni</u>	15	5	7	9	21	19.0
<u>O. hyalinipennis</u>	15	6	3	8	17	19.0
Totals	30	11	10	17	38	
$\chi^2_{(1)} = 0.21, P = \text{not significant}$						
3. <u>O. fieberi</u>	15	6	7	4	17	20.0
<u>O. hyalinipennis</u>	15	4	9	10	23	20.0
Totals	30	10	16	14	40	
$\chi^2_{(1)} = 0.45, P = \text{not significant}$						

Results of these tests indicate that R. bicolor (yellow form) does not discriminate in the choice between any of the Oxycarenus species. $\chi^2_{(1)}$ values obtained for the other two colour forms were not significant at 5% level.

2. Spiders

A total of 123 spider webs were examined in the field:

52 on Abutilon mauritianum, 61 on Sida acuta, 3 on Ceiba pentandra with ripe dehisced fruits and 7 on the ground

in the vicinity of a silk cotton tree. The spiders belonged to the families Salticidae (jumping spiders), Araneidae and Uloboridae as well as several unidentified species of much less importance. Adults and larvae of all species of Oxycarenum were caught in the traps but it was only on two occasions that spiders (one Salticid and one Araneid) were actually seen feeding on adult Oxycarenum.

Forty-one adults and 6 larvae were retrieved from the webs examined together with adults and larvae of several other insects. Some Salticidae and Araneidae were observed stalking their prey on the branches and on the ground among the floss of kapok, which also harboured several species of seed feeding insects, mainly Dysdercus.

Although the foregoing figures indicate that all the three species of Oxycarenum are caught in the web of spiders, it is doubtful whether the latter are able to exercise any control on the numbers of Oxycarenum in the field. Extensive work will be needed to establish the role of spiders in the regulation of levels of Oxycarenum populations.

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Vertebrate predators

Vertebrate predation on Oxycarenum appeared unimportant. Throughout the duration of this project, no vertebrates were observed feeding on any of the Oxycarenum species studied. Examination of 97 faecal pellets and stomach contents of 5 Agama agama^(L) lizards living in the same area with colonies of Oxycarenum failed to reveal the presence of undigested parts. When adults and larvae of O. dudgeoni were offered to lizards living in the same area, the bugs were ignored but when adults and larvae of Dysdercus sp. were given, a few of each were readily eaten. Thus, it seems Oxycarenum does not normally form part of the food of Agama agama lizards.

2.3.9 Defensive mechanisms

In the larvae of many Heteroptera, there are normally one to three secondarily paired or unpaired functional abdominal glands, but the occurrence of four glands has been reported in Joppeicidae (Davis and Usinger, 1970) and Cryptostemmatidae (Leston 1954). These glands become functionless in adults, their defensive role being taken over by the paired metathoracic glands. However, recently, Calam and Scott (1969) have shown the presence of functional dorsal glands in adults of Dysdercus intremedius Distant

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(Pyrrhocoridae). In mirids, Brindley (1929) described the position and number of the glands in the larvae.

In the larvae of Oxycarenus, a pair of epidermal odoriferous glands is situated medially on the under-surface of the fourth and fifth abdominal terga. These glands open dorsoposteriorly into the intersegmental membranes of segments 4 and 5, and 5 and 6, respectively. Closer observation reveals that the orifices are especially thickened, black in colour and sealed with a transparent cuticle. Aryeetey and Kumar (1973) have reported similar observations in cocoa-capsids (Miridae: Heteroptera). In adults, the function is taken over by the paired metathoracic glands. Mishandling of specimens caused highly pungent smelling secretions to be discharged that could not be seen. These secretions persist for as long as one hour after discharge and are sufficient to repel any would be attackers. They do not, however, seem to have any effect on themselves or on reduviid predators, which readily impale their victims on their rostrums without any resistance. Studies by Aryeetey and Kumar (1973) on Bathycoelia thalassina Schouteden (Pentatomidae: Heteroptera), a pest of cocoa in Ghana have shown that when stimulated mechanically, these bugs are able to produce an instantaneous discharge of a secretion that is shot at a distance of

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4 - 7 cm., and furthermore, are able to orientate the spray in a desired direction. These authors did not notice this feature in cocoa capsids, and in the present work, it was not noted in Oxycarenum either.

Analysis of secretions from similar glands in adults and larvae of Dysdercus melanoderes Karsch by Youdeowei and Calam (1969) shows that n-tetradecane is the major hydrocarbon in the secretions. This component of the secretion, according to them, is found in the defensive secretions of bugs of several species and usually occurs in association with aldehydes, including hex-2-en-1-al. The function of n-tetradecane is "believed to be two-fold: to prolong the action of the active repellents by retarding their rate of evaporation, and to aid penetration of these substances into the predator's cuticle".

If the secretions from the scent glands of Oxycarenum do not have any effect on reduviid predators, then the protective function of these glands should be questioned since reduviids have been established in the present work as the main predators of Oxycarenum. It must, however, be remembered that the secretions may offer protection from other groups of predators and parasites which were not investigated in this study.

3. LIFE CYCLE, MORPHOMETRICS AND GROWTH PATTERNS
OF OXYCARENUS SPECIES

3.1 INTRODUCTION

There has been a remarkable progress, as stated in the general introduction, in the study of the biology of immature stages of many Heteroptera. However, large gaps exist in our knowledge of many groups of Heteroptera and little work has been done on the life cycle and immature stages of Oxycarenus species. These aspects are considered in the present work.

3.2. MATERIALS AND METHODS

3.2.1 Materials

All the material used in this work was collected by the writer from the field, and a part was reared in the laboratory. Three species were studied and these were:

- (1) Oxycarenus dudgeoni Distant, collected from blown masses of silk cotton (Ceiba pentandra) and also from Sterculia foetida in the University of Ghana Botanical Gardens.
- (2) O. hyalinipennis (Costa) collected from Madina, near Legon on Abutilon mauritianum and A. guineense.
- (3) O. fieberi Stål^o, collected from Madina and Achimota

near Legon, and Mampong and Mamfe in the Eastern Region (Fig.2.1).

3.2.2. Methods

3.2.2.1 Methods for rearing of instars

Males and females were collected from the field and a stock culture was maintained in the laboratory in large perspex containers. Food (seeds of appropriate host plants) and water were provided as well as damp cheese cloth on the floor to serve as egg laying substrate. Five mating pairs were kept per container as greater numbers resulted in overcrowding, with high mortalities and fewer eggs being laid.

For O. dudgeoni, seeds of Ceiba pentandra soaked in tap water for a few hours were supplied as food, and a clean, wet swab of cotton wool was supplied for egg laying. Dry seeds of Sida acuta were supplied to O. fieberi with damp cotton wool for egg laying. Dry seeds of Abutilon mauritianu served as food for O. hyalinipennis and damp blotting paper was used to line the floor of the container. Eggs were deposited in the space between the paper and the bottom of the container.

The substrate was examined twice daily and any eggs laid were removed, dated, and placed for rearing in plastic dishes measuring 5.0 cm. diameter and 2.0 cm. depth, and provided with a cover. Inside the dishes were small quantities of

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soaked seeds of the same kind supplied to the adults. Drinking water was supplied in wet cotton wool. A few drops of water were added every other day to offset losses due to evaporation. Mouldy seeds and cotton wool were replaced. Moulded skins were removed with a wet camel hair brush and handling was reduced to a minimum. Records were kept of changes in the life history.

3.2.2.2 Methods for description of immature stages

Colour descriptions, measurements of the various parts as well as drawings of all stages are based on fresh laboratory reared as well as field collected specimens. A stereo-binocular microscope fitted with an ocular micrometer was used for all measurements. A freshly killed specimen was placed on a white tile beneath the microscope. Legs, rostrum and antennae were detached from the body and laid flat on the tile. Measurements are all expressed in millimeters.

Definitions of the measurements, terms and symbols used are as follows:

Head length

Length of the head, excluding the neck, measured mid-dorsally.

Head width

Greatest width taken through and including the eyes,

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measured dorsally.

Interocular width

Distance between the inner angles of the eyes on dorsum.

Antennal length

First segment, including the antennifer, is measured ventrally.

Pronotal length

Length of pronotum along the dorsal midline.

Egg length and width

Measurements pertain to maximum size in the dorsal aspect when the egg is laid on the tile.

Lengths of leg segments

Femora, tibiae were measured separately, tarsal segments 1 and 2 taken together and then 3. "Constant" means all the measurements for a particular segment are the same. Figures in parentheses refer to the mean of the readings for the particular case.

All illustrations were made with a camera lucida and, unless otherwise stated, are drawn to scale.

The growth ratio between any two successive instars was obtained by dividing the mean head width for each instar by that of the preceding instar. From these values, the mean

growth ratio was calculated.

3.2.2.3 Methods for studying oviposition preferences

Mating pairs in copula were collected from the field, and two pairs were kept in egg laying perspex dishes in which pairs of egg laying substrates were arranged. Ten replicates for each were set up.

For O. fieberi, the following pairs were used:

- (a) Mature Sida acuta seed heads (unopened) and cotton seeds on which was lint.
- (b) The same as (a) but this time the cotton seeds were hollowed out.
- (c) Mature Sida acuta seed heads and mature green Abutilon mauritianum seed heads.

In addition to (a) and (c) mentioned above, cotton seeds with lint and Ceiba pentandra seeds with kapok were also offered to O. dudgeoni; and cotton seeds with lint and Abutilon mauritianum seeds were arranged for O. hyalinipennis.

3.2.2.4 Methods for studying aggregation

In this study, fourth and fifth instars as well as adults were used. Specimen were collected from the field and starved for 24 hours. The bottom of a plastic dish of diameter 85 mm was covered with blotting paper on which 10 similar

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cotton seeds were arranged equidistant from each other around the circumference, and stuck in place with white glue. The seeds were numbered and a damp cloth was positioned in the centre to serve as a source of drinking water. A small hole was made in the centre of the cover for the dish. Ten starved insects were dropped into the centre of the dish and allowed to settle. Records were taken of the number of insects feeding on each seed within every 30 minutes. Results for four replicates were obtained for each instar used.

In a second experiment, five seeds were pierced with the end of a ball point pen and alternated with five unpierced seeds around the circumference of a plastic petri-dish in the manner described above. Ten starved fourth instars were dropped in at the centre and the experiment was continued as before.

In a third experiment, the antennae of a number of insects were amputated or only the fourth segment was amputated. They were starved for 24 hours and then offered seeds of cotton to assess their ability to locate and feed on them. The number of bugs feeding was recorded every 5 minutes for 45 minutes and a control was run for each replicate. The maximum numbers recorded feeding in the treated and untreated series were compared by means of a 2 by 2 chi-squared test.

3.3. RESULTS AND OBSERVATIONS

3.3.1 Life Cycle

The life cycle of three of the four species of Oxycarenius that occur in Ghana were studied in the laboratory which experienced a range of temperature changes from 29.0°C. to 31.0°C., and a relative humidity averaging 65%.

3.3.1.1 Precopulating behaviour

In Oxycarenius, as in many other insects, mating is always preceded by some kind of courtship which is essentially similar in all the three species studied. The male, which is smaller in size, always initiates courtship and surveys the female by probing her with the antennae. The female becomes stationary and still probing, the male first cleans his fore wings by brushing with the hind pair of legs and then the rostrum, using the first pair of legs. The male turns round until the terminalia are in contact with the antennae of the female, then changes position and lies side by side with the female, their heads in the same direction and maintaining antennal contacts. Various other positions may be assumed before the male finally mounts the female.

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3.3.1.2 Mating

In a successful attempt, the male, still holding the female with some or all the legs, slips the tip of his abdomen to one side in an attempt to bring the tip of the abdomen beneath that of the female which has by then been raised. This will enable the male to engage the genital capsule with that of the female. It is usually relatively fast, but once engaged, the pair spends between 30 and 40 seconds in that posture before the male slips off the female's back to face the opposite direction. Obviously, this is to ensure firm engagement.

After an unsuccessful attempt, the female briskly walks over the back of the male before the latter makes further attempt in engaging her in copulation. A forceful attempt to mount her results in a violent scuffle during which the female tries to throw the male off her back. A male which has been rejected by either of these methods may either chase the female or go off in another direction until re-encountering the female to start the sequence all over again.

Once in copula in the end to end position, the larger female moves along, dragging the male partner and virtually dictating both the speed and direction of movement. A pair in copula is very active and seldom stationary, except to feed. When disturbed, they do not part so readily and when they do,

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they either re-engage almost immediately without going through any courtship rituals or may not mate at all or not until after some time in which case an abbreviated courtship may be exhibited.

The males were found to be polygynous and the females polyandrous. This was demonstrated by putting two females and a male in a perspex dish and vice versa. Twenty observations were made in each case. The two females in a dish were distinguished by different colours placed on the membrane of the fore wing. A similar method was used to distinguish the two males in a dish.

3.3.1.3 Oviposition

Mating occurs 1 - 2 days after emergence and eggs are oviposited a few hours after the last mating. Mating may occur either once in which case the pair remains in copula for a longer period (up to about 2 days) or may be continued or discontinued on and off a few times during this interval. Mating alone does not indicate that a female is able to lay eggs, and mating females have been found to contain no eggs when they were dissected (Kirkpatrick 1923; Odhiambo 1957). Oviposition is usually completed in one day but may extend into the second day.

In the laboratory, oviposition occurred underneath what-

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ever material lined the floor of the plastic dishes in which the bugs were kept. In the absence of any suitable oviposition site, as for example the case where no lining was provided, females ready for oviposition wandered about for longer periods and the eggs were either re-absorbed or the females died without oviposition. On no occasion were the eggs deposited on the bare floor or on the sides of the container. Dead females were occasionally seen with their abdomens distended with eggs. Eggs retrieved from dead females either incubated successfully or failed to do so entirely; in the latter case, the eggs had begun to shrink. Total numbers of eggs laid by single females in the laboratory were: (10 observations in each case) O. fieberi 3 - 25 (15), O. hyalinipennis 8 - 25 (19), and O. dudgeoni 6 - 17 (11). (Means are given in brackets).

In the field, eggs of O. dudgeoni were deposited singly among the strands of kapok from the silk cotton tree, Ceiba pentandra, and were attached firmly at the anal pole by a white cement, probably secreted by the accessory glands of the females' internal reproductive organs.

Eggs of O. fieberi in the field were deposited inside mature fresh seed heads, in the space between the seeds and the carpel wall. Never were any eggs found on the stem or leaf but occasionally eggs were found embedded in the centre

77.

of the seed head and also within developing buds and enveloped completely by the overlapping calyx. On cotton, as reported by Odhiambo (1957), eggs were found among the strands of the lint in the opened or partially opened bolls and were generally not far from the seeds. In young bolls, eggs were often found inside the calyx surrounding the bolls. The number of eggs per batch ranged from 1 to 25 with an average of 15 (10 observations). Oviposition may be completed in 1 - 2 days.

Oviposition by O. hyalinipennis in the field was studied on Abutilon mauritianum, okro and cotton. On Abutilon, eggs were found in mature seed heads next to the carpel wall and occasionally at the bases of the seed compartments in expanded and semi-expanded fruits. However, the preferred oviposition site was in the trough between ridges on the external surface of the fruit. Protection was further afforded by the stiff hairs which beset the surface of the fruit. Total number of eggs per batch ranged from 1 - 25 (10 observations).

On cotton, oviposition sites were found to be similar to O. fieberi as have been described above. In all cases, clustered eggs touched each other and were sometimes stuck together, although there was no obvious cementing substance in between them.

Results of the oviposition preference tests are presented

78.

in Tables 3.1 - 3.3.

Table 3.1: Oviposition preference of Oxycarenus hyalinipennis

Laying dish Number	Number of batches of eggs						Total number of eggs					
	S	C	S	A	C	A	S	C	S	A	C	A
1	0	4	0	7	2	0	0	23	0	18	15	0
2	1	0	0	6	2	0	13	0	0	12	18	0
3	2	1	3	4	0	6	8	9	17	12	0	8
4	2	4	2	1	1	0	4	19	11	5	7	0
5	2	1	0	8	0	0	7	8	0	17	0	0
6	0	5	0	9	3	0	0	17	0	24	5	0
7	1	4	0	10	3	4	8	13	0	19	11	6
8	0	0	0	8	5	0	0	0	0	15	8	4
9	3	0	0	9	0	0	22	0	0	24	0	0
10	5	3	0	0	6	0	9	5	0	0	9	0
Totals	16	22	5	62	21	10	71	94	28	146	73	14
t _{9df}	0.74		4.38		1.13		0.53		3.28		2.32	
P	> 0.05		< 0.05		> 0.05		> 0.05		< 0.05		< 0.05	

Key: S = Sida acuta seed head. C = Cotton seeds with lint on them.
A = Abutilon mauritianum seed head.

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Table 3.2: Oviposition preference of Oxycarenus dudgeoni

Laying dish Number	Number of batches of eggs						Total number of eggs					
	S	C	S	A	C	CE	S	C	S	A	C	CE
1	0	3	0	0	4	3	0	7	0	0	4	3
2	0	1	2	0	1	3	0	4	11	0	4	8
3	1	2	2	0	5	0	3	5	10	0	5	0
4	0	0	0	1	1	1	0	0	0	9	1	5
5	0	0	1	4	6	0	0	0	3	7	11	0
6	1	0	0	0	3	3	9	0	0	0	3	9
7	0	4	0	3	1	4	0	11	0	11	5	13
8	2	2	4	0	0	0	7	10	5	0	0	0
9	0	3	3	2	4	4	0	14	3	5	6	10
10	0	1	2	6	1	0	0	6	10	8	2	0
Totals	4	16	14	16	25	18	19	57	42	40	41	48
* χ^2 df	2.35		0.25		0.91		1.88		0.05		0.39	
P	< 0.05		> 0.05		> 0.05		> 0.05		> 0.05		> 0.05	

Key: See Table 3.1.

CE = Ceiba pentandra seeds with kapok on them.

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Table 3.3: Oviposition preferences of Oxycarenus fieberi

Laying dish Number	Number of batches of eggs						Total number of eggs					
	S	C	S	HC	S	A	S	C	S	HC	S	A
1	6	0	2	2	3	0	33	0	34	27	19	0
2	4	0	5	0	0	6	24	0	38	0	0	11
3	0	1	3	1	1	1	0	4	14	14	13	3
4	1	1	2	1	4	0	10	2	7	8	25	0
5	3	4	0	2	4	0	15	18	0	17	29	0
6	0	1	1	0	2	3	0	29	16	0	14	9
7	5	0	0	1	0	5	42	0	0	7	0	13
8	4	0	0	0	6	7	46	0	0	0	32	10
9	6	0	3	2	5	0	38	0	9	24	29	0
10	5	0	3	3	1	3	38	0	17	11	17	8
Totals	34	7	19	12	26	25	246	53	135	108	178	54
$t_{9 \text{ d.f.}}$	2.81		1.17		0.08		2.44		0.60		2.57	
P	<0.05		>0.05		>0.05		<0.05		>0.05		<0.05	

Key: See Table 3.1

HC = HOLLOWED OUT COTTON SEEDS.

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Analysis of the results of oviposition preference tests indicates that both in terms of the number of batches of eggs and the total number of eggs laid, Oxycarenum hyalinipennis showed no preference for either cotton or Sida acuta while Abutilon mauritianum was preferred to Sida acuta. Although more eggs were laid on cotton than on Abutilon, the number of batches of eggs was not significantly different. This means that more eggs per batch were laid on cotton than on Abutilon, the principal feral host plant.

O. dudgeoni preferred cotton to Sida for egg laying. Between Sida and Abutilon, and between cotton and Ceiba pentandra, no preferences were shown.

For O. fieberi, Sida acuta the principal feral host plant was preferred to cotton for egg laying. Almost equal number of batches of eggs were laid on Sida and on Abutilon, however, the total number of eggs laid on the former was more than on the latter. Thus, the average number of eggs per batch was more on Sida than on Abutilon. Hollowed out cotton seeds enhanced their choice for egg laying, the hollowness being reflected in the ability to offer concealment to the eggs.

In a similar study, Odhiambo (1957) reported that Sida was preferred to cotton for egg laying. These results were, however, indeterminate since a mixture of O. dudgeoni and O. fieberi was used. It was also found by the same author

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that the hollowness of cotton seeds enhanced their choice for egg laying. By the results of further experiments, three decisive factors were listed in the preference for Sida as follows:

- (a) Whether the mature seed heads had opened or not
- (b) The "hollowness" of the seed heads, and
- (c) The presence of seeds in the seed heads.

These factors were found to be operative for cotton, and therefore, the choice depended on the condition of the seed heads.

3.3.1.4 Egg

Southwood (1956^a) gave an account of the egg and egg bursters of terrestrial Heteroptera and reported their utility in the higher classification of this group. The eggs of Oxycarenus, typical of Lygaeidae in general, are oblong in shape, and possess a pseudo-operculum. The cephalic pole takes a slightly larger diameter and is ringed with micropylar processes which are small, short, constricted at their bases and enlarged at their apices. Their number varies between 4 and 6 per egg. The external chorionic surface is sculptured with numerous longitudinal grooves which converge at each pole. When first laid, the eggs are cream coloured, changing gradually to light-straw with deep red outlines of the eyes, the fourth antennal segments and the bands across the abdomen of the developing embryo seen from beneath the chorion as incubation pro-

gresses.

Table 3.4: Egg measurements of Oxycarenius species studied

Means for 10 measurements are given in parentheses

<u>Species</u>	<u>Max. Length (in mm.)</u>	<u>Max. Width (in mm.)</u>
<u>O. dudgeoni</u>	0.80 - 0.90 (0.88)	0.25 - 0.30 (0.28)
<u>O. fieberi</u>	0.80 - 0.88 (0.85)	0.25 - 0.28 (0.26)
<u>O. hyalinipennis</u>	0.80 - 0.88 (0.85)	0.25 - 0.28 (0.26)

3.3.1.4.1 Incubation

The period of incubation was studied under laboratory conditions of 29°C - 31°C temperature and about 65% R.H. The period of incubation, larval development and the duration of instars of Oxycarenius species are given in Tables 3.5 and 3.6.

Table 3.5: Period of incubation and larval development of Oxycarenius species. Data based on 10 individuals. Means in parentheses.

<u>Species</u>	<u>Incubation (days)</u>	<u>Larval period</u>	<u>Total number of days (from egg laying to adult)</u>
<u>O. fieberi</u>	5 - 7 (6)	17 - 21 (19)	22 - 28 (26)
<u>O. dudgeoni</u>	4 - 5 (5)	14 - 20 (16)	18 - 25 (24)
<u>O. hyalinipennis</u>	5 - 6 (6)	16 - 22 (19)	22 - 29 (27)

Table 3.6: Duration of instars of Oxycarenius species. Data based on 10 individuals. Figures are expressed in days. Means in parentheses

Species	1st instar	2nd instar	3rd instar	4th instar	5th instar
<u>O. dudgeoni</u>	4 - 4.5 (4.2)	2 - 3 (2.4)	2 - 4 (2.7)	2.5 - 3 (2.8)	4 - 5 (4.8)
<u>O. fieberi</u>	4 - 5 (4.8)	3 (const)	3 - 4 (3.2)	3 - 4 (3.8)	4 - 5 (4.3)
<u>O. hyalinipennis</u>	4 - 5 (4.5)	2 - 3 (2.8)	3 - 4 (3.3)	3 - 4 (3.6)	4 - 6 (4.9)

3.3.1.4.2 Hatching

Owing to the absence of a true perculum, hatching in Oxycarenius is facilitated by the egg-burster which, according to Southwood (1956^a), is the median sclerotized areas of the vertex of the embryonic cuticle. Southwood (1956^a) stated further that insects with eggs of thick chorions, for example, Pentat^{at}inae and Coreidae, have much stronger egg bursters than of those eggs with thinner chorions such as Lygaeidae and Pyrrhocoridae.

At the end of the incubation period, the embryo, now matured, lies along the long axis of the egg with the head immediately below the pseudo-operculum. The antennae, rostrum and legs are all directed backwards and adhere closely to the ventral surface of the abdomen. At eclosion, the head of the embryo forces up the pseudo-operculum through a series of pulsating movements of the body fluids. A small slit begins from the dorsal aspect and

travels along the periphery of the pseudo-operculum in either direction, leaving a portion adjacent to the mouthparts of the embryo. The larva crawls out of this slit still covered anteriorly by the embryonic cuticle. To free itself, the forelegs are released, then the midlegs, the antennae and finally the hind legs. Hatching takes approximately 10 - 15 minutes, and all eggs in a batch emerge within about 6 hours of each other.

3.3.1.4.3 Egg Burster

During larval eclosion, the egg burster together with the embryonic cuticle separates from the egg case. (Sketches and descriptions ~~are~~ based upon the composite structure found lying on the floor of the plastic rearing dish.) The embryonic cuticle is tubular and dome-to-bell-shaped with a long process coming off at the apex. On closer observation, the process is seen to consist of a long white to hyaline flat blade sculptured with numerous ridges along the length, and a second smooth one of equal length or slightly longer than the blade. Two areas of the embryonic cuticle are clearly discernible based on texture and transparency. The egg burster is transparent, with one pointed edge. Dorsally, the surface is slightly convex making a smooth protusion near the base of the dome of the embryonic cuticle (Fig.3.1).

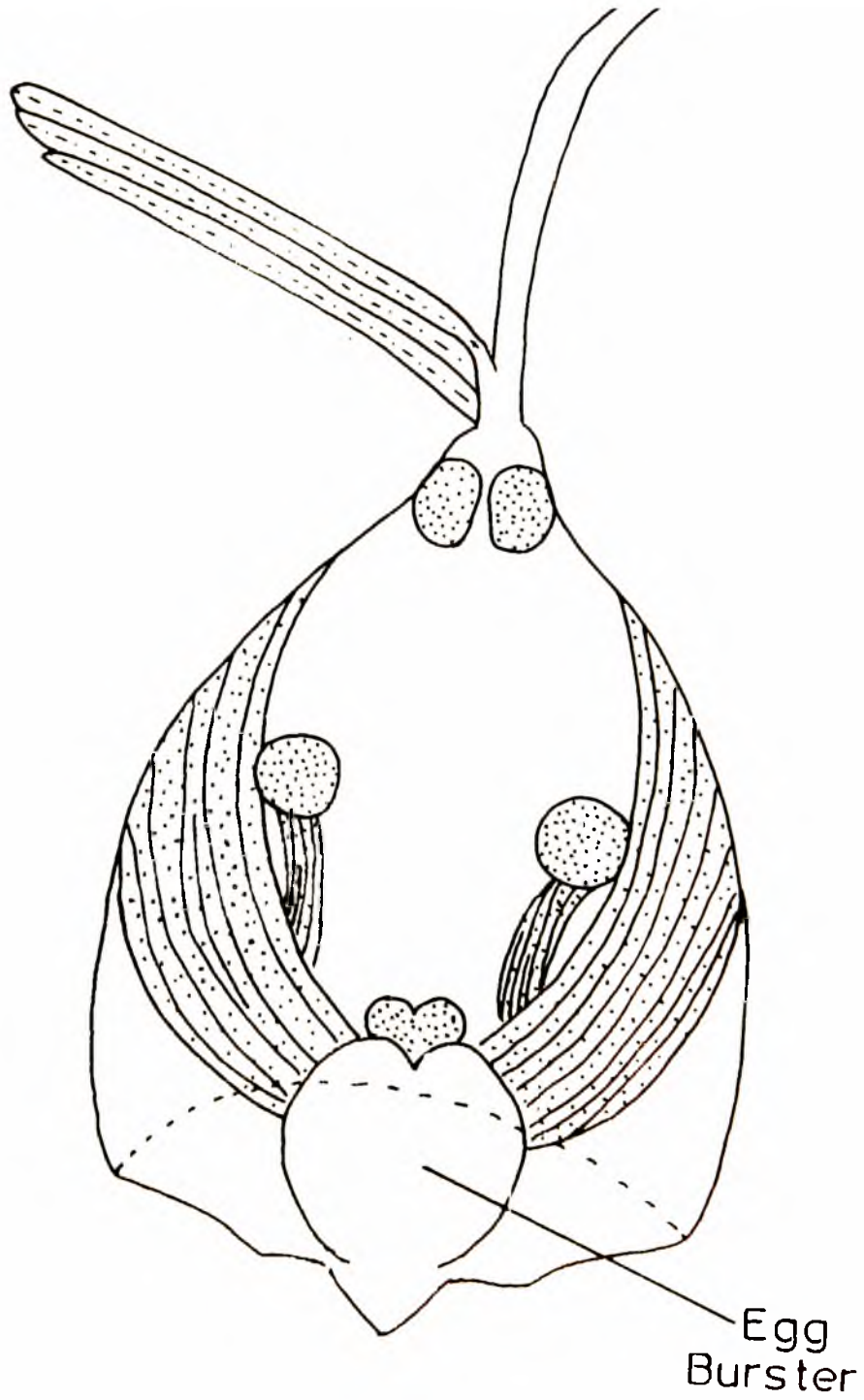


Fig. 3.1: Embryonic cuticle of *O. fieberi* showing egg burster.

86.

3.3.1.5 Larval Instars 1 - 2

Immediately after hatching in the laboratory, first instars formed large aggregations beneath the lining of the container. There was a strong negative phototactic response which kept them on the underside of larger objects and away from the direct rays of light. In the field, first instars were not frequently observed. Being prone to desiccation, they formed aggregations next to the carpel wall where humidity appeared relatively high and were shielded from external atmospheric influence by the calyx of the developing fruit. Feeding was restricted to collection of dew which formed on the exposed parts of the fruit. A well fed first instar was easily distinguished from an unfed one by the large distended abdomen. In an unfed instar, signs of desiccation were visible; the abdomen became crumpled and the various segments were telescoped one into another. The rostrum could be seen protruding from beneath the tip of the abdomen.

Second instars fed mainly on young vegetative growth as found on the terminal buds and young flowers. On Sida and Abutilon, they were often found in aggregations among mature seeds which had been rendered soft by droplets of dew collected at the bases of the seedheads.

Early instars as well as adults of O. dudgeoni in kapok (silk cotton) experienced very high fluctuations of temperature

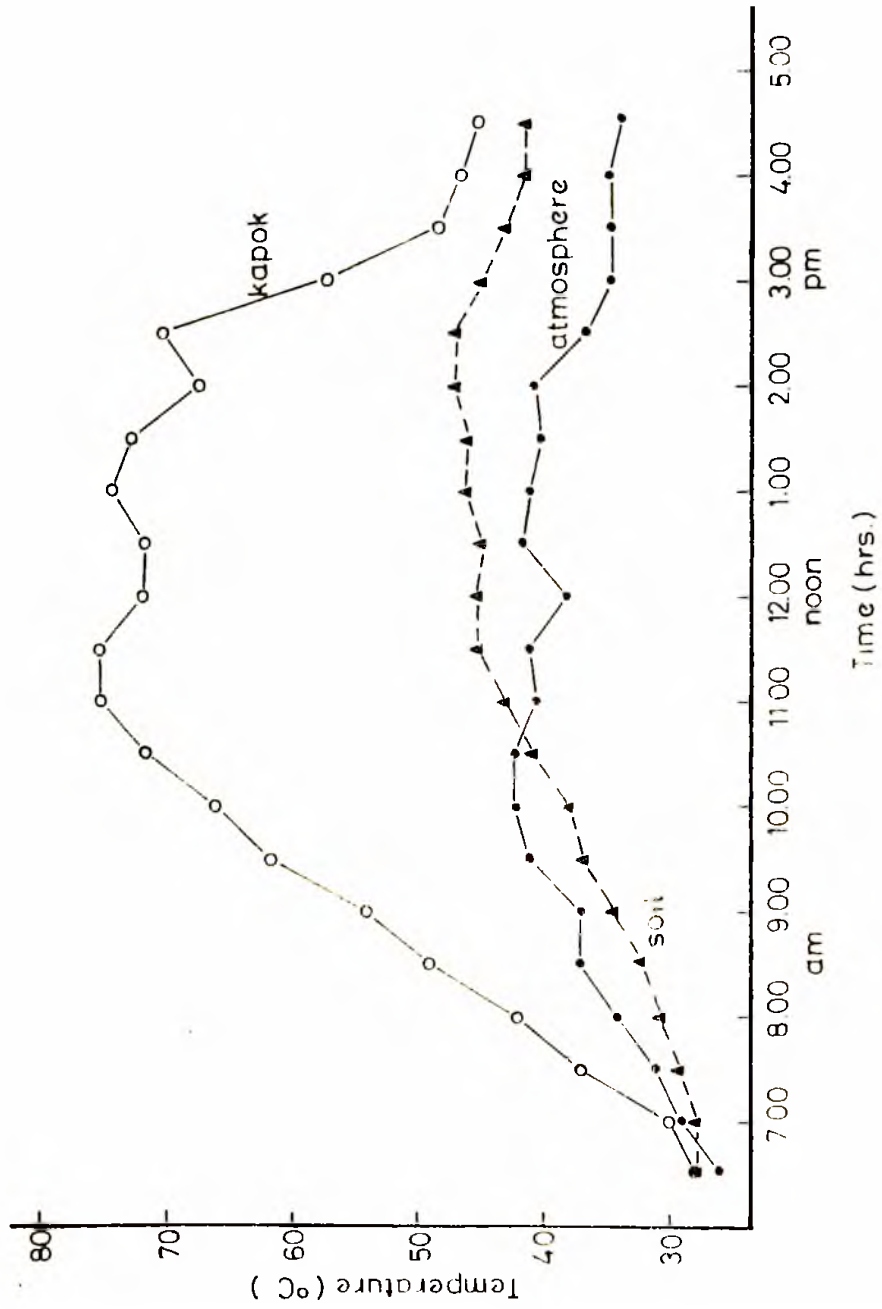


Fig. 3.2: Temperature of soil, atmosphere and kapok.

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inside the masses of silk cotton where a range of 28.0°C - 75.1°C was recorded on a sunny day with corresponding figures of 26.0°C - 42.0°C for atmospheric and 28.0°C - 47.0°C for the soil surface. Temperature recordings at half-hour intervals were plotted (Fig.3.2). Both adults and larvae were observed working their way out from the centre of the mass to the periphery apparently to seek the lower temperature. The only source of water was the droplets which collected from the early morning and late evening dew. All stages moved out to drink water and moved in to feed. Thus, the movement in and out is in response to water, food and a suitable ambient temperature.

3.3.1.6 Aggregation

Larvae of all stages of Oxycarenius form large aggregations observed both during feeding and at rest. Intimate physical contact is maintained between individuals in an aggregation either through antennal contacts, leg to leg or body to body.

88.

Results of experiments on aggregation

Table 3.7: The distribution of insects on the ten seeds

Seed No.	No. of 4th instars				No. of 5th instars				No. of adults			
	a	b	c	d	a	b	c	d	a	b	c	d
1		6	5	4	3							1
2					2	4	4	5				2
3	2		2	5		3	1	1		1		
4											3	1
5	4										2	
6									4	3		
7				1	2			1		1		4
8											2	
9		2	1		1				3	3		
10											3	
Not feeding	4	2	2	0	2	3	5	3	3	2	2	2

a, b, c, d: replicates, 10 seeds were used for each replicate (see text for full details).

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The data in Table 3.7 was analysed. Results of the 40 seeds were pooled together for each instar. If the dispersion of the insects on the seeds is

- (a) Random, then $S^2 = \bar{x}$; \bar{x} = observed number of insects per seed.
- (b) Regular, then $S^2 = 0$; S^2 = variance
- (c) Clumped, then $S^2 > \bar{x}$

	4th Instars	5th Instars	Adults
\bar{x}	$\frac{32}{40} = 0.80$	$\frac{27}{40} = 0.675$	$\frac{33}{40} = 0.825$
x^2	122	87	93
$\frac{(x)^2}{n}$	$\frac{1024}{40} = 25.6$	$\frac{729}{40} = 18.2$	$\frac{1089}{40} = 27.23$
$S^2 = \frac{x^2 - \frac{(x)^2}{n}}{n-1}$	$\frac{122 - 25.6}{39} = 2.47$	$\frac{87 - 18.2}{39} = 1.76$	$\frac{93 - 27.23}{39} = 1.686$
$\frac{\bar{x}}{S^2}$	$\frac{0.8}{2.47} = 0.324$	$\frac{0.675}{1.76} = 0.384$	$\frac{0.825}{1.686} = 0.489$

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$$t = \frac{\text{observed ratio} - 1}{\text{standard error of ratio}} = \frac{\text{observed ratio} - 1}{\sqrt{\frac{2}{n-1}}}$$

	4th Instar	5th Instar	Adult
t	$= \frac{0.324 - 1}{\sqrt{\frac{2}{39}}}$	$= \frac{0.384 - 1}{\sqrt{\frac{2}{39}}}$	$= \frac{0.489 - 1}{\sqrt{\frac{2}{39}}}$
	$= \frac{0.676}{0.226}$	$= \frac{0.616}{0.226}$	$= \frac{0.511}{0.226}$
	$= 2.99$	$= 2.73$	$= 2.26$
39d.f	0.001 < P < 0.01	0.001 < P < 0.01	0.05 > P > 0.01

The results of these experiments suggest that instars 4, 5, and the adults have a tendency to aggregate during feeding. This means that, once a seed has been pierced by a feeding bug, the seed becomes more attractive to other bugs.

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Results of the second experiment are given in Table 3.8.

Table 3.8: Distribution of 4th instars on the ten seeds

Replicate No.	Pierced seeds					Unpierced seeds					Not feeding
	1	3	5	7	9	2	4	6	8	10	
1		2		1	2						5
2	1	3			2						4
3	1	3			2						4
4		5			2						3
5	2	1	3		2			1			1
6	3			3				1			3
7	2		3	2							3
8	4	1	1			2					2
9	4		1								5
10	5				1						4

These results were analysed in the same manner as before, $t_{49d.f} = 1.35$, $P > 0.1$ for unpierced seeds and $t_{49d.f} = 2.05$, $0.1 > P > 0.01$ for pierced seeds, thereby indicating aggregation on pierced cotton seeds. These results lend further support to results of experiment 1.

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Importance of antennae in locating the food

Results of the third experiment are given in Table 3.9

Table 3.9: Comparison between treated and control of Oxycarenius hyalinipennis using a mixture of 4th and 5th instars

Treatment	Total No. of insects	Number feeding		χ^2
		Treated	Control	
1. One antenna amputated	44	31	39	N.S.
2. Both antennae amputated	40	3	34	P<0.001
3. 4th segments only amputated	40	5	31	P<0.001

These results indicate that the antennae and more specifically, the 4th segment was important in locating the food during feeding.

3.3.1.7 Moulting

The process of moulting in Oxycarenius can best be understood if the ecdysial lines are considered first. These lines of weaknesses, particularly the ventral ones, are of considerable interest. Extensive work has been done by Hinton (1963) on endopterygote larvae. He has shown that these lines are highly variable in their position and shape and cannot be relied upon as landmarks in interpreting the structure of the cranium. Not much information, however, exists on exopterygote larvae but mention must be made of the work of Kumar (1966) on

Australian bugs of the Superfamily Coreoidea.

All the species of Oxycarenum studied possess a dorsal U-shaped ecdysial line on the head in all the larvae without any variation in the extent of development (Figs.3.3 - 3.20). It is, however, missing in the adults. The anterior arms graze the inner angles of the eyes. A second line runs mid dorsally from the anterior edge of the pronotum to the end of the mesonotum.

Ventrally, there is a pair of fully developed ecdysial lines (= genal sutures of Stys, 1964) in the larvae studied. They take their origin from the region of the antennifers and reach the posterior end of the head.

Larvae about to moult stop feeding and remain quiescent from a few hours to one day in the 5th instar. The first visible sign of the inception of moulting is the shrinking of the abdomen from the old abdominal skin. This causes the thoracic region to expand and in later stages the wing pads become swollen. The insect becomes stationary and a slit runs quickly down from the pronotum medially and widens gradually up to the end of the first abdominal segment. The abdomen is gradually worked out of the old skin by spasmodic contractions but just before the insect is completely out, a second slit occurs along the U-shaped ecdysial line on the head, beginning from the trough and spreading into each arm. The slit extends

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into the arc around the anterior angles of the eyes so that the cuticle between the arms remains attached to the region of the vertex of the head. The first pair of legs are the first to be liberated. Using these, the cuticle is pushed away from the body to release the second pair which then takes over the function of pushing away the old cuticle resulting in the release of the hind pair of legs. The antennae are released by a backward tilting of the head and a forward push on the skin by the front pair of legs. The rostrum and stylets are then freed, before finally the abdomen. Once free, the insect makes a quick dash forward and rests for a short time. Resting time for adults varies between 20 - 30 minutes and within this period, the wings develop fully and harden.

3.3.2 MORPHOLOGY AND MORPHOMETRICS OF IMMATURE STAGES

3.3.2.1 Oxycarenius dudgeoni

FIRST INSTAR (Fig.3.3)

Head

Triangular, apex bearing rostrum, straw to brown in colour, dorsum smooth, with a yellow U-shaped ecdysial line; compound eyes deep red; rostrum four segmented, first three segments hyaline, fourth black, extending to end of second abdominal segment, hairs short and stiff with bulbous ends, one row running along the midline beginning from anteclypeus and falling short of the vertex with two other shorter rows, one on either side, elsewhere arrangement not regular; antennae four segmented, scape and first three segments hyaline, fourth deep red and beset with numerous tiny stiff hairs also with bulbous ends arranged into five rows on the first three segments, fourth segment without well defined arrangement; ventral head pale to creamy.

Thorax

Pro- and meso-notum concolorous with head, a single row of short hairs each on anterior and posterior margins; metanotum white; no wing pads visible; ventrally, thorax creamy white.

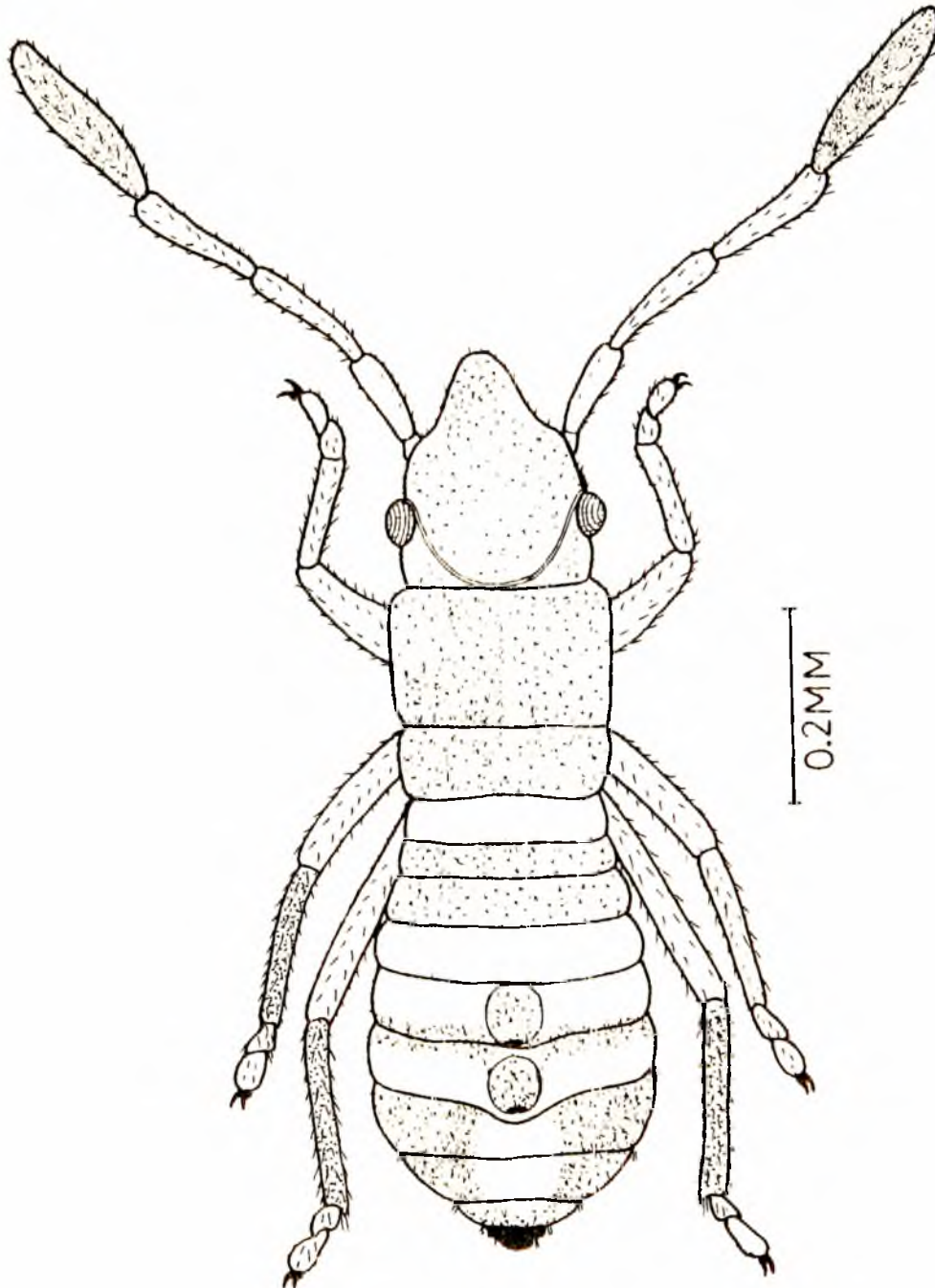


Fig. 3.3: Oxycarenum dudgeoni Distant: First instar.

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Legs

All femora hyaline and sparsely hairy; hairs without definite arrangement; tibiae if mid- and hindlegs dull red; ^{of?} fore-tibiae hyaline with five rows of hairs; tarsi hyaline with much pubescence of no definite arrangement.

Abdomen

First and second abdominal terga red, third creamy and concolorous with first three-quarters of fourth segment; last quarter of segment four and first quarter of 5th segment deep red, forming a red band across the abdomen; median sections of segments 6 - 8 khaki with a red tinge stretching to either side dorso-laterally; 9th and 10th segments black; and abdominal segments with two rows of short stiff hairs sparsely distributed and increasing in length towards their lateral margins; terminal abdominal segments with more pubescence; two larval odoriferous glands straw to light brown in colour, one each situated medially on segments 4 and 5; intersegmental suture separating 4th and 5th and 5th and 6th ^{segments} looping posteriorly in the region of the mid-line thus giving more room for developing odoriferous glands; below each gland and opening into the intersegmental suture is a sickle-shaped orifice with black borders which serve as the opening of the glands; ventral abdomen creamy tending to straw with a red tinge, becoming more conspicuous on 1st and 2nd sterna; devoid of

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pubescence.

Dimensions

These are given in Table 3.10.

SECOND INSTAR (Fig.3.4)

Head

Straw coloured dorsally; U-shaped ecdysial line yellow; eyes deep red; antennal scape similar in colour to head; first three segments hyaline; 4th deep red; apart from dimensions rostrum similar to first instar, and extends to end of 4th abdominal segment.

Thorax

Apart from dimensions, other features as in first instar.
Wing pads appear as small protuberances on mesonotum.

Legs

Coxae and femora concolorous with head; coxal insertions also similar in colour to head with a red tinge in the region of the thoracic pleura; tibiae of 2nd and 3rd legs with a deep red tinge; tarsi hyaline with much pubescence; claws black.

Abdomen

Apart from dimensions, other features as in first instar.

Dimensions

These are given in Table 3.10.

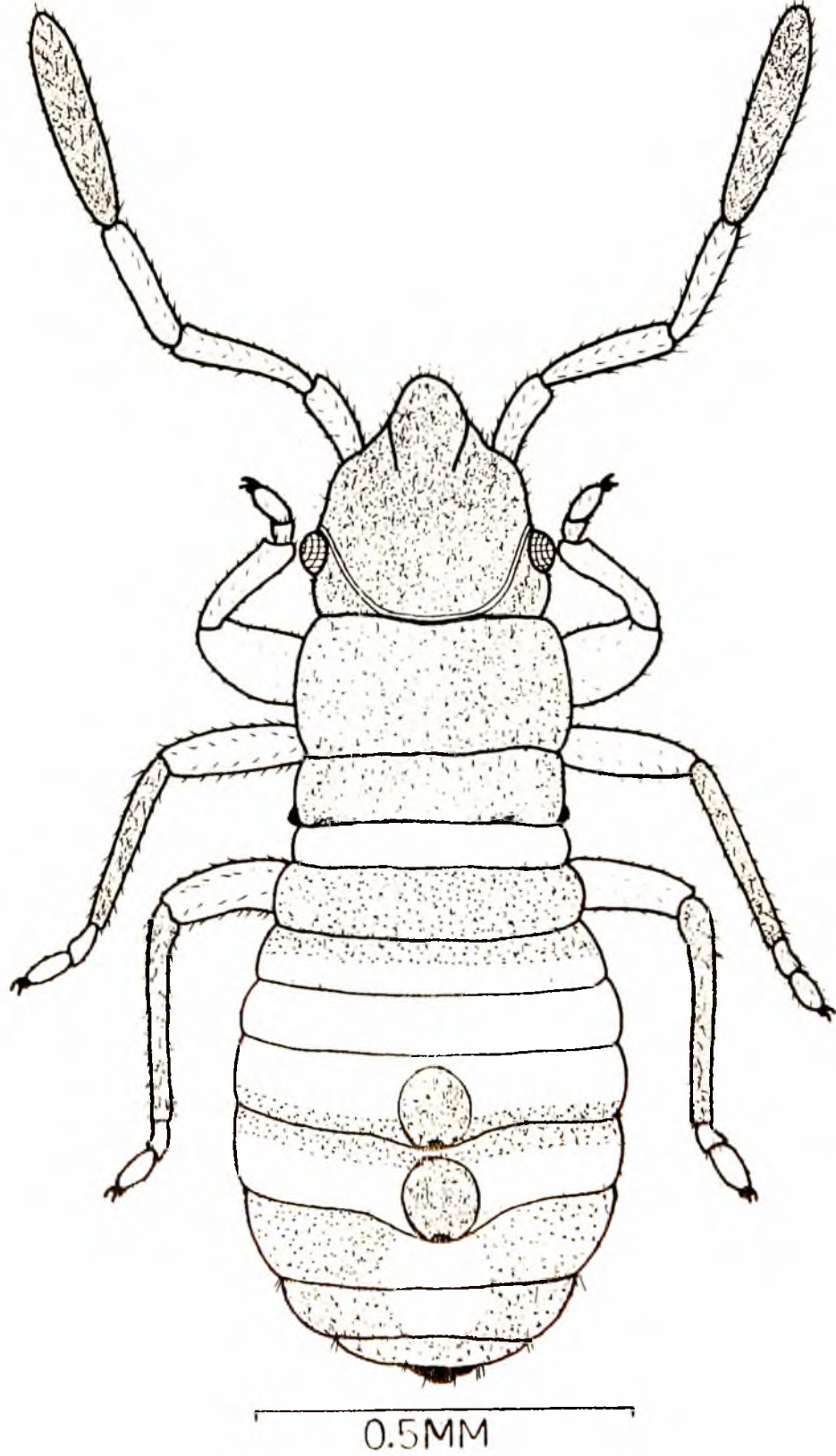


Fig. 3.4: *O. dudgeoni*: Second instar.

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THIRD INSTAR (Fig.3.5)Head

Brown tending to black; U-shaped ecdysial line yellow; eyes deep red; 4th segment of rostrum black, all others hyaline with black intersegmental sutures; 1st segment of antennae light brown to straw coloured, 2nd and 3rd hyaline, 4th deep red; gena straw coloured with a tinge of red.

Thorax

Pronotum and mesonotum similar in colour to head with a median longitudinal yellow ecdysial line; metanotum white; thoracic pleura straw with a red tinge; wing buds and concolorous with head.

Legs

Coxae reddish brown; femora brown; tibiae brown save last quarter which is hyaline and concolorous with tarsi; claws black.

Dimensions

These are given in Table 3.10.

FOURTH INSTAR (Fig.3.6)Head

Brown to black dorsally; eyes deep red; paired ocelli

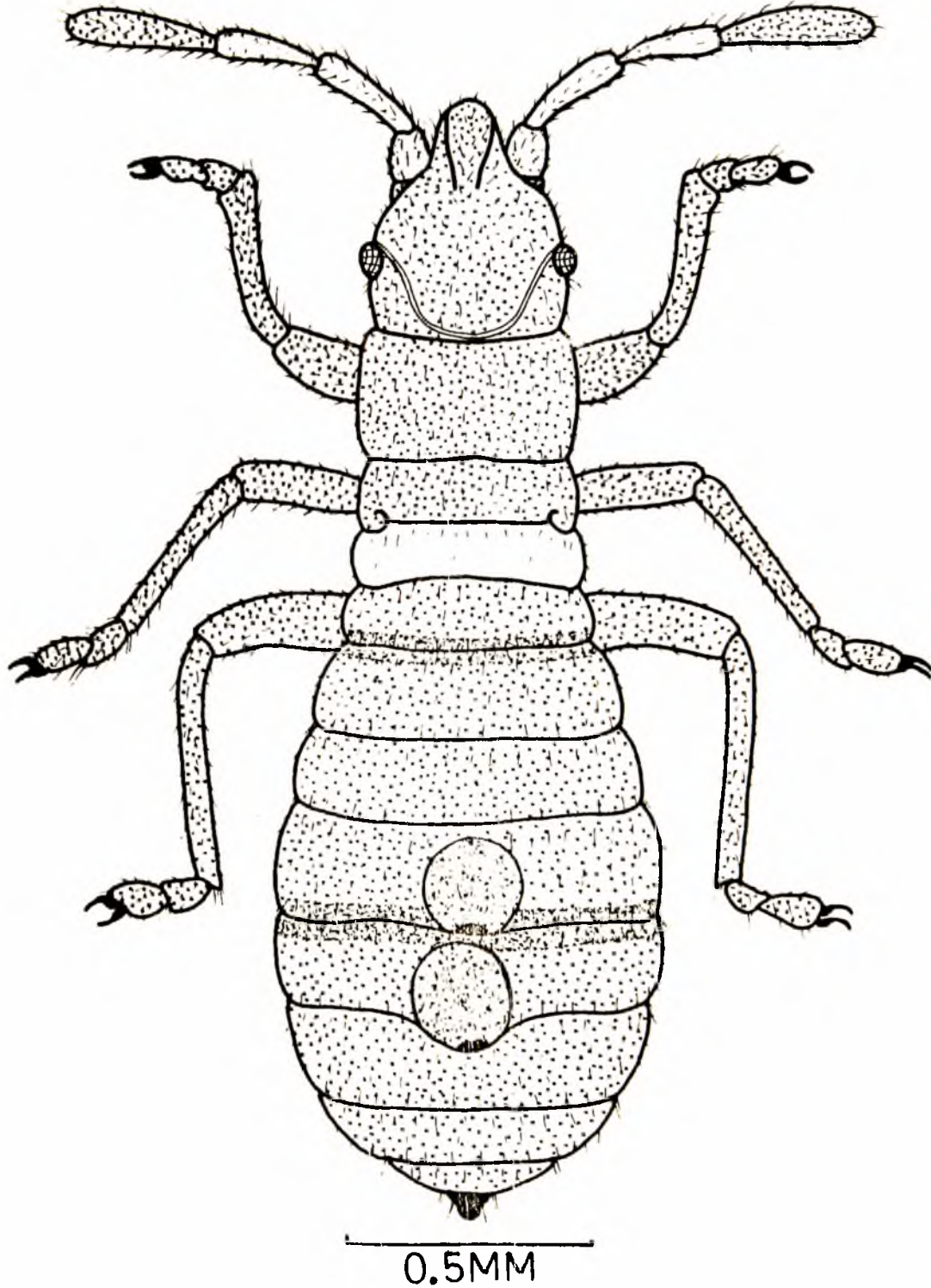


Fig. 3.5: *O. dudgeoni*: Third instar.

99.

clearly visible; situated about a third from the eye down each arm of the U-shaped ecdysial suture; antennal insertions black dorsally, deep red ventrally, all other segments black, first three with five longitudinal rows of regular minute stiff hairs, arrangement on 4th segment not clearly defined; intersegmental sutures of antennae hyaline to white; first three segments of rostrum pale brown; proximal half of 4th segment hyaline, distal half deep brown to black; rostrum extends to end of 4th abdominal segment.

Thorax

Pronotum and mesonotum black dorsally, fringed with stiff hairs becoming shorter and more sparse from the lateral margin to the midline; metanotum white; fore-wing pads black and similar in colour to pronotum, extending halfway over the first abdominal segment, right half marked off from left by a distinct deep red ecdysial groove; hind wing pads white, lying beneath fore-wing pads and closely applied to them.

Legs

All segments deep brown to black; tarsi black dorsally, fringed with dense mass of relatively longer hairs; ventral aspect white; claws black.

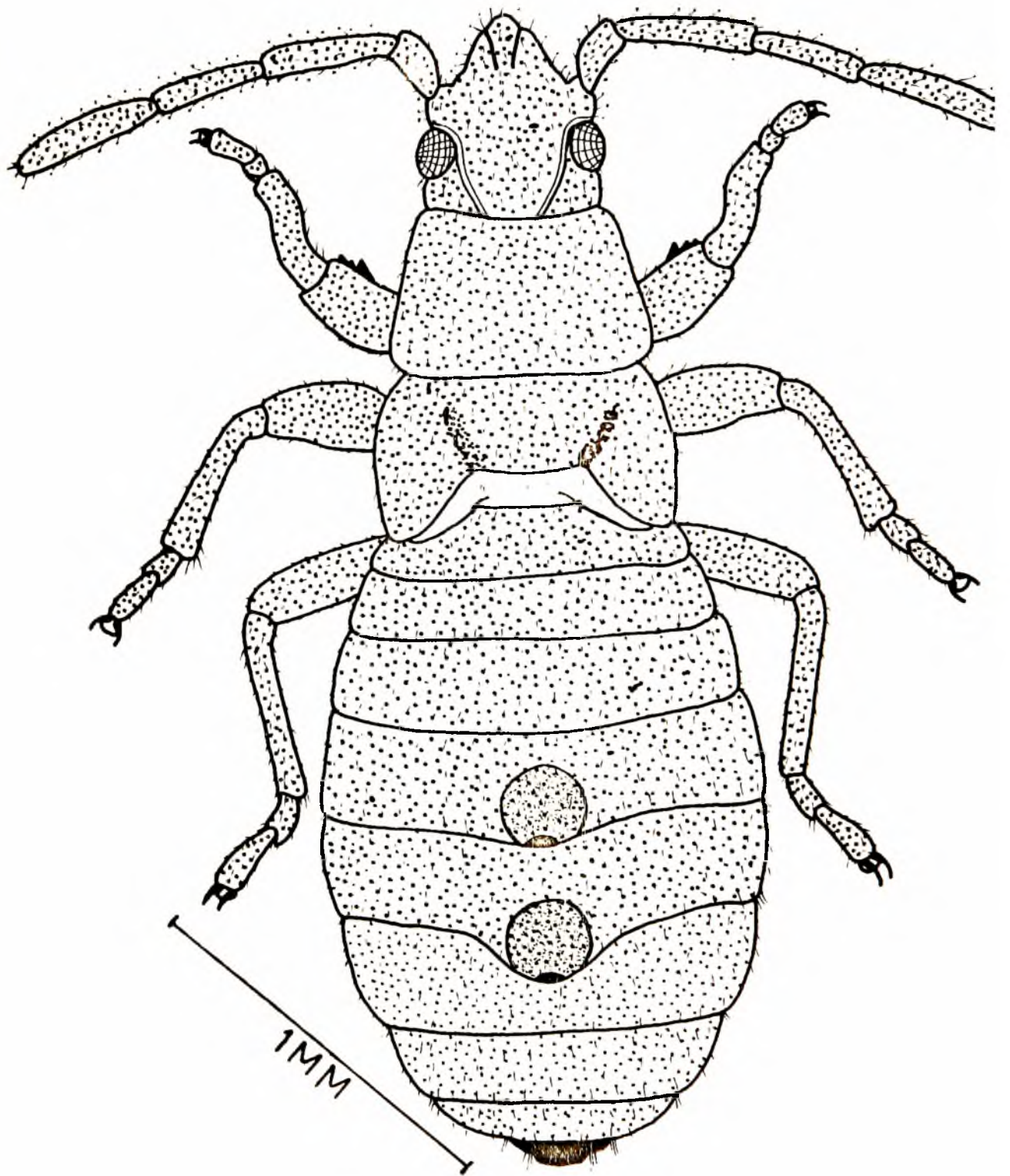


Fig. 3.6: *O. dudgeoni*: Fourth instar.

100.

Abdomen

Reddish brown dorsally; odoriferous glands seen as diffused straw coloured patches with black sickle shaped orifices opening into intersegmental membranes of segments 4 and 5, and 5 and 6; segments 9 and 10 black.

Dimensions

These are given in Table 3.10.

FIFTH INSTAR (Fig.3.7)

Thorax

Wing pads extend, depending on the nutritional state, over either the second or the third abdominal terga. In well fed instars, the abdomen becomes distended and only the 2nd tergum may be covered; in starved individuals the segments become shrunk and telescoped into one another with the pads covering the third; this situation may be observed not only in the laboratory but also in the field.

Apart from dimensions, all other features as in 4th instar; females can be distinguished from males by a hyaline oval patch stretching from mid 4th sternum to mid 8th with a black semi-circular patch at its posterior margin; from the underlying structures can be discerned a developing ovipositor.

Dimensions

These are given in Table 3.10.

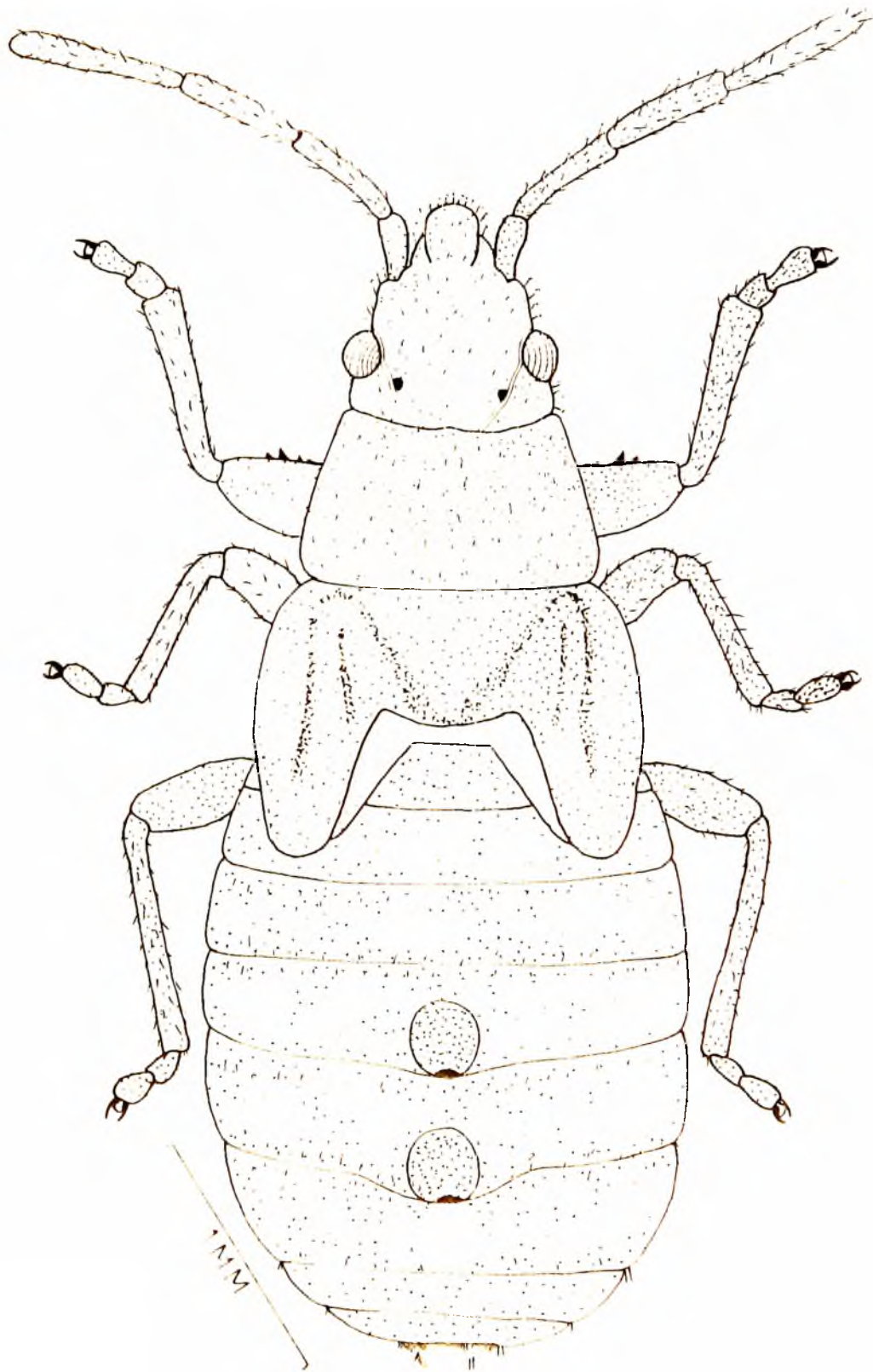


Fig. 3.7: O. dudgeoni: Fifth instar.

101.

ADULTS (Fig.3.8)

Description of adult O. dudgeoni¹⁵ given by Samy (1969).

Dimensions

These are given in Table 3.10.

Post moulting colour changes in adult O. dudgeoni

Part of the body	Just after emergence	One hour after emergence
Head	Orange	Dark brown
Eyes	Deep red	Deep red
Antennal segments 1	Orange	All segments dark brown to black
2	White	
3	Prox. half white, distal half orange	
4	Orange	
Rostrum	Hyaline	Dark brown
Pronotum	Orange, annulated with black	Anterior half deep brown to black, posterior half brown
Wing: Membrane	White	Hyaline
Corium	White with orange veins	White with a light brown tinge
Clavus	White	Dark brown
Scutellum	Orange	Anterior half deep brown; posterior half light brown
Forelegs, Mid- and Hindlegs: Femur	Orange	All femora deep brown
Tibia	White to hyaline	Tibiae black annulated
Tarsus	White to hyaline	Centrally with white; tarsi white; claws black

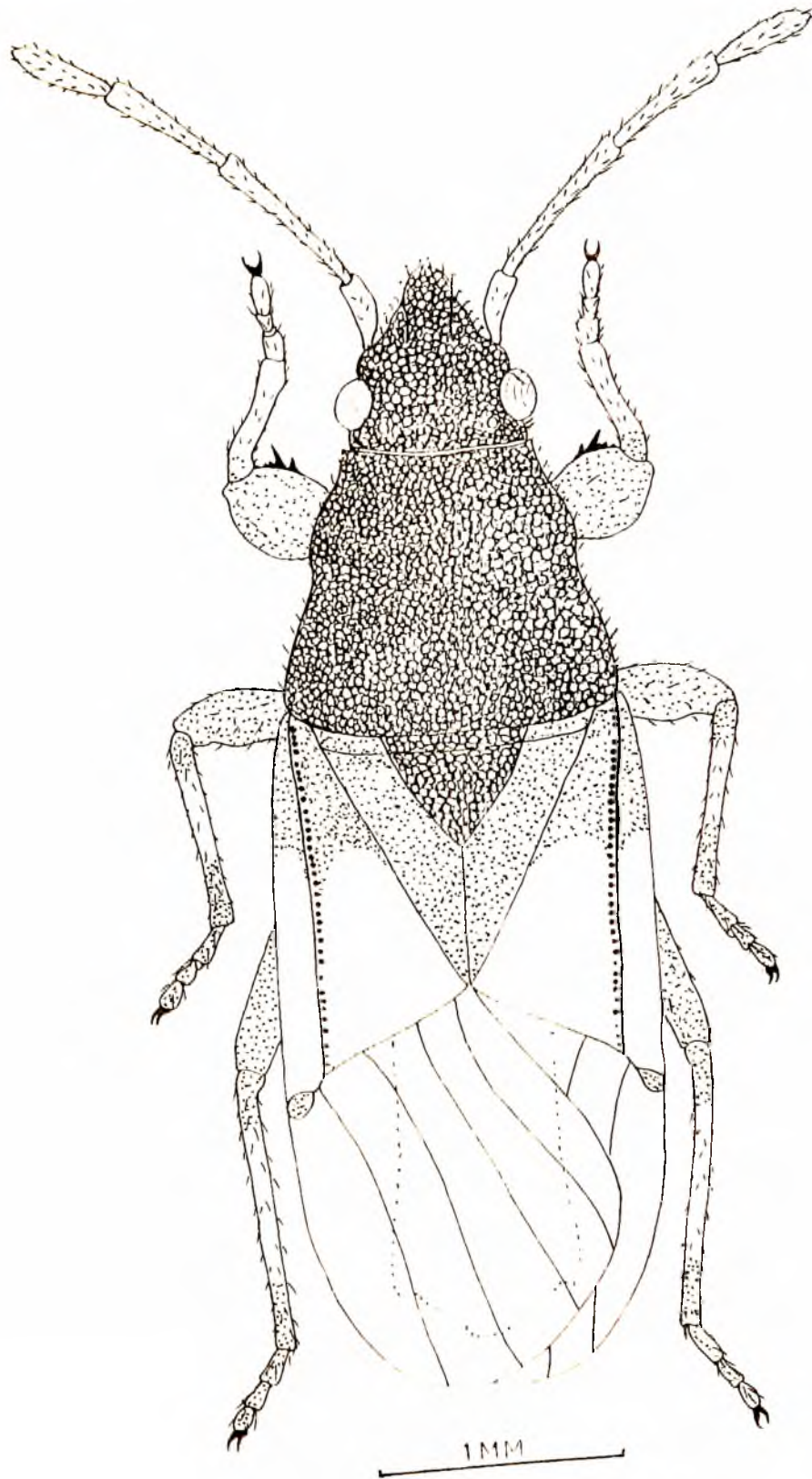


Fig. 3.8: *O. dudgeoni*: Adult.

3.3.2.2 Oxycarenum fieberi Stal^O

FIRST INSTAR (Fig.3.9)

Head

Straw coloured; U-shaped ecdysial line khaki, tending to become yellow; compound eyes deep red; rostrum four segmented, first three segments hyaline tending to become creamy; distal half of fourth segment with black tinge, extends to second abdominal segment; hairs short and stiff with bulbous ends; one row running along the mid-line from anteclypeus and falling short of the vertex, with two other rows, one on either side; elsewhere arrangement not clearly defined; antennae four segmented, scape and first three segments hyaline, fourth deep red; hairs stiff with bulbous ends arranged into five rows on first three segments, arrangement on fourth segment not clearly defined.

Thorax

Pronotum and mesonotum similar in colour to head; median longitudinal ecdysial line yellowish brown; a single row of short hairs on anterior and posterior margins of pronotum; metanotum white; no wing pads visible.

Legs

Femora and tarsi hyaline; tibiae with a dull red tinge.

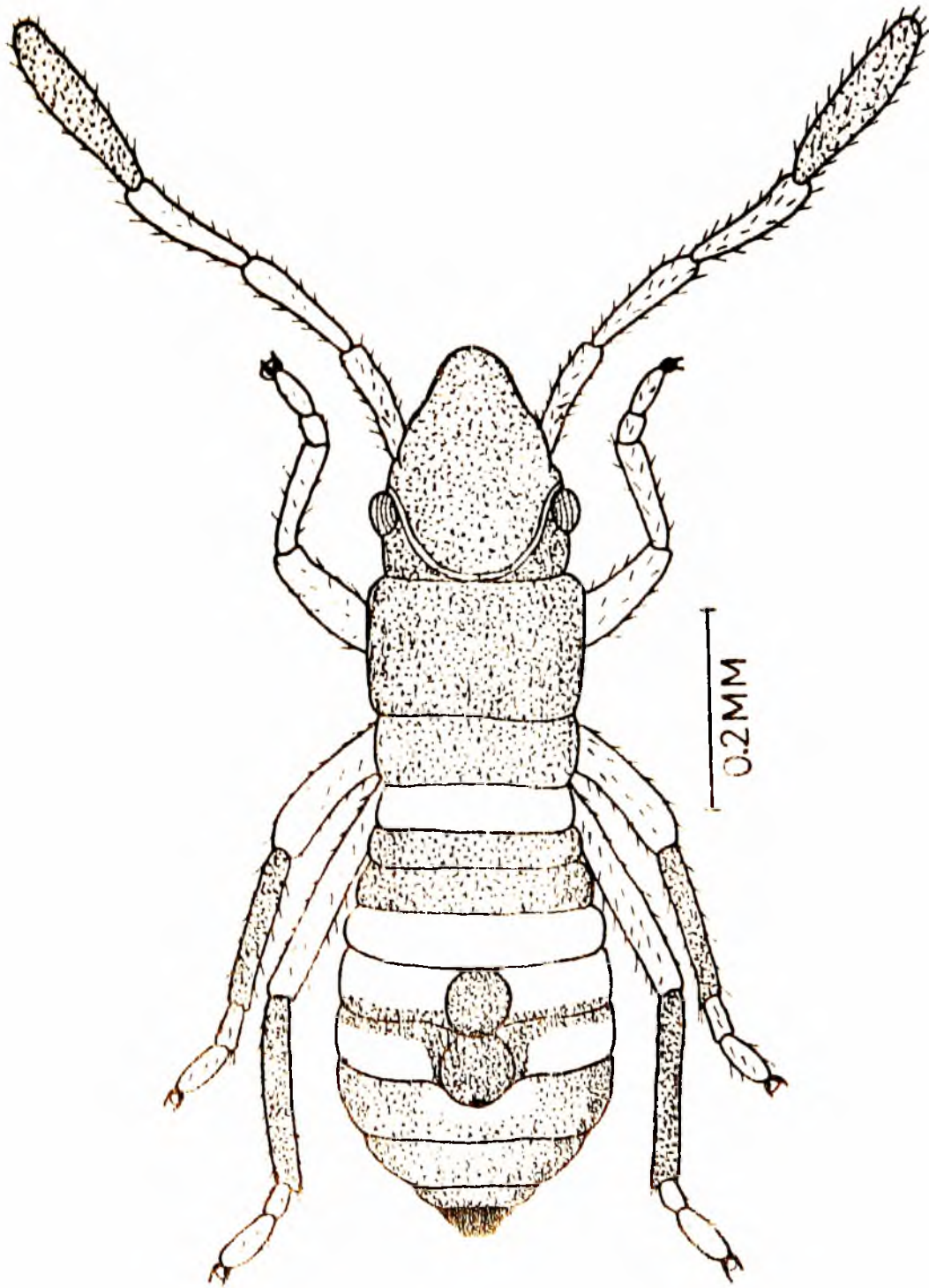


Fig. 3.9: O. fieberi: Larval instar.

104.

Abdomen

Tergum of first segment red; second tergum creamy with a tinge of red; third tergum creamy; last quarter of fourth segment and first quarter of fifth with a deep red tinge forming a red^{band} across the abdomen; 6th - 8th segments cream coloured with a red tinge; 9th and 10th segments black; all abdominal terga with two rows of short stiff hairs sparsely distributed, increasing in length towards their lateral margins; terminal abdominal segments with more pubescence; larval odoriferous glands yellowish brown, visible as round patches situated medially on terga 4 and 5; other features as in O. dudgeoni.

Dimensions

These are given in Table 3.11.

SECOND INSTAR (Fig.3.10)Head

Straw coloured, darker than 1st instar; antennal scape concolorous with head; ecdysial line yellowish brown; eyes deep red, rostrum extends to end of 2nd abdominal segment; apart from dimensions, other features as in 1st instar.

Thorax

Pronotum and mesonotum concolorous with head, metanotum white; median ecdysial line similar to first instar; wing pads visible as small lateral protuberances.

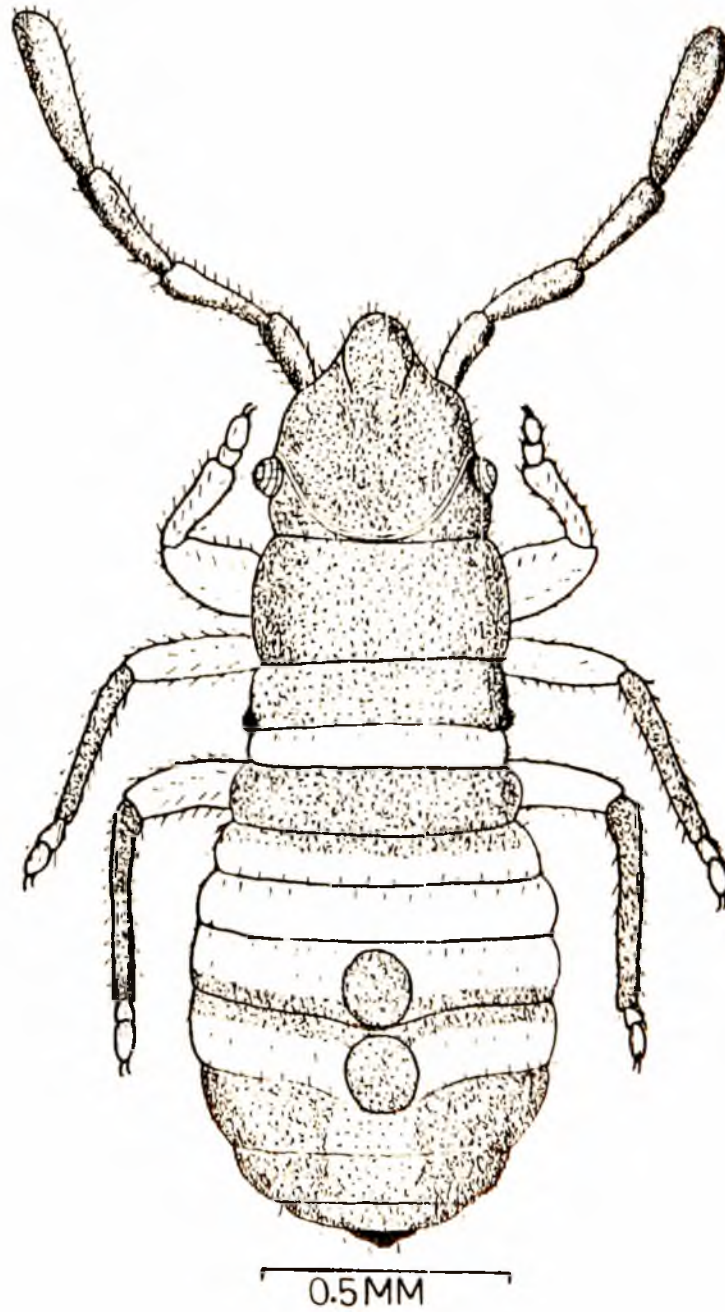


Fig. 3.10: *O. fieberi*: Second instar.

105.

Legs

Excepting dimensions, other features as in first instar.

Dimensions

These are given in Table 3.11.

THIRD INSTAR (Fig.3.11)

Head

Brown; U-shaped ecdysial line straw coloured; eyes reddish brown; antennal scape and first segment concolorous with head; 2nd and 3rd light brown; 4th reddish brown; arrangement of hair as in 1st instar; 1st and 2nd segments of rostrum concolorous with head; 3rd hyaline, proximal third of 4th segment hyaline; distal two-third black; intersegmental sutures black.

Thorax

Pronotum deep brown with light brown median ecdysial line; mesonotum lighter in colour to pronotum; metanotum white; wing pads extend backwards on mesonotum.

Legs

All femora concolorous with head; tibiae brown; tarsi hyaline to white, claws black.

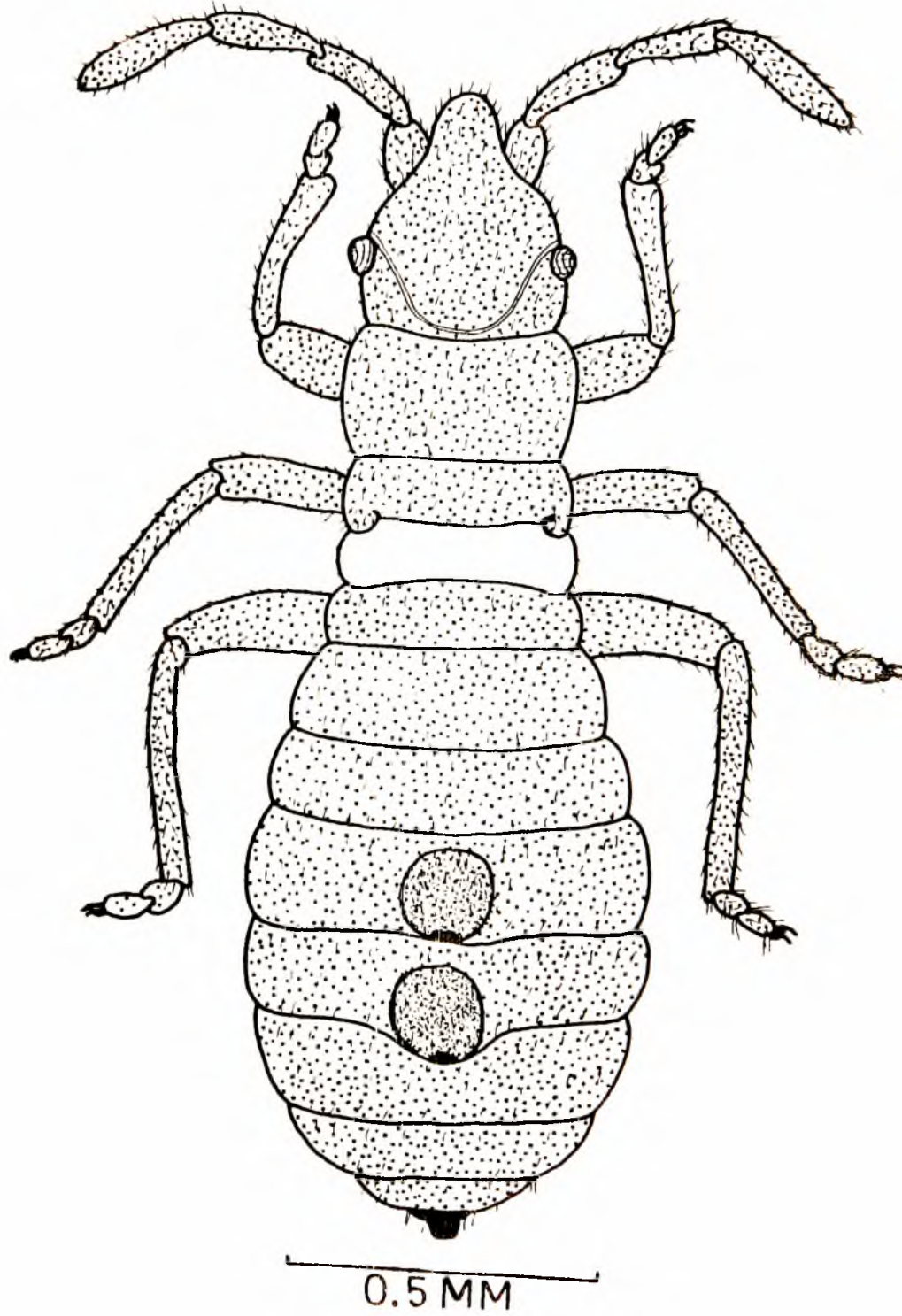


Fig. 3.11: O. fieberi: Third instar.

106.

Abdomen

Segments 1 - 3 deep brown with a shade of green; 4 - 8 deep brown tending to black; 9 and 10 black; each abdominal tergum with two transverse rows of short stiff hairs, particularly conspicuous along the lateral margins; odoriferous glands as in O. dudgeoni.

Dimensions

These are given in Table 3.11.

FOURTH INSTAR (Fig.3.12)

Head

Dark brown to black; ecdysial line brown; eyes dull red; antennal segments 1 - 3 light brown, 4th segment deep brown; arrangement of hair as in 1st instar; segments 1 - 3 of rostrum hyaline, distal three-quarters of fourth segment black, proximal one-quarter hyaline.

Thorax

Pronotum and mesonotum concolorous with head, metanotum white; fore-wing pads extend to proximal half of first abdominal segment, second wing pads closely applied to underside of fore-wing pads.

Legs

All femora and tibiae brown; tarsal segments hyaline to colourless.

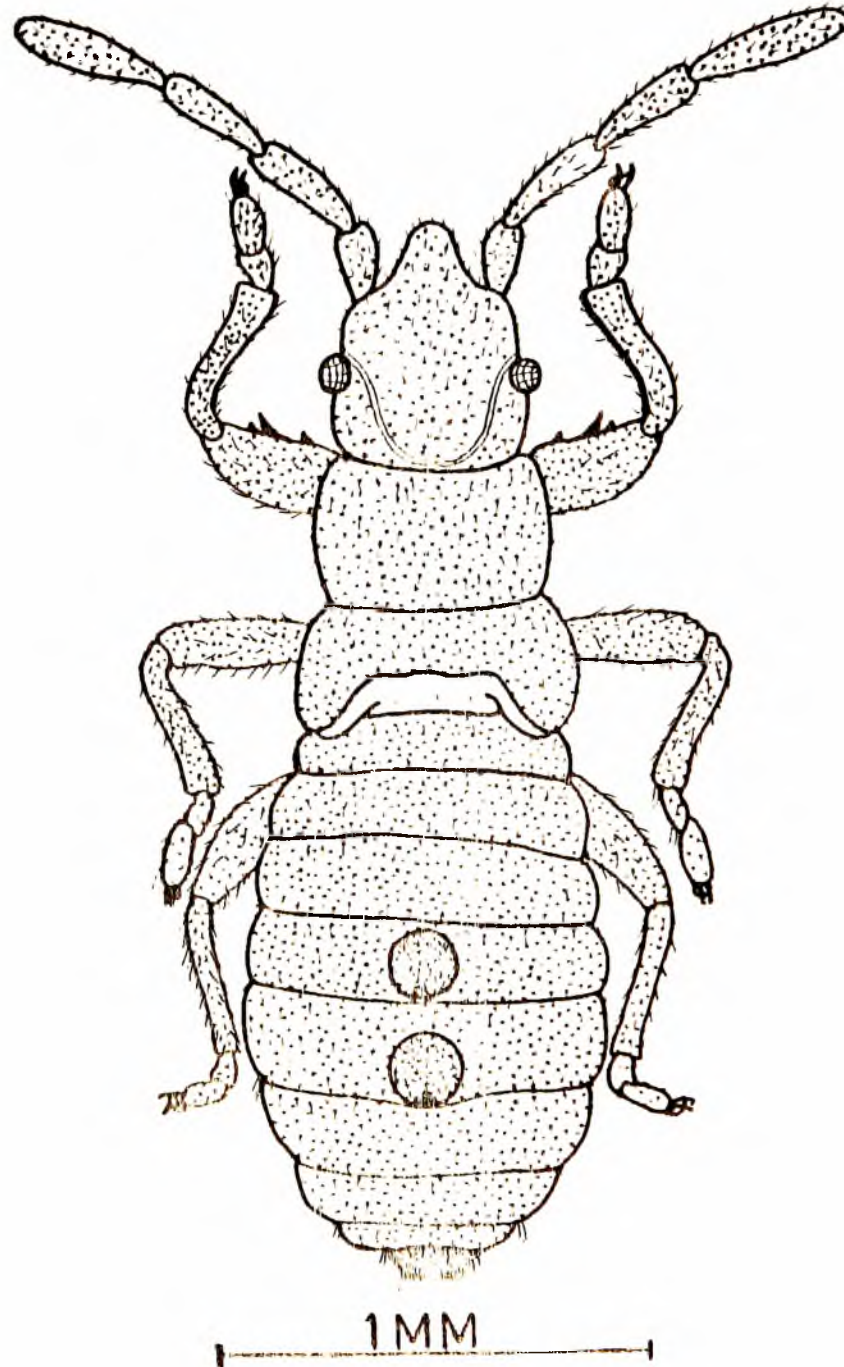


Fig. 3.12: *O. fieberi*: Fourth instar.

107.

Abdomen

Segments 1 - 8 brown, 9 and 10 black; odoriferous glands deep brown; all other features as in 3rd instar; ventral abdomen light brown with a light greenish tinge.

Dimensions

These are given in Table 3.11.

FIFTH INSTAR (Fig. 3.13)Head

Dark brown to black; eyes dull red; all antennal segments concolorous with head; rostrum hyaline with distal half of last segment black.

Thorax

Pronotum, mesonotum and metanotum concolorous with head; a light brown ecdysial suture present medially.

Legs

All femora deep brown; tibiae dark brown; tarsal segments black dorsally, hyaline ventrally; claws black.

Abdomen

Segments 1 - 8 deep brown to black, 9 and 10 black; odoriferous glands deep brown with black sickle shaped orifices between segments 4 - 5 and 5 - 6; all other features as in fourth

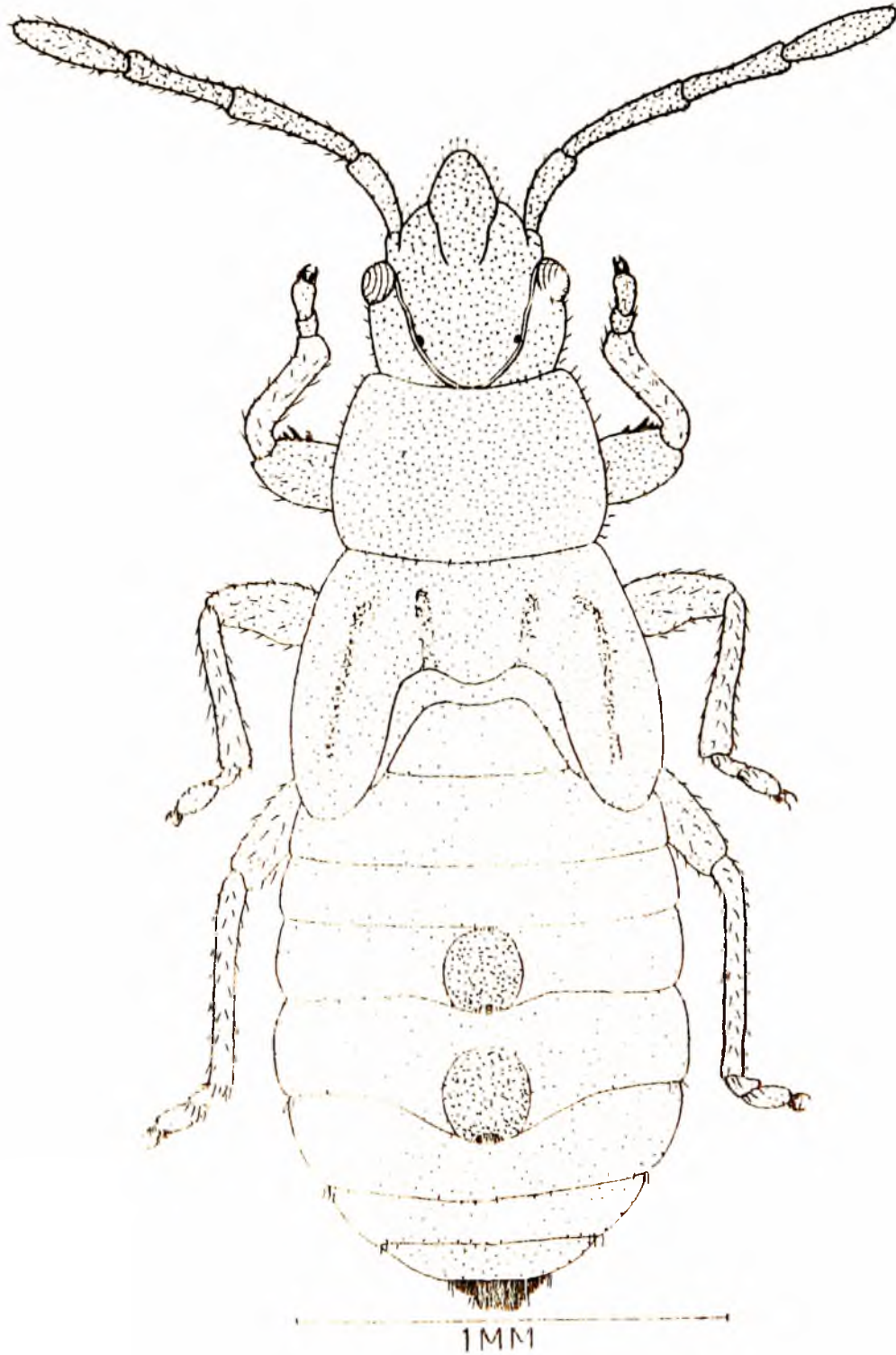


Fig. 3.13: *O. fieberi*: Fifth instar.

108.

instar; ventrally, abdomen deep brown.

Dimensions

These are given in Table 3.11.

ADULT (Fig.3.14)

Description of adult O. fieber^{is} given by Samy (1969).

Dimensions

These are given in Table 3.11.

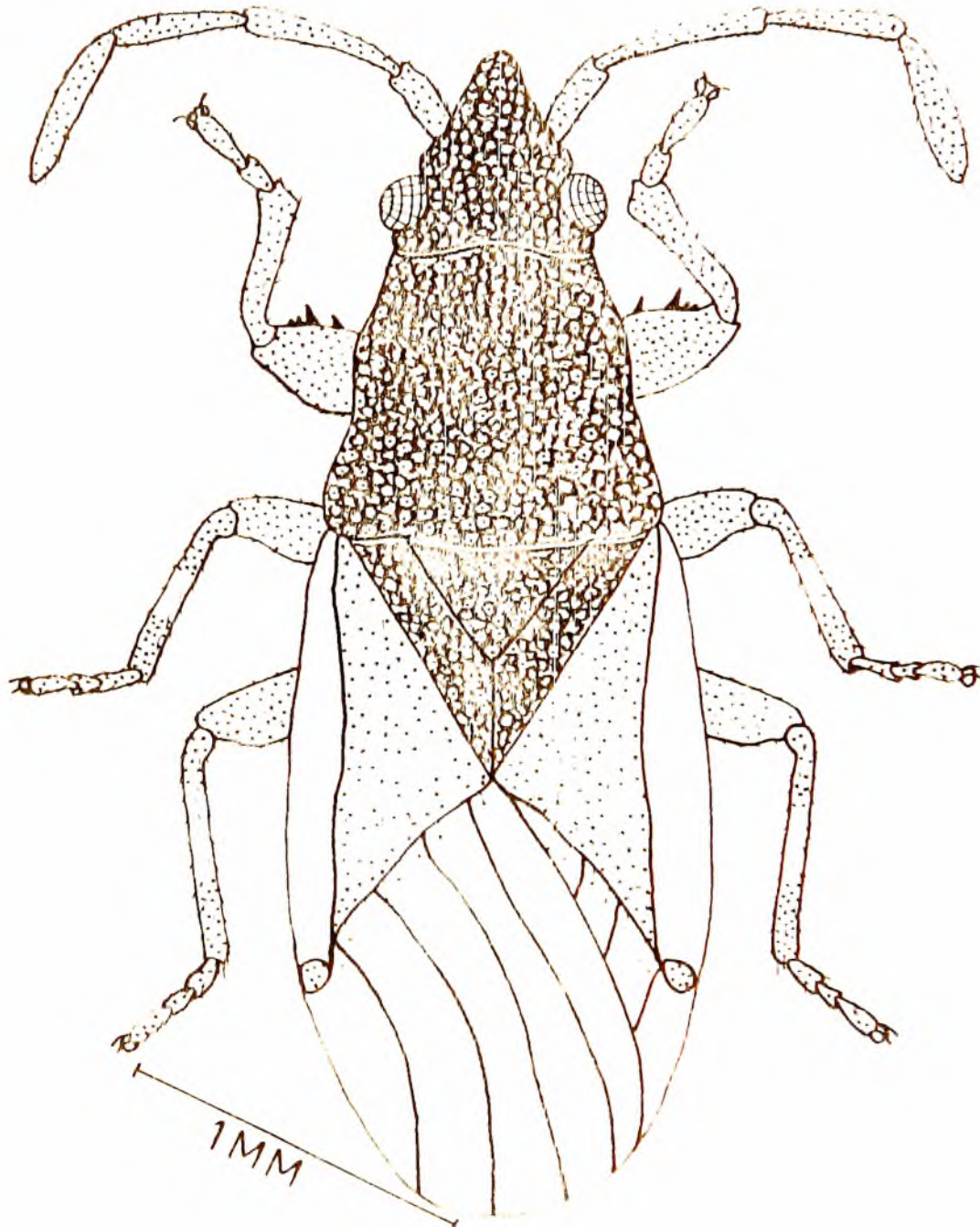


Fig. 3.14: *U. fieberi*: Adult.

109.

Post moulting colour changes in adult *O. fieberi*

Part of the body	Just after emergence	One hour after emergence
Head	Orange	Reddish-brown
Eyes	Deep red	Deep red
Antennal segments 1	All segments Orange	All segments reddish- brown
2		
3		
4		
Rostrum	Hyaline	Hyaline
Pronotum	Orange	Reddish-brown
Wing: Membrane	All parts of wing white	Hyaline
Corium		Red
Clavus		Reddish-brown
Scutellum	Orange	Reddish-brown
Forelegs, Mid- and Hindlegs: Femur	Orange	Reddish-brown
Tibia	Hyaline	Tibiae of mid- and hind legs reddish-brown annulated centrally with white; of forelegs reddish-brown; Tarsi hyaline to white.
Tarsus	Hyaline	

111.

3.3.2.3 Oxycarenum hyalinipennis (Costa).FIRST INSTAR (Fig.3.15)Head

Cream coloured, tending to straw at various places, eyes deep red; U-shaped ecdysial line khaki coloured; rostrum four segmented, first three segments hyaline, tip of fourth segment with a black tinge; hairs on head short and stiff with bulbous ends and their arrangement as in O. fieberi; antennae four segmented, first three segments hyaline, fourth deep red, beset with numerous tiny stiff hairs with bulbous ends, arranged into five rows on the first three segments; on the fourth segment, arrangement irregular.

Thorax

Pro- and meso-nota concolorous with head; metanotum white, no wing pads visible.

Legs

All femora concolorous with head; fore tibiae hyaline; mid- and hind tibiae with a tinge of dull red and five rows of hairs; claws black; tarsi hyaline.

Abdomen

First abdominal segment red, 2nd with a tinge of red, 3rd - 4th creamy; 5th - 8th cream coloured with a tinge of red;

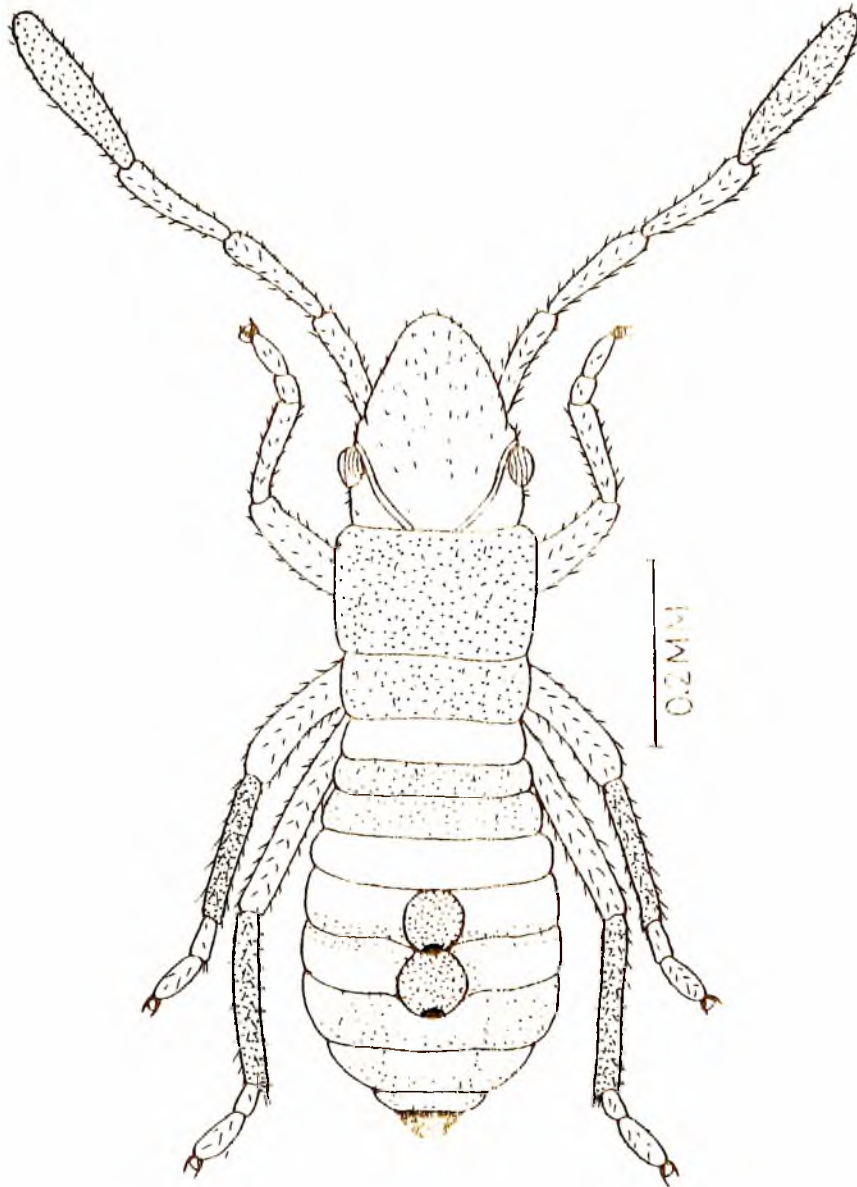


Fig. 3.15: Oxycarenum hyalinipennis (Costa): First instar.

112.

9th - 10th black; two larval odoriferous glands straw coloured situated medially on segments 4 and 5; all other features as in O. fieberi; ventral abdomen creamy tending to straw coloured; a tinge of red conspicuous on 1st and 2nd sternae; ventrally abdomen devoid of pubescence.

Dimensions

These are given in Table 3.12.

SECOND INSTAR (Fig.3.16)

Head

Dark creamy dorsally; eyes deep red; ecdysial line khaki coloured; antennal scape concolorous with dorsal head, first three segments hyaline, fourth deep red; rostrum extends to fourth abdominal segment, other features as in first instar.

Thorax

Pro- and meso-nota similar in colour to head, metanotum white; other features as in first instar; ventrally, thorax creamy, wing pads as in O. fieberi

Legs

All femora creamy tending to khaki; fore tibiae hyaline, mid- and hind tibiae with a dull red tinge; tarsi creamy; claw black.

Dimensions

These are given in Table 3.12.

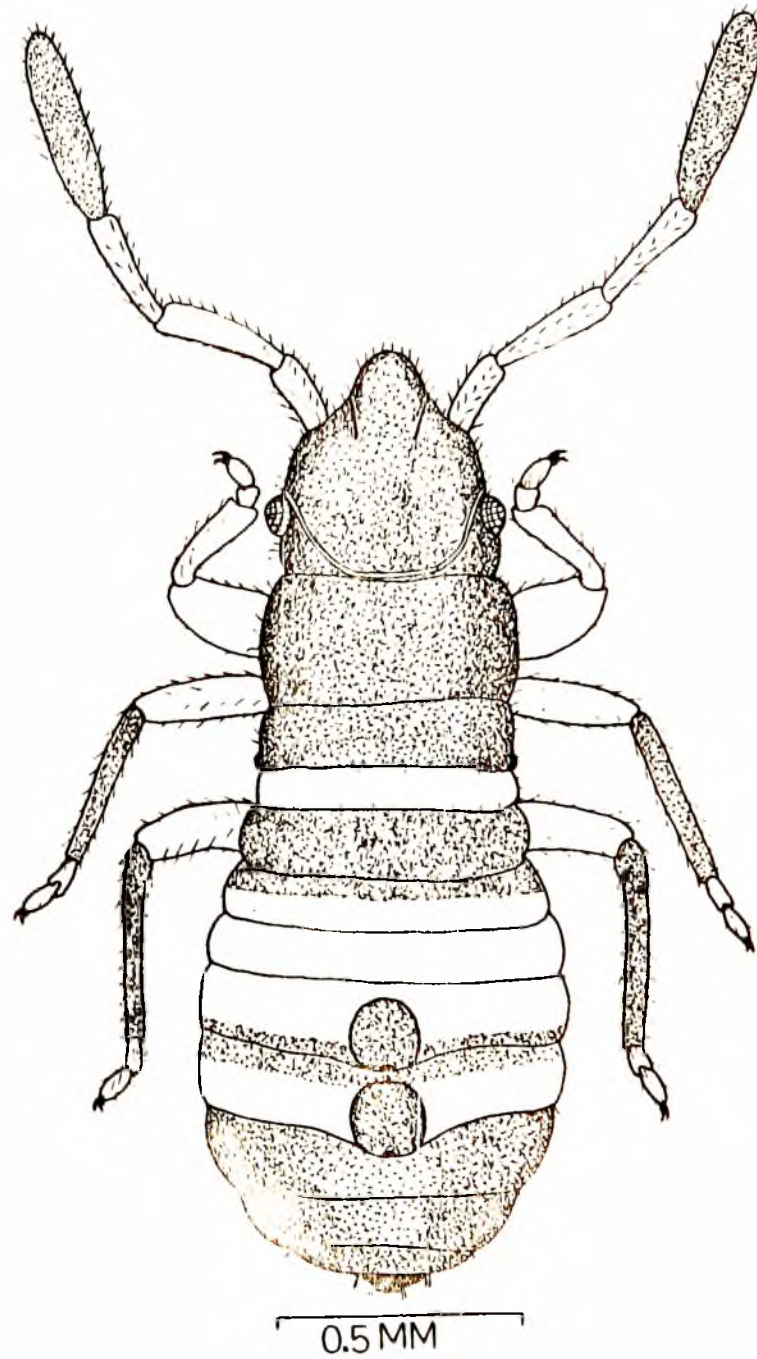


Fig. 3.16: *O. hyalinipennis*: Second instar.

113.

THIRD INSTAR (Fig.3.17)Head

Darker than in second instar; eyes deep red; U-shaped ecdysial line creamy; antennal segments 1 - 3 hyaline, 4th deep red; all other features as in 2nd instar; rostrum extends to 3rd abdominal segment.

Thorax

Pro- and meso- nota similar to head in coloration, metanotum white; wing pads better developed protuberances on the mesonotum.

Legs

All femora concolorous with head; fore tibiae hyaline, mid and hind with a tinge of dull red; tarsi hyaline; claws black.

Abdomen

First abdominal segment red, 2nd segment dark creamy with a tinge of red, 3 - 4 dark creamy with a greenish tinge, 9 - 10 black, others dark creamy with a tinge of red; other features as in 2nd instar; ventrally, abdomen creamy with a shade of red on 1st sternum and on sterna 4 - 8.

Dimensions

These are given in Table 3.12.

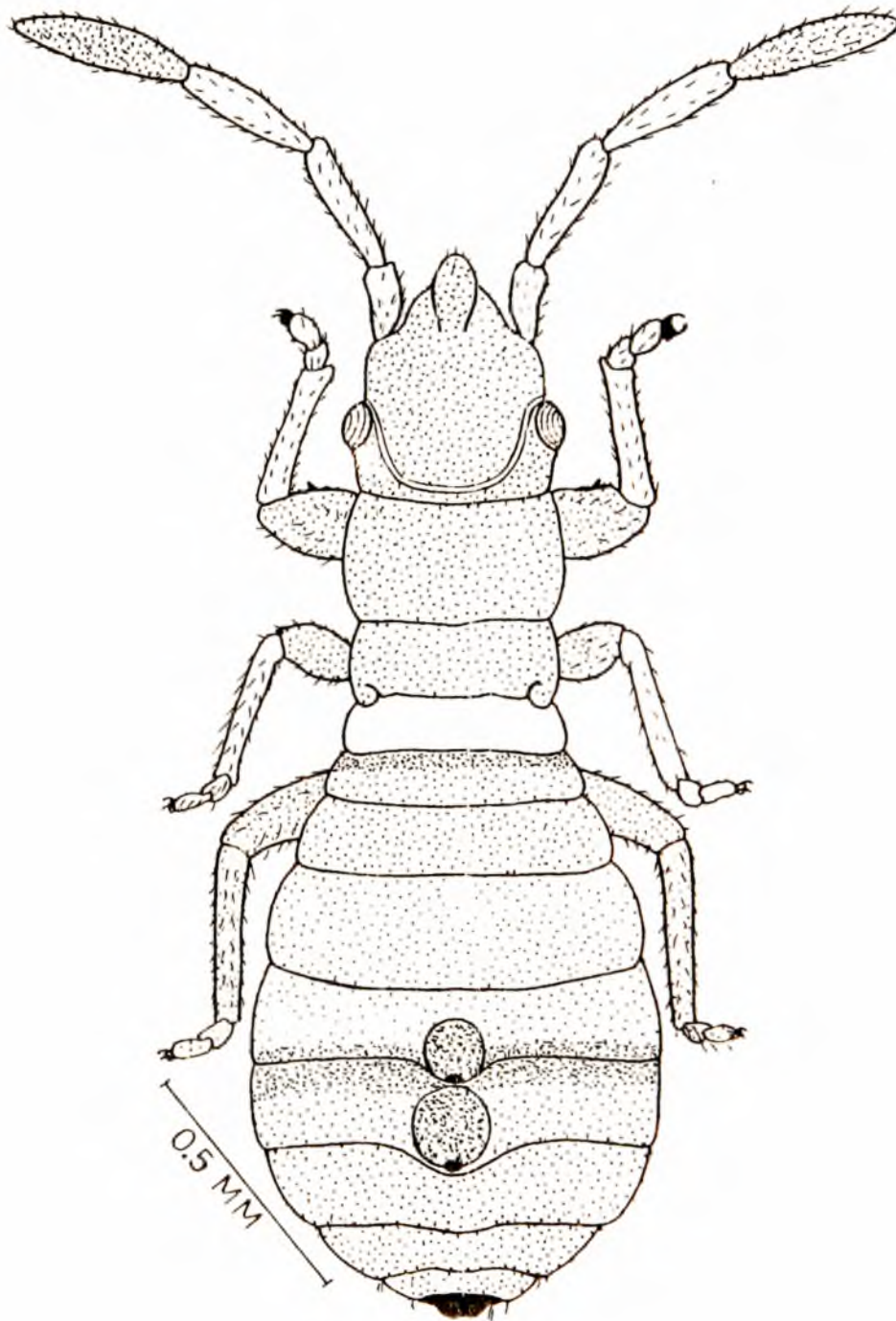


Fig. 3.17: *O. hyalinipennis*: Third instar.

114.

FOURTH INSTAR (Fig.3.18)Head

Deep brown to black; ecdysial line khaki-brown; eyes orange-red; antennal scape and 1st segment similar to head in colour, 2nd and 3rd segments creamy, 4th brownish to black; first three segments of rostrum hyaline, second half of fourth segment black; pubescence as described for first instar.

Thorax

Pronotum concolorous with head, mesonotum brown with a shade of green, metanotum white; wing pads extend over either the whole first abdominal segment or covers only half of it; ventrally, thorax orange.

Legs

All femora brown; front tibiae hyaline, mid- and hind tibiae brown; tarsi hyaline; claws black; arrangement of hairs as in first instar.

Abdomen

Segments 1 - 8 brown with a tinge of green, 9 - 10 black; odoriferous glands as in O. dudgeoni; ventrally, abdomen brown with a greenish tinge.

Dimensions

These are given in Table 3.12.

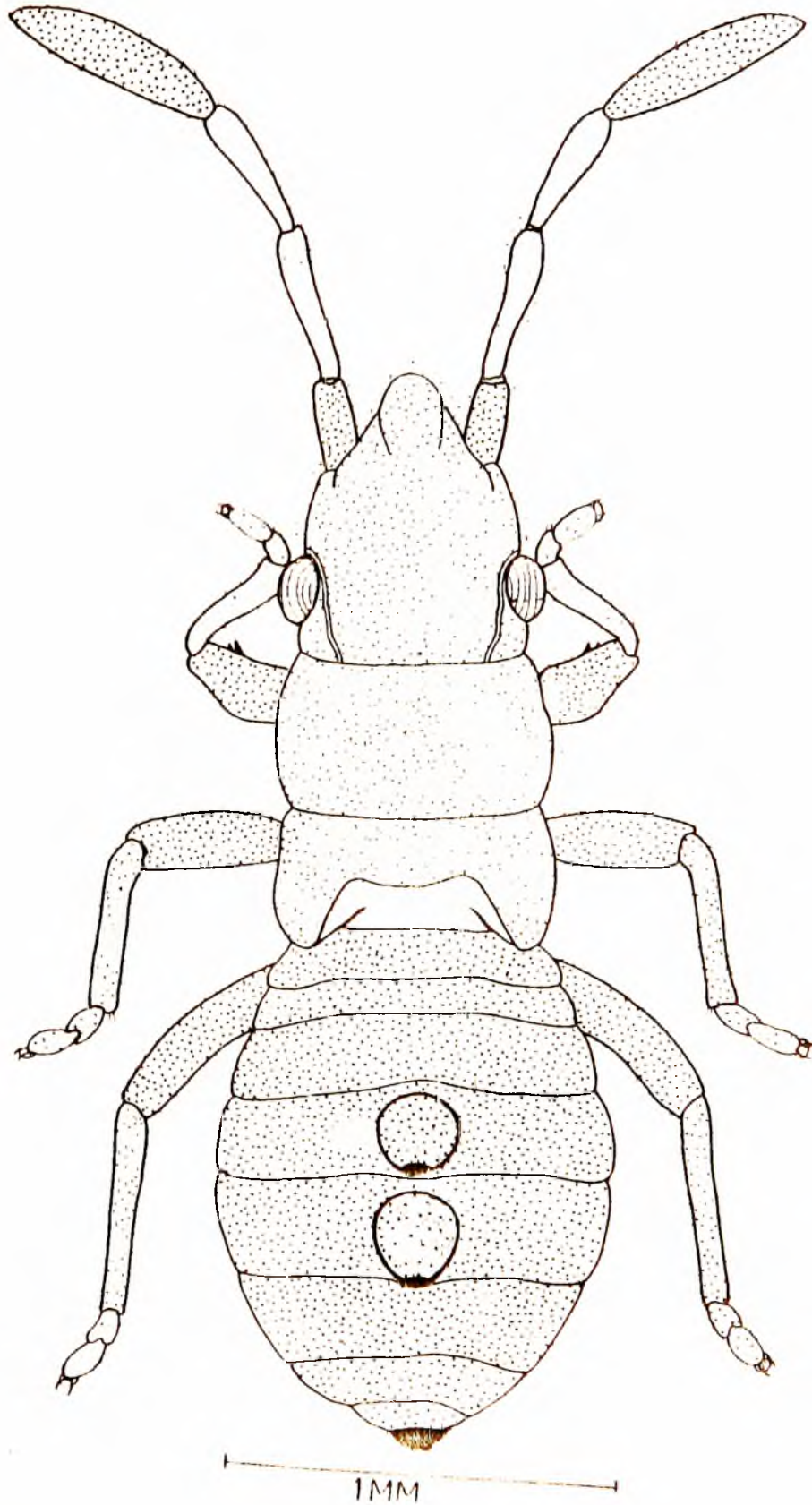


Fig. 3.18: *O. hyalinipennis*: Fourth instar.

115.

FIFTH INSTAR (Fig.3.19)Head

Proximal half of 3rd antennal segment hyaline, distal half black; all other features as in fourth instar.

Thorax

Wing pads extend over either the second or third abdominal segment; other features as in fourth instar; the sexes can be distinguished by the same character as for O. dudgeoni.

Legs and Abdomen

Features as in fourth instar.

Dimensions

These are given in Table 3.12.

ADULTS (Fig.3.20)

Description of adult O. hyalinipennis¹⁵ given by Samy (1969).

Dimensions

These are given in Table 3.12.

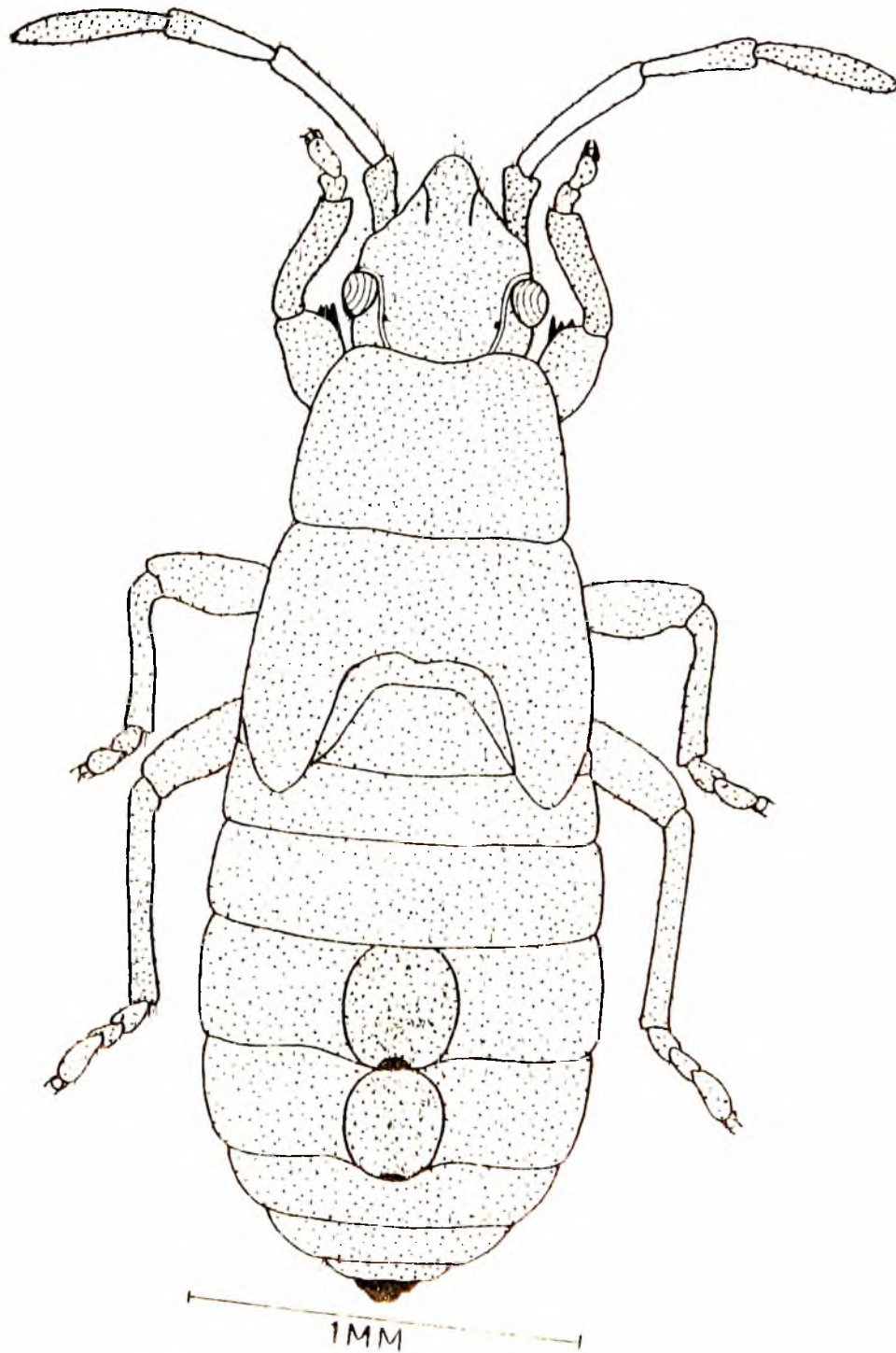


Fig. 3.19: *O. hyalinipennis*: Fifth instar.

116.

Post moulting colour changes in adult O. hyalinipennis

Part of the body	Just emerged	One hour after emergence
Head	Orange-red	Silvery brown
Eyes	Deep red	Deep red
Antennal segments 1	Orange-red	Dark brown to black
2	Hyaline	Prox. half hyaline, distal half brown
3	Hyaline	Dark brown to black
4	Orange-red	Dark brown to black
Rostrum	Hyaline	Hyaline
Pronotum	White with an orange-red tinge	Deep brown to black
Wing	All parts of wing white	Membrane and corium white; clavus white with a tinge of brown
Scutellum	Orange-red	Dark brown to black
Forelegs: Femur	Orange-red	Reddish-brown
Tibia	Hyaline	White
Tarsi	Hyaline	Hyaline
Mid- and Hindlegs	Femora orange-red, other parts hyaline	Femora reddish brown, tibiae dark brown to black at extremities, annulated centrally with white.

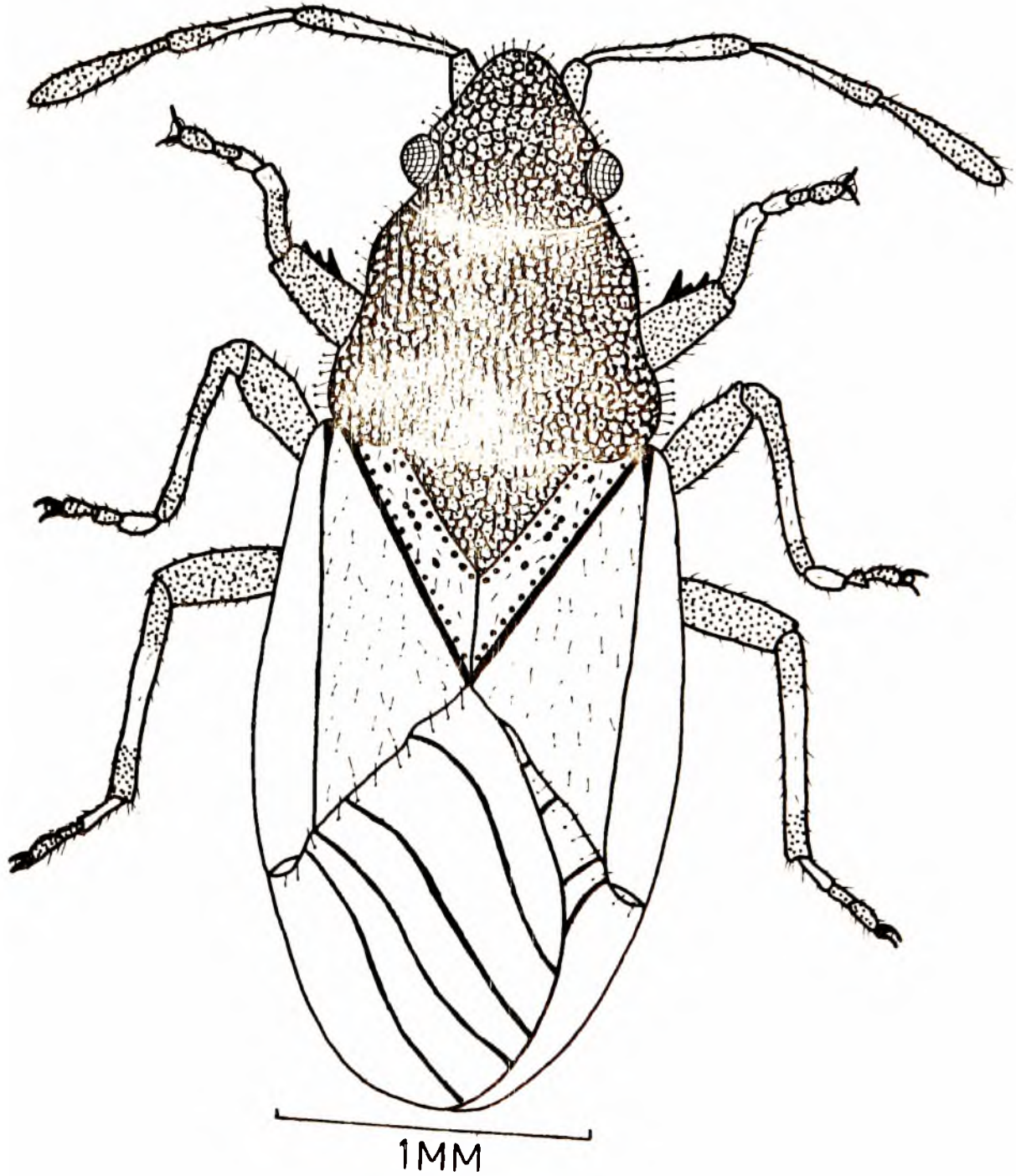


Fig. 3.20: *O. hyalinipennis*: Adult

118.

3.3.3 Key for identification of adults and larvae of Oxycarenius species studied

1. No wing pads visible. Features in all three species similar and indistinguishable 1st instar
Wing pads visible 2
2. Wing pads appear as small lateral protuberances on mesonotum (Figs.3.4, 3.10, 3.16)2nd instar (4)
Wing pads better developed and protrude backwards on mesonotum 3
3. Wing pads as small buds protruding just onto metanotum (Figs.3.5, 3.11, 3.17)3rd instar (6)
Wing pads extending over first abdominal segments or covering anterior half of it (Figs.3.6, 3.12, 3.18)...4th instar (8)
Wing pads extend over abdominal segments 2 - 3 (Figs.3.7, 3.13, 3.19)5th instar (10)
4. First three antennal segments hyaline 5
First three antennal segments with light brown tinge O. fieberi
5. Abdominal segments with a yellowish tinge. Fore tibiae with a reddish tinge dorsally O. dudgeoni
Abdominal segments with a greenish tinge. Fore tibiae hyaline O. hyalinipennis
6. First three antennal segments hyaline 7
First three antennal segments with a light brown tinge O. fieberi
7. Abdomen with a greenish tinge O. hyalinipennis
Abdomen with a yellowish tinge O. dudgeoni

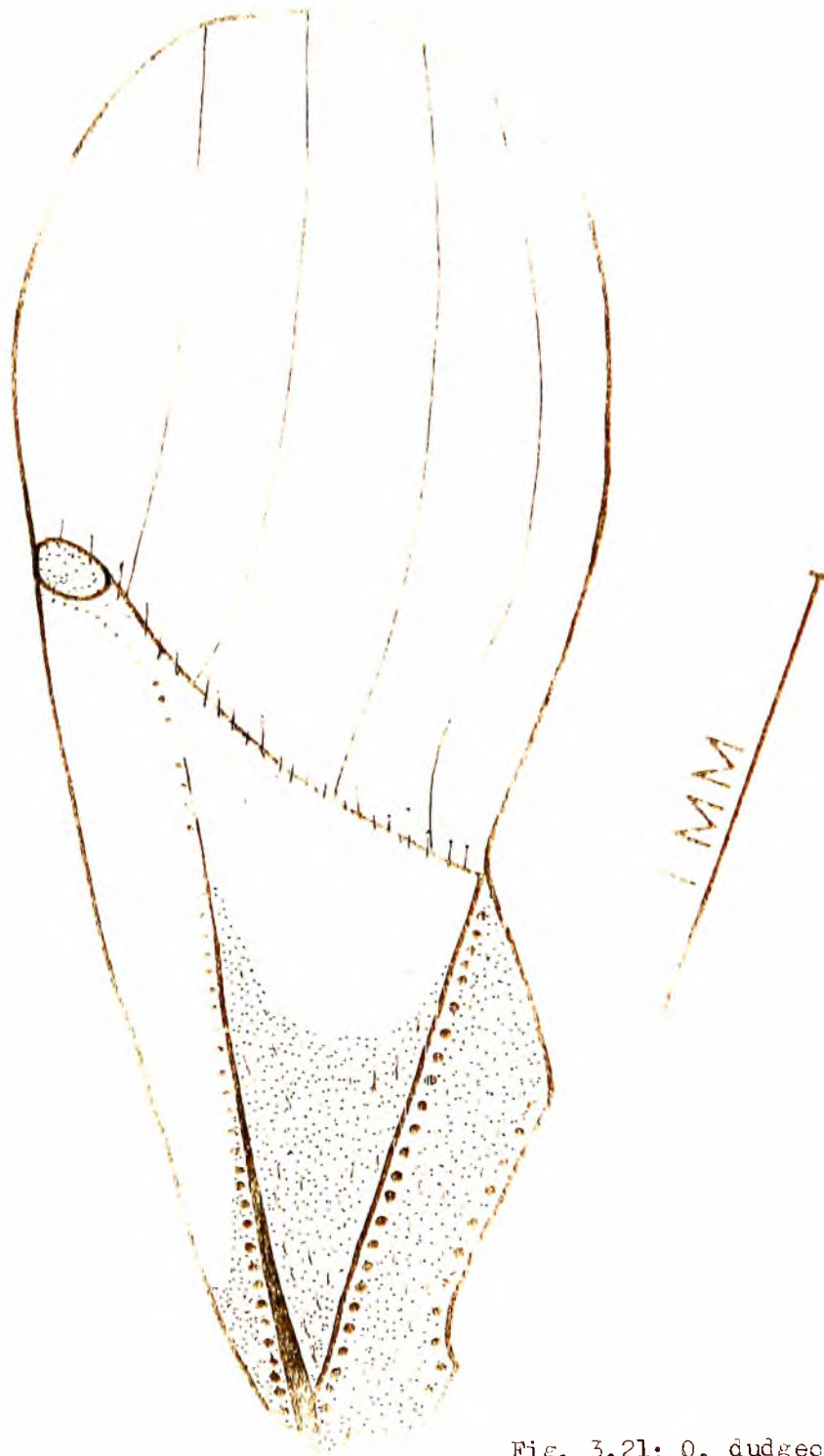


Fig. 3.21: *O. dudgeoni*: Forewing

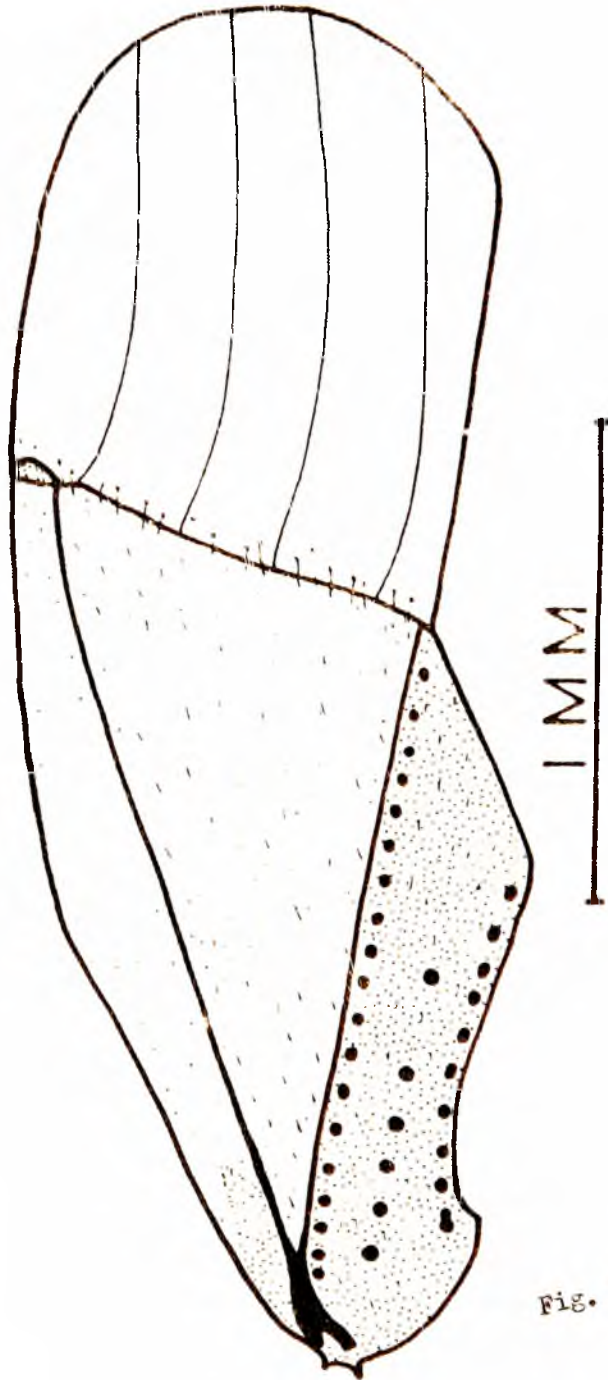


Fig. 3.22: *Q. fieberi*: Forewing

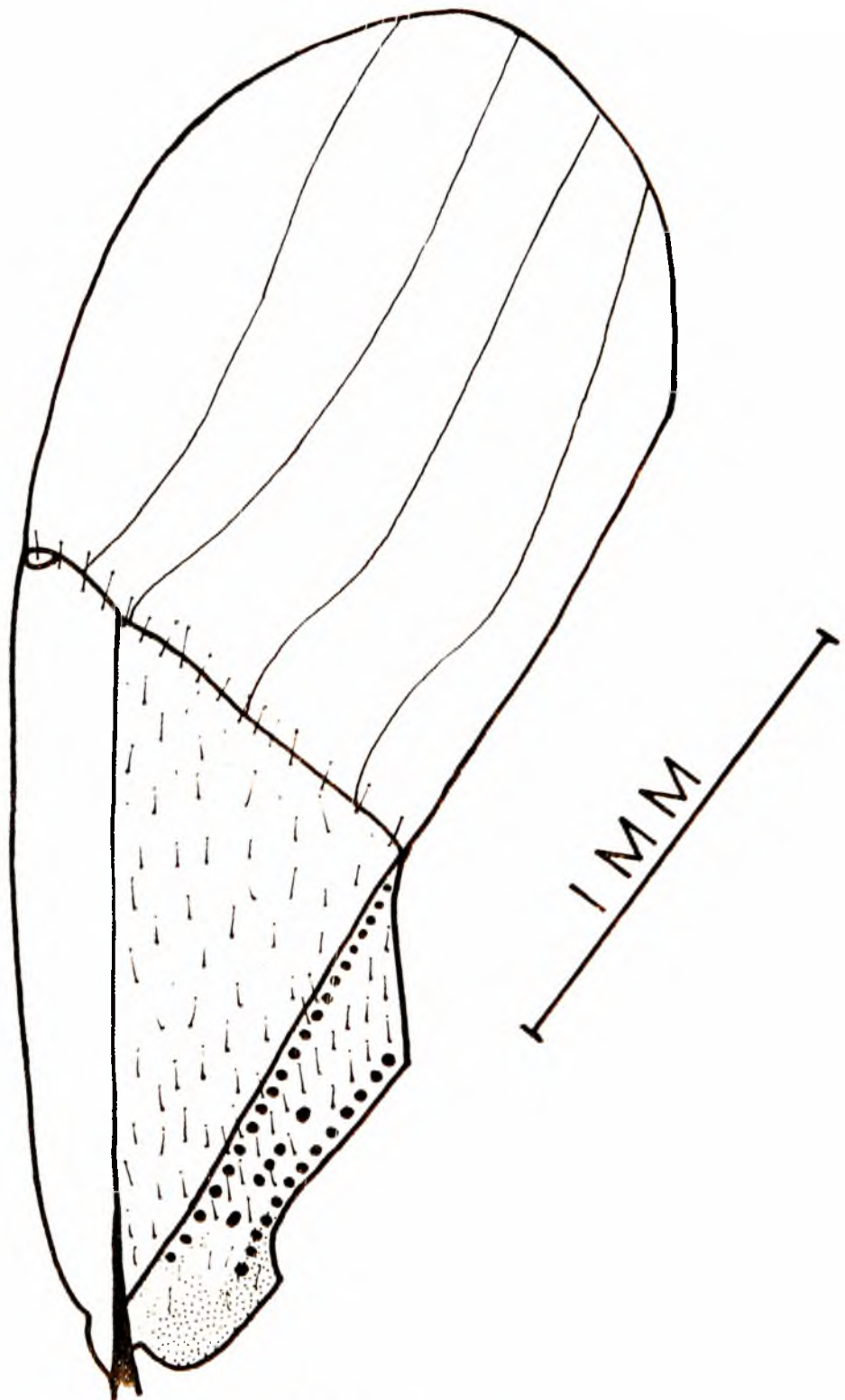


Fig. 3.23: *O. hyalinicennis*: Forewing

119.

8. Antennal segments 2 and 3 brown or black 9
 Antennal segments 2 and 3 hyaline to creamy. Abdomen
 with a greenish tinge O. hyalinipennis
9. Antennal segments 2 and 3 brown, abdomen deep brown
 to black O. fieberi
 Antennal segments 2 and 3 black, abdomen reddish
 brown O. dudgeoni
10. All antennal segments deep brown or black 11
 Antennal segment 2 and proximal half of 3rd segment
 hyaline to creamy O. hyalinipennis
11. Intersegmental sutures of antennae brown O. fieberi
 Intersegmental sutures of antennae hyaline to
 creamy O. dudgeoni

Adults

1. All antennal segments, head and pronotum black 2
 Not as above 3
2. Basal part of corium black, the rest of it hyaline
 or colourless (Fig.3.21) O. dudgeoni
 Black pigment not extending to corium; the latter
 pink or red (Fig.3.22) O. fieberi
3. Antennae with basal portions of segments 2 and 3 light
 brown; pronotum dark brown to black; clavus pale with
 faint brown tinge concolorous with corium (Fig.3.23)....
 O. hyalinipennis

3.3.4

GROWTH PATTERNS

The head widths of all the instars and adults for each of the three species of Oxycarenius were regressed on the duration of each instar (time). The head widths were plotted against time and regression lines were drawn to see how the data fit into the regression equation (Table 3.13 and Figs. 3.24 - 3.26).

The scatter diagrams of head widths and duration of instars for all the three species studied all lie on a sigmoid curve. The calculated regression lines pass through the scatter of the points (Figs. 3.24 - 3.26).

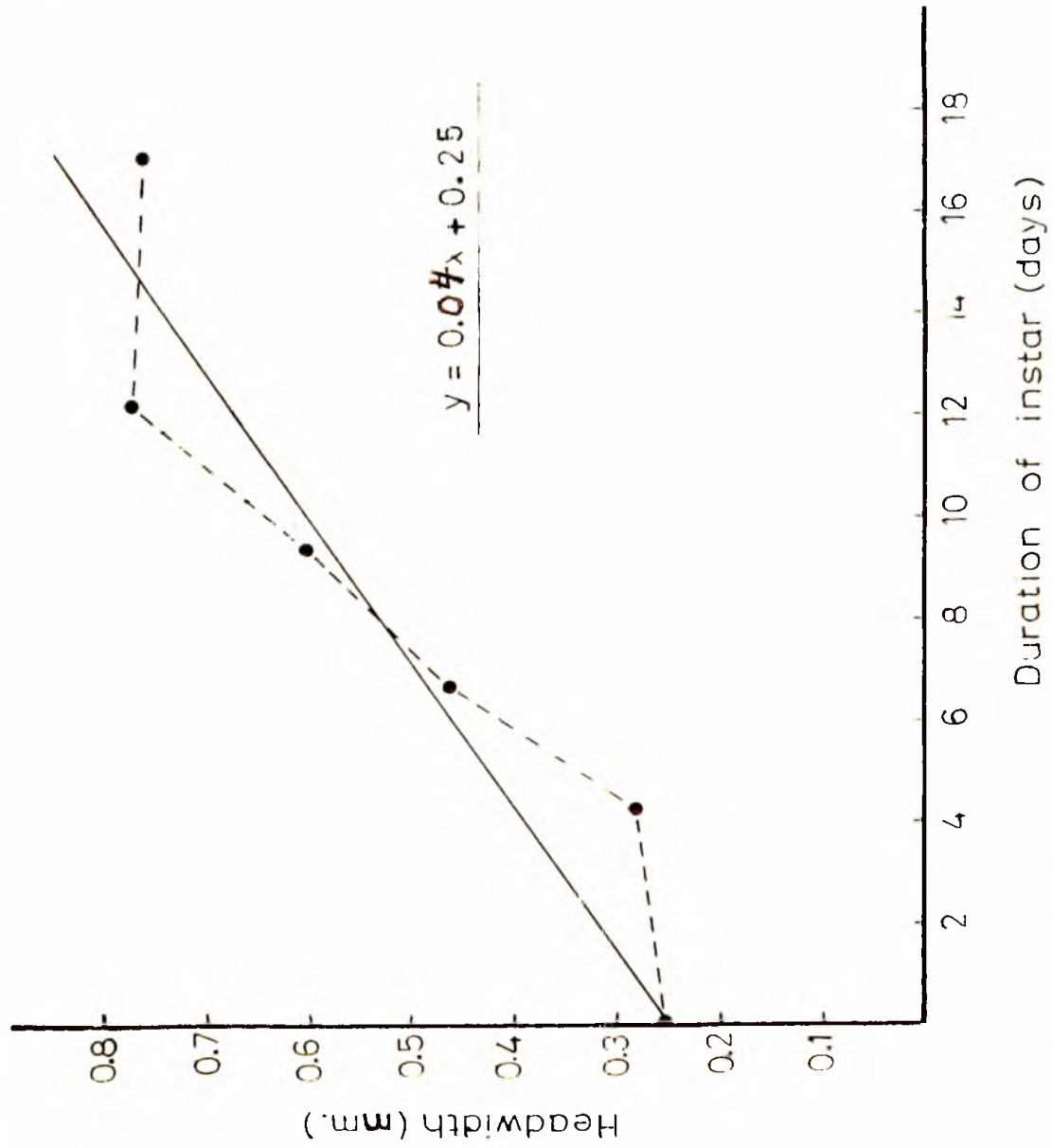


Fig. 3.24: O. dudgeoni: Relationship between measurements of headwidths and duration of instars.

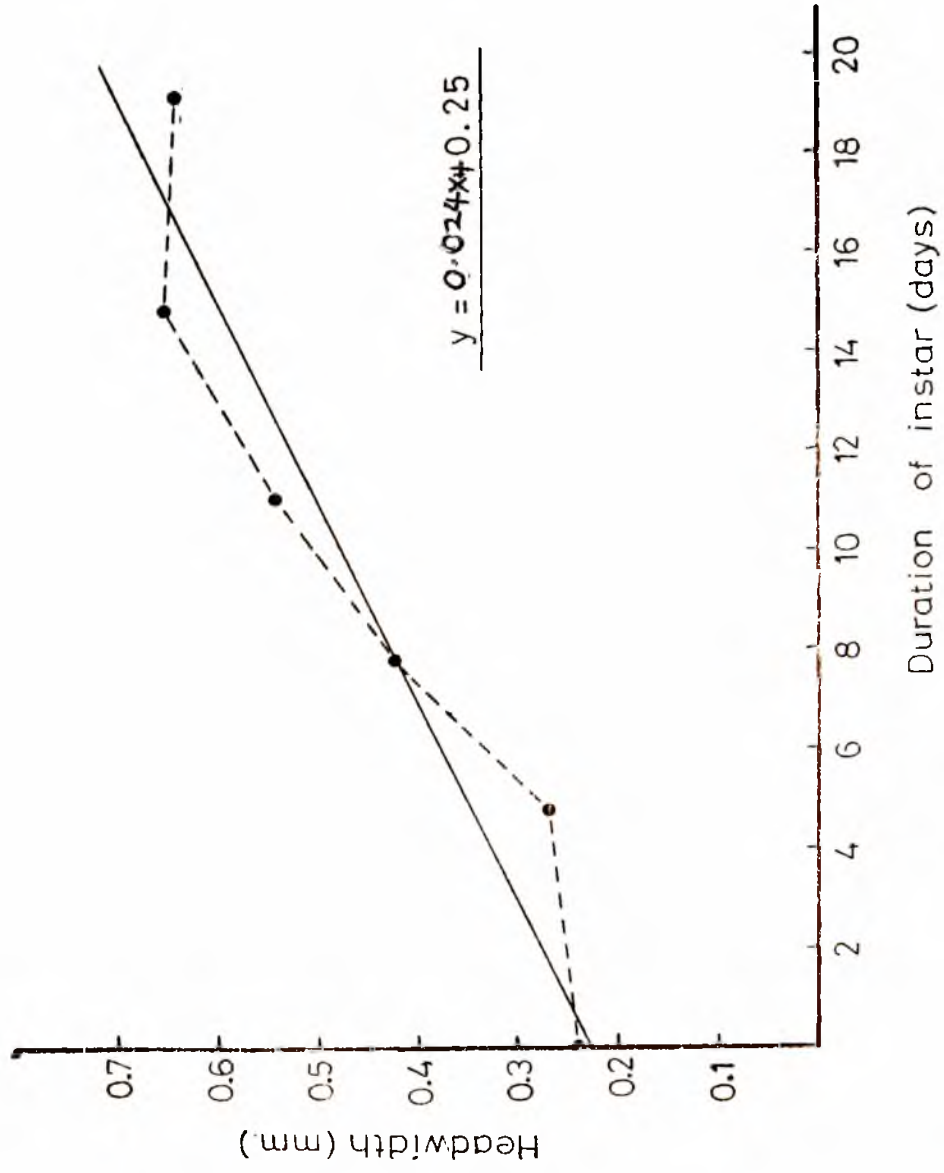


Fig. 3.25: O. fieberii: Relationship between measurements of headwidths and duration of instars.

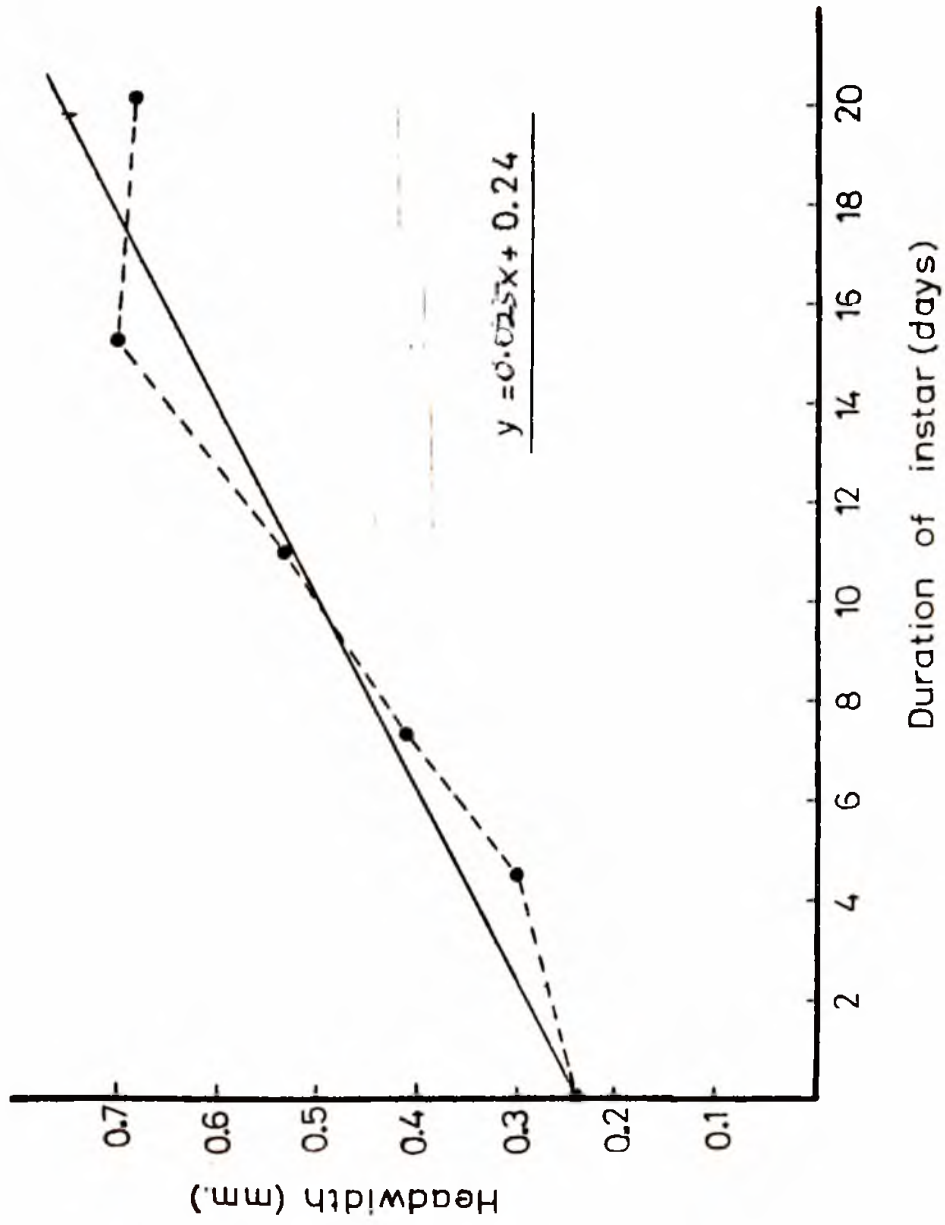


Fig. 3.26: O. hyalinipennis: Relationship between measurements of headwidths and duration of instars.

121.

Table 3.13: Head widths and duration (days) of instars of the three species of Oxycarenus

<u>Species</u>	<u>Stage</u>					
	I	II	III	IV	V	Adult
<u>O. dudgeoni</u>						
Mean head width (mm)	0.25	0.28	0.46	0.60	0.77	0.76
Duration of stage (days)	4.2	2.4	2.7	2.8	4.8	-
Accumulated days	0	4.2	6.6	9.3	12.1	16.9
Regression of y (head width) on x (accumulated days), $y = 0.07x + 0.25$						
<u>O. fieberi</u>						
Mean head width (mm)	0.24	0.27	0.42	0.54	0.65	0.64
Duration of stage (days)	4.8	3.0	3.2	3.8	4.3	-
Accumulated days	0	4.8	7.8	11.0	14.8	19.1
Regression of y (head width) on x (accumulated days), $y = 0.024x + 0.25$						
<u>O. hyalinipennis</u>						
Mean head width (mm)	0.24	0.30	0.41	0.53	0.70	0.68
Duration of stage (days)	4.5	2.8	3.6	4.3	4.9	-
Accumulated days	0	4.5	7.3	10.9	15.2	20.1
Regression of y (head width) on x (accumulated days), $y = 0.025x + 0.24$						

3.3.5 Relationship Between Measurements of Successive Instars of Oxycarenius species

Dyar (1890) has observed a relationship between the head widths of successive instars of Lepidopterous larvae, and that successive measurements form a geometrical progression, bearing a constant ratio to one another. The application of this rule serves to discover whether an instar has been overlooked. Przibram and Megusar (1912) gave a theoretical progression factor of 1.26 for insects in general and suggested that the number of body cells is normally doubled at each moult. Przibram's factor was applied to the head widths of all stages of the three species of Oxycarenius. The mean growth ratios are given in Table 3.14, and in every case do not equal the theoretical progression factor.

123.

Table 3.14: Mean growth ratios of all stages of the three species of Oxycarenus

Instars and their head widths	S p e c i e s		
	<u>O. dudgeoni</u>	<u>O. fieberi</u>	<u>O. hyalinipennis</u>
$\frac{2nd}{1st}$	$\frac{0.28}{0.25} = 1.12$	$\frac{0.27}{0.24} = 1.13$	$\frac{0.30}{0.24} = 1.25$
$\frac{3rd}{2nd}$	$\frac{0.46}{0.28} = 1.64$	$\frac{0.42}{0.27} = 1.55$	$\frac{0.41}{0.30} = 1.37$
$\frac{4th}{3rd}$	$\frac{0.60}{0.46} = 1.30$	$\frac{0.54}{0.42} = 1.29$	$\frac{0.53}{0.41} = 1.29$
$\frac{5th}{4th}$	$\frac{0.77}{0.60} = 1.28$	$\frac{0.65}{0.54} = 1.21$	$\frac{0.70}{0.53} = 1.32$
$\frac{Adult}{5th}$	$\frac{0.76}{0.77} = 0.99$	$\frac{0.64}{0.65} = 0.98$	$\frac{0.68}{0.70} = 0.97$
Mean	1.27	1.27	1.24

3.4

DISCUSSIONMating behaviour

Studies by many authors, including Mitchell and Mau (1969) on Nezara viridula L. and Mukerji and Le Roux (1965) on Podisus maculiventris (Say) (both pentatomids), have shown that the males are polygynous and the females polyandrous, and that during mating the males are more aggressive than the females. Similar observations have been made by Smith (1927) on the Rutherglen bug, Nysius vinitor Berg. (Lygaeidae), Andre (1934) on the Milkweed bug, Oncopeltus fasciatus (Dallas) (Lygaeidae), Johnson (1942) on the Bed bug, Cimex lectularius L. (Cimicidae), Khalifa (1950) on Rhodnius prolixus Stål (Reduviidae) and by Louis (1974) on the Harpactorinae (Reduviidae). It seems, therefore, that many Heteroptera exhibit this behaviour which is also seen in Oxycarenus.

The mating posture adopted by Oxycarenus ensures free movement by the pair. Although the female trailed the male during copulation, the latter was not passive but also moved in unison with the female as though both were parts of a single insect. Dislocation of the male genitalia did not therefore occur since no stress was involved. When disturbed sufficiently, the need may arise to disengage for each to make a quick dash to safety, and this they do.

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Oviposition

Oviposition behaviour in insects is varied and is adjusted mostly to specific requirements and living conditions of the larvae (Engelmann, 1970). In Oxycarenus, egg laying habits vary. While some members of the genus lay eggs in batches, others lay singly. Species which lay single eggs on one host plant may lay clustered eggs under different conditions. Whichever behaviour adopted depends on the condition of the substrate available for oviposition. This is reflected in the ability or otherwise to stick the ovipositor into the medium in an attempt to conceal the eggs. In O. dudgeoni, eggs were scattered singly among the kapok fibers but when damp cotton wool was used as egg laying substrate, the gravid female inserted the ovipositor into the mass of cotton wool and eggs were laid in clusters. In O. fieberi and O. hyalinipennis, eggs were retained in the abdomen until death if the substrate provided was dry cotton wool; but from damp cotton wool, clusters of eggs were retrieved. Under natural conditions in the field, O. dudgeoni lays single eggs in kapok while O. hyalinipennis ^{and O. fieberi} lay anything from single eggs to as many as 25 eggs per batch.

Michalk (1935) classified the eggs of Heteroptera based on their oviposition sites into ten categories. These divisions were criticized by Leston (1953) as being too narrow and cutting

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right across family barriers, as well as being artificial from an ecological perspective. Oviposition sites have been correctly grouped into four broader categories by Southwood (1956) based on their relationship to the environment. Clustered eggs in Oxycarenum are deposited in a condition described by Southwood (1956) as "semi-exposed". Included in this category are some Cydnidae, most other Lygaeidae, Pyrrhocoridae, most Reduviidae and some Miridae, notably Stroglylocoris. Laying eggs singly is obviously more advantageous than laying in masses since a single egg is exposed to the same hazards that a whole mass may collectively encounter (Louis 1974). In "semi-exposed" eggs, there is a consequent reduction in effect of atmospheric hazards, predation as well as parasitism. The egg chorion is normally thin and unpigmented, with numerous short micropylar processes.

While the white secretion serves only to glue the eggs to the substratum in Oxycarenum, there are other bugs belonging to the Harpactorinae (Reduviidae) in which groups of eggs are totally covered by the secretion. This has been considered by Cohen^b (1968) as an approach towards formation of an ootheca, and according to this author, the extent of glue production has some taxonomic value. It seems, however, that the formation of an ootheca without an adequate protective cover as seen in the Harpactorinae (Reduviidae) is of doubtful

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value, since it exposes several eggs collectively to the hazards that a single egg might normally encounter (Louis 1974).

Moulting

During the period of moulting, the insect is in a helpless condition and at the mercy of other members of the same species or other insects with cannibalistic tendencies, as well as environmental conditions such as the drying effects of the sun. The bright colours, usually orange, associated with newly moulted insects do not blend with the immediate surroundings and render them easy targets for predators. The new skin is soft and can be pierced by the rostrum of would be predators. In crowded or starved cultures, cannibalism during moulting is more often encountered and groups of "predators" aggregating and sucking fluid from newly moulted individuals become common. In the field, more cast skins are found on the underside of leaves than on exposed surfaces. This is believed to be a means of avoiding both the sun's rays and to avoid predators, mainly reduviid bugs. One hour search in the field for cast skins revealed 71 skins of which 59 were on the underside: a correlation significant by inspection.

Colour changes associated with moulting are remarkable. Parts of the body which later assume various colorations are

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initially cream coloured in newly hatched larvae. Parts which are hyaline, the rostrum, for example, remain so throughout the development of the insect. The eyes are orange to deep red. The fourth antennal segment is reddish brown until the third instar, and then assumes a deep brown or black colour in later instars and the adult. The dorsum is always darker than the venter and with more pubescence.

The ventral ecdysial lines in Diptera as suggested by Hinton (1963, p.56) probably function as hinges "that facilitate the outward movement of the two halves of the head when the dorsal ecdysial line splits". In Oxycarenum, the ventral ecdysial lines and the area enclosed by them (gula) appear lighter both in colour and texture in the shed cuticle and probably function in a manner suggested by Hinton (1963).

Parental care

Parental care is known in several families of Heteroptera but is absent in Oxycarenum. Groups such as Oncomerinae, Natalicorinae, Cydnidae, Scutelleridae and Acanthosomatidae (all Pentatomoidea) show varying degrees of maternal care which has been reported as a primitive feature by Coben^b (1968) and Kumar (1969).

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Cannibalism

While attempting to rear nymphs of Oxycarenum, a cannibalistic tendency was observed. Nymphs were seen sucking haemolymph from the bodies of their sibs which were especially vulnerable to attack whilst moulting. This tendency was on the increase in crowded or starved colonies of the bugs. Egg cannibalism was also observed in egg laying females. Contents of freshly laid eggs were seen to be sucked up completely, leaving empty chorions. Odhiambo (1957) observed two caged female Oxycarenum sucking 22 of the eggs they had laid, leaving only one to hatch. Although Oxycarenum are considered to be phytophagous, such cannibalistic tendencies are thought to be employed to supplement their protein and water requirements when these fall short, as for example, in crowded cultures. In addition, it can be envisaged as serving a natural means of population control.

Aggregation

Youdeowei (1966), after extensive work on aggregation of feeding Dysdercus intermedius Distant, concluded that olfactory receptors were involved in the location of the seeds prior to feeding. Four types of sensory receptors were identified and were all borne on the terminal antennal segments. The same number of sensory receptors has been reported for

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the antennae of D. fasciatus Signoret (Madge, 1965) and Rhodnius prolixus (Wigglesworth and Gillet, 1934). Miles (1958) showed that in Dindymus versicolor H. Sch. (Heteroptera: Pyrrhocoridae), chemoreceptors were confined to the antennal tip whereas in Oncopeltus fasciatus Dallas (Lygaeidae) and Nezara viridula (L.) (Pentatomidae), chemoreceptors occurred on the antennae and on the tarsi.

Although olfactory responses aided location of the food, it was the visual responses that demonstrably led to the formation of aggregation (Youdeowei 1966). Intimate physical contact was maintained between individuals in an aggregation, so that insects have a great tolerance for one another. This tolerance is also exhibited in aggregation of land isopods (Allee 1926) and Nebria brevicollis (F.) (Greenlade 1964), being an important factor in maintaining aggregations (Youdeowei 1966). Withycombe (1924) suggested that the appreciable increase in numbers of D. howardii Ballou on cotton plants depended on a volatile substance given off from the inside of the bolls. More recently, Saxena (1965) showed that D. koenigii (F.) began feeding on cotton seeds in response to stimulation from lipids. These observations indicate that cotton seeds contain an "arrestant" or a "feeding stimulant" or both, (Dethier et al 1960). From results of the three experiments on aggregation, it becomes apparent that Oxycarenus

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like other seed feeding bugs, responds to the chemical stimuli from the seeds with the help of the antennae, more specifically the 4th segment. The nature of the stimuli remains work for the future.

The importance of social aggregation in phytophagous insects is best appreciated when it is noted that severe damage to crops results from local action of aggregated individuals.

Microclimate

It was said earlier that the three species of Oxycarenus are found in sympatric association on Sida sp. and Abutilon sp. in the savanna localities. It is to be added here that O. dudgeoni has a micro-habitat during the period when kapok from Ceiba pentandra is available. The high temperature recorded inside the masses of kapok (Fig.3.2) confers micro-climatic conditions on the adult and all the developmental stages.

Wing pads

The development of wing pads is an interesting feature in the heteroptera. In the present study, the mesonotal wing pads were found to make their appearance in the second instar as

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dle of the lateral margins of the mesonotum. Similar examples are seen in Tessaratomidae (Kumar 1969) and Pentatomidae (Decoursey and Esselbaugh, 1962). Kumar and Ansari (1974) reported that amongst the Cimicomorphan heteroptera, in the Bryocorinae (mirids), the mesonotal wing pads are well developed in the third larval instar, generally reaching the posterior ends of the mesonotal pads. On the other hand, in the family Reduviidae, the mesonotal pads are but slightly developed in the third instar.

In Pyrrhocoridae the pattern of wing pad development exhibits remarkable differences. Fuseini and Kumar (1975) reported the absence of wing pads in the first two instars. Mesonotal wing pads make their appearance as tiny structures in the third instar and develop greatly in the fourth instar reaching about the posterior end of the first abdominal tergum. In the fifth instar, both the meso- and metanotal wing pads extend to the third abdominal segment. A similar pattern of wing pad development is also seen in Physopelta famelica Stål^o (Heteroptera: Largidae), though in the third instar they are even more poorly developed. Other examples of a similar pattern of wing pad development are found in Phaenacantha australiae Kirkaldy (Colobathristidae), a family which is considered by some authors (Kumar 1967) to belong to Lygaeidae, and also in Dieuches notatus (Dallas) (Lygaeidae).

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Study of the development of wing pads in other groups of Heteroptera is undoubtedly desirable as it might prove helpful in an adequate assessment of the significance of the differences in the extent of development of wing pads in different group of Heteroptera.

Growth patterns

Richards (1949), working on some grasshoppers, Chorthippus
(Zetterstedt) parallelus (Acrididae) and Locusta migratoria
(Reiche and Fairmaire) (Solitaria), noted that there was some regular relationship between measurements of the instars taking into account variations in their developmental periods. Fuseini and Kumar (1975) noted a similar pattern in cotton stainers (Heteroptera: Pyrrhocoridae) in Ghana. In the present work, a similar pattern was noted. An explanation of the sigmoid curve is that growth in early and late stages of development is slower than in the middle stages.

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SUMMARY

1. Biology of the Oxycarenus species found in Southern Ghana was studied.

2. Oxycarenus hyalinipennis was found to be a species of the Guinea savanna vegetation of the Northern Ghana and also ranges along the coastal forest-savanna mosaic belt of the Central Region and in the dry savanna of the Accra plains. Old extensive clearings in the forest zone were also found to be colonized. O. dudgeoni is a forest species with a range co-extensive with that of the Tropical African forest. Its occurrence in the forest-savanna interface was attributed to the occurrence of the feral host plant Ceiba pentandra in these areas. O. fieberi is a common bug of clearings in the forest zone and the derived savanna areas which were once forest.

3. Host plants of O. fieberi and O. hyalinipennis are limited to the Malvaceae. On the other hand, O. dudgeoni was found to colonize Malvaceae, Sterculiaceae, and Bombacaceae. The principal feral host plant of O. fieberi was found to be Sida acuta; of O. hyalinipennis, Abutilon mauritianum; and of O. dudgeoni, Ceiba pentandra.

4. Malvaceous host plants flower throughout the year, while Sterculiaceae and Bombacaceae flower at particular

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periods of the year. A succession of colonization of host plants, governed by host preference and seasonal changes in host plant fruiting was found.

5. Some host plants were found to be preferred to others. O. dudgeoni prefers cotton to Sida acuta; cotton and Ceiba pentandra are equally preferred. However, Ceiba and Abutilon were equally preferred when these seeds were offered together. For O. fieberi, cotton was preferred to Abutilon and Sida was preferred to Abutilon, while Sida and cotton, Sida and Ceiba and Ceiba and cotton enjoyed equal preferences. O. hyalinipennis prefers cotton to Abutilon and Sida. Abutilon and Sida are equally preferred, and cotton and kenaf (Hibiscus cannabinus) are also equally preferred. In all the species of Oxycarenus studied, cotton is either preferred or enjoys equal preference with their principal feral host plants. A shift over from their wild host plants to cotton plantations should readily commence when cotton is grown on large scale in Southern Ghana. It is suggested that to cut down the incidence of Oxycarenus species, all wild host plants should be destroyed before cotton plantations are established.

6. Populations of adults and larvae of Oxycarenus were found to exhibit fluctuations but no single factor appeared

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to be solely responsible. However, the most important parameters identified were rainfall, humidity, and the physiological state of the host plants, which was reflected in the quantity of dry seeds available at any particular period.

7. O. dudgeoni, which enjoys a wider range of host plants, proved to be more mobile than both O. fieberi and O. hyalinipennis. In addition, O. dudgeoni in kapok was found to enjoy a greater ability for dispersal in all stages as well as inhabiting micro-climatic conditions.

8. Precopulatory behaviour, mating, moulting and hatching were studied. The egg and egg burster are described. Oviposition preferences were established. The life cycles of all three species were followed in the laboratory.

9. The immature stages of all the three species of Oxycarenus are described, and their growth ratios studied. Keys are constructed to distinguish between larvae and adults of all the three species studied.

10. A definite relationship was found to exist between measurements of the instars and variations in the durations of their development.

11. Few parasites and predators attack Oxycarenus in Ghana. Egg parasitism was never observed.

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5.

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6.

R E F E R E N C E S

- Allee, W.C., 1926: Studies in animal aggregations - causes and effects of bunching in land isopods. J. Exp. Zool. 45, 255-277.
- * Anderson, T.J., 1927: Ann. Rept. Dept. Agric. Kenya (1926), 135-147.
- Andre, F., 1934: Notes on the biology of Oncopeltus fasciatus (Dallas). Iowa State Coll. J. Sci. 9, 73-87.
- * Anonymous, 1922: J. Dept. Agric. Union S. Afr. Pretoria, 4, No.3, 208.
- Aryeetey, E.A. and Kumar, R., 1973: Structure and function of the dorsal abdominal gland and defence mechanism in cocoa - capsids (Miridae: Heteroptera). J. Ent. (A), 47 (2), 181-189.
- Ballou, H.A., 1919: Cotton and the Pink Bollworm in Egypt. West Indian Bulletin, Barbados 17, No.4, 250.
- Beck, S.D., Edwards, C.A. and Medler, J.T., 1958: Feeding and nutrition of the milkweed bug, Oncopeltus fasciatus (Dallas). Ann. Ent. Soc. Amer. 51, 283-288.
- Bedford, H.W., 1923: The pests of cotton in the Anglo-Egyptian Sudan. Wellcome Tropical Research Laboratories, Entom. Sect. Bull., No.19.
- Brindley, M.D.H., 1929: On the repugnatorial glands of Corixa. Trans. Ent. Soc., London, 77, 7-13.
- Brown, E.S., 1951: The relation between migration-rate and type of habitat in aquatic insects, with special reference to certain species of Corixidae. Proc. Zool. Soc. London, 121, 539-545.
- Butler, E.A., 1923: "A biology of the British Hemiptera - Heteroptera". (H.F. and G. Witherby: London), 1-682.

140.

- Calam, D.H. and Scott, G.C., 1969: The scent gland complex of adult cotton stainer bug, Dysdercus intermedius. J. Insect Physiol. 15, 1695-1702.
- Carayon, J., 1958: Etudes sur les Hemipteres. Cimicoidea 1. Mem. natn. Hist. nat. (Zool.), Paris, 26, 141-172.
- Cobben, R.H., 1968: Evolutionary trends in Heteroptera; Part 1. Eggs, architecture of the shell, gross embryology and eclosion. Centre for Agricultural Publishing and Documentation, Wageningen, 1-465.
- Cotterell, G.S., 1928: Cotton pests of Southern British Togoland and Trans-Volta District. Bull. Dept. Agric. Gold Coast, No.12, 42 pp.
- Davis, N.T. and Usinger, R.L., 1970: The biology and relationships of Joppeicidae (Heteroptera). Ann. Ent. Soc. Am. 63, 577-587.
- Decoursey, M.R. and Esselbaugh, C.O., 1962: Descriptions of the nymphal stages of some North American Pentatomidae (Hemiptera-Heteroptera). Ann. Ent. Soc. Am. 55, 323-342.
- Del Guercio, G., 1918: Oxycarenum hyalinipennis, a Hemipteron injurious to cotton in Italian Somaliland. Agricoltura Coloniale, Florence, 12, No.13, 147-166.
- Dethier, V.G., 1954: Evolution of feeding preferences in phytophagous insects. Evolution, 8, 33-54.
- Dethier, V.G., Browne, L.B. and Smith, C.N., 1960: The designation of chemicals in terms of the responses they elicit from insects. J. Econ. Ent., 53, 134-136.

141.

- Dingle, H., 1972: Migration strategies in insects. Science, 175, 1327-1335.
- Duviard, D., 1972: Le vols migratoires des Dysdercus voelkeri Schmidt (Heteroptera: Pyrrhocoridae) en Cote d'Ivoire. Coton Fibr. trop., 27, 379-388.
- Dyar, H.G., 1890: The number of moults of Lepidopterous larvae. Psyche, 5, 420-422.
- Engelmann, F., 1970: The physiology of insect reproduction. International series of monographs in pure and applied Biology, Vol.44, 1-307.
- Entwistle, P.F., 1972: Pests of cocoa. Tropical Science Series, Longman, 1-779.
- Eyles, A.C., 1963: Descriptions of the immature stages of five Rhyparochrominae (Heteroptera: Lygaeidae). Trans. Soc. Br. Ent. 15, 277-294.
- Eyles, A.C., 1964: Feeding habits of some Rhyparochrominae (Heteroptera: Lygaeidae) with particular reference to the value of natural foods. Trans. R. Ent. Soc. Lond., 116 (5) 89-114.
- Fieber, F.X., 1837: Bietrage zur Kenntniss der Schnabelkerfen IV. Families Lygaeoidea. Beitr. ges. Natur-U. Heilwissenschaft 1, 337-355.
- Forsyth, J., 1966: Agricultural insects of Ghana. Ghana Universities Press, 1-163.
- Fraenkel, G.S. 1959: The raison d'etre of secondary plant substances. Science, 129, 1466-1470.
- Frings, H. and Piessner, L., 1952: Substitutes for milkweed seeds in the rearing of milkweed bugs. J. Econ. Ent., 45-752.

142.

- Frings, H., Frings, M. and Little, F., 1957: Peanuts as substitute food for the large milkweed bug. J. Econ. Ent. 50, 363-364.
- Froggatt, W.W., 1901: "Notes on Australia Hemiptera", Agric. Gaz., N.S.W., Misc. Publ., 538, 1-10.
- Fuseini, B.A. and Kumar, R., 1975: Ecology of cotton stainers (Dysdercus spp., Heteroptera; Pyrrhocoridae) in Southern Ghana. Biol. J. Linn. Soc., 7, No.2, 113-146.
- Geier, P.W., 1960: Physiological age of codling moth females (Cydia pomonella L.) caught in bait and light traps. Nature, Lond., 185-709.
- Gibbs, D.G. and Leston, D., 1970: Insect phenology in a forest cocoa-farm locality in West Africa. J. Appl. Ecol., 7, 519-548.
- Gowdey, C.C., 1912: An account of insects injurious to economic products and their control. Dept. Agric., Entebbe (Uganda) (1912), 11-12.
- Greenslade, P.J.M., 1964: Further notes on aggregation in Carabidae (Coleoptera), with special reference to Nebria brevicollis (F.). Entomologist's Mon. Mag., 99, 109-114.
- Gulde, J., 1902: Die Dorsaldrusen der Larven der Hemiptera-Heteroptera. Ein Beitrag zur Kenntnis desselben. Ber. Senckenburgh nat. Ges. a.M., 1902, 85-136.
- Haine, E., 1955: Aphid take-off in controlled wind speeds. Nature, Lond., 175, 474-475.

143.

- Harris, H.V., 1936: Annotated list of insects injurious to cotton in Tanganyika. Bull. Ent. Res. Lond. 27, 523-528.
- Hinton, H.E., 1963: The ventral ecdysial lines of the head of endopterygote larvae. Trans. R. Ent. Soc. Lond., 115, 39-61.
- Hutchinson, J. and Dalziel, J.M., 1954-1958: Flora of West Tropical Africa; 2nd ed., edited by R.W.J. Keay, Lond., Crown Agents, 1-828.
- Institut National pour l'Etude Agronomique du Congo, 1963: Flore du Congo du Rwanda et du Burundi 10, 1-352.
- Johnson, C.G., 1942: The ecology of the Bed-bug Cimex lectularius L. in Britain. Report in Research 1935-1940. J. Hyg. Camb., 41, 345-461.
- Johnson, C.G., 1963: Physiological factors in insect migration by flight. Nature, Lond., 198, 423-427.
- Johnson, C.G., 1969: "Migration and Dispersal of insects by flight". Methuen & Co., London, 1-763.
- Keay, R.W.J. (Ed.), 1959: Vegetation map of Africa South of the tropic of Cancer. London, O. U. P.
- Kehat, M. and Wyndham, M., 1973: Flight activity and displacement in the Rutherglen bug Nysius vinitor (Hemiptera: Lygaeidae). Aust. J. Zool. 21, 413-426.
- Kehat, M. and Wyndham, M., 1974: Differences in flight behaviour of male and female Nysius vinitor Bergroth (Hemiptera: Lygaeidae). J. Aust. Ent. Soc., 13, 27-29.
- Kennedy, J.S., 1961: A turning point in the study of insect migration. Nature, Lond., 189, 785-791.
- Kennedy, J.S. and Booth, C.O., 1963: Free flight of aphids in the laboratory. J. Exp. Biol. 40, 67-85.
- Khalifa, A., 1950: Spermatophore production and egg-laying behaviour in Rhodnius prolixus Stal (Hemiptera: Reduviidae) Parasitology, 40, 283-289.

144.

- Kirkpatrick, T.W., 1923: The Egyptian cotton seed bug, (Oxycarenus hyalinipennis (Costa)). Its bionomics, damage and suggestions for remedial measures. Bull. Minist. Agric. Egypt. Tech. Scient. Serv., 35, 107 pp.
- Kullenberg, B., 1946: Studien über die Biologie der Capsiden. Zool. Bidr. 23, 1-522.
- Kumar, R., 1966: Studies on the biology, immature stages and relative growth of some Australian bugs of the superfamily Coreoidea (Hemiptera: Heteroptera). Aust. J. Zool. 14, 895-991.
- Kumar, R., 1967: Aspects of the morphology and relationships of the superfamilies Lygaeoidea, Piesmatoidae and Pyrrhocoroidea (Hemiptera: Heteroptera). Entomologist's Mon. Mag., 103, 251-261.
- Kumar, R., 1969: Morphology and relationships of the Pentatomoidae (Heteroptera). IV. Oncomerinae (Tessaratomidae). Aust. J. Zool., 17, 553-606.
- Kumar, R. and Ansari, A.K., 1974: Biology, immature stages and rearing of cocoa capsids (Miridae: Heteroptera). Zool. J. Linn. Soc., 54, No.1, 1-29.
- Lea, A.O. and Niswander, R.E., 1950: Oncopeltus fasciatus reared for laboratory testing on watermelon seeds. J. Econ. Ent., 43, 386.
- Leston, D., 1953: The eggs of Tingidae (Hem.) especially Acalypta parvula (Fallen). Ent. Mon. Mag., 89, 132-134.
- Leston, D., 1954: Notes on Cryptosemmatidae. Ent. Mon. Mag., 89, 115-117.
- Leston, D., 1970: The identity and pest potential of Oxycarenus spp. (Hem: Lygaeidae) in Ghana. Bull. Ent. Res., 60, 285-289.

145.

- Leston, D. and Scudder, G.G.E., 1956: A key to the families of British Hemiptera - Heteroptera. Entomologist, 89, 223-231.
- Louis, D., 1974: Biology of Reduviidae on cocoa-farms in Ghana. Amer. Nat., 91, 68-89.
- Madge, D. S., 1965: The responses of Cotton Stainers (Dysdercus fasciatus Sign.) to relative humidity and temperature and the location of their hygrosensors. Entomologia Exp. Appl., 8, 135-152.
- Michalk, O., 1935: Zur Morphologie und Ablage der Eier bei den Heteropteren sowie über ein System der Eiablagetypen. Dtsch. Ent. Z., 1935, 148-175.
- Miles, P.W., 1958: Contact chemoreception in some Heteroptera, including chemoreception internal to the stylet food. J. Insect. Physiology, 2, 338-347.
- Mitchell, W.C. and Mau, R.F.L., 1969: Sexual activity and longevity of the southern Green Bug, Nezara viridula L. Ann. Ent. Soc. Amer., 62, 1246-1248.
- Morstatt, H., 1914: Die Schädlinge der Baumwolle in Deutsch-Ostafrika, Beiheft zum pflanzer, Dar-es-Salaam, 10, No.1, 1-50.
- Mukerji, M.K. and Le Roux, E.J., 1965: Laboratory rearing of a Quebec strain of the Pentatomid predator, Podisus maculiventris (Say) (Hemiptera: Pentatomidae). Phytoprotection, 46, 40-60.
- Odhiambo, T.R., 1957: The bionomics of Oxycarenus species (Hemiptera: Lygaeidae) and their status as cotton pests in Uganda. J. Ent. Soc. Sth. Afri., 20, 235-249.

146.

- Peacock, A.D., 1913: Entomological pests and problems of Southern Nigeria. Bull. Ent. Res. London, 4, 191-220.
- Pearson, E.O., 1958: The insect pests of Cotton in Tropical Africa. Em. Cott. Grow. Corp. and Commonw. Inst. Ent., London, 1-355.
- * Pomeroy, A.W.J., 1921: Ann. Rept. Dept. Agric. Southern Provinces, Nigeria 1st Jan. 1920 - 31st March 1921, 21-23.
- Przibram, H., and Megusar, F., 1912: Wachstumsmessungen an Sphodromantis bioculata Brum. 1. Lange und Masse. Arch. Ent. Mech. Org., 34, 680-711.
- Puchkov, V.G., 1958: Larvae of Hemiptera - Heteroptera. 1. Lygaeidae. Ent. Obozrenie (Moscow) 37, 392-413.
- Puchkov, V.G., 1959 (a): Larvae of Hemiptera - Heteroptera belonging to the super family Pentatomoidea. 1. Identification keys to the families Pentatomoidea and of the species of Acanthosomidae, Cydnidae, and Scutelleridae. Zool. Zhur. 38, 1190-1206, (Translation from Russian).
- Puchkov, V.G., 1959 (b): Larvae of families Coreidae and Arenocoreidae (Coreidae, Heteroptera) of the fauna of the European part of the U.S.S.R. Dopov. Akad. Nank. Ukr. R.S.R., 10, 1156-1161. (Translation from Ukrainian).
- Rao Ramachandra, Y., 1921: A preliminary list of insect pests of Iraq. Dept. Agric. Iraq, Baghdad, memoir No.7, 35 pp.
- Richards, O.W., 1949: The relation between measurements of successive instars of insects. Proc. R. Ent. Soc., Lond. (A), 24, 5-10.

- Samy, O., 1969: A revision of the African species of Oxycarenus (Hemiptera: Lygaeidae). Trans. R. Ent. Soc., Lond., 121, 79-165.
- Saxena, K.N., 1965: Control of the orientation and feeding behaviour of Red Cotton Bug, Dysdercus koenigii (F.) by chemical constituents of plants. Proc. XII Inst. Congr. Ent., London (1964), 1-294.
- Shepherd, R.F., 1966: Factors influencing the orientation and rates of activity of Dendroctonus ponderosae Hopkins (Coleoptera: Scolytidae). Can. Ent., 98, 507-518.
- Sickenberger, E., 1890: Insect life, Vol.III, 1-68.
- Slater, J.A., 1964: A catalogue of the Lygaeidae of the World. The University of Connecticut, Storrs, 1-1668.
- Smith, J.H., 1927: Life history notes on Rutherglen bug. Qd. Agric. J. 27, 285-302.
- Southwood, T.R.E., 1956 (a): The structure of the eggs of the terrestrial Heteroptera and its relationship to the classification of the group. Trans. R. Ent. Soc. Lond., 108, 163-221.
- Southwood, T.R.E., 1956 (b): A key to determine the instar of an heteropterous larva. Entomologist, 89, 220-221.
- Southwood, T.R.E., 1960: The flight activity of Heteroptera. Trans. R. Ent. Soc. Lond., 112, 173-220.
- Southwood, T.R.E., 1962: Migration of terrestrial arthropods in relation to the habitat. Biol. Rev., 37, 171-214.
- Southwood, T.R.E., and Johnson, C.G., 1957: Some records of insect flight in May 1954 with particular reference to the massed flights of Coleoptera and Heteroptera from concealing habitats. Ent. Mon. Mag., 93, 121-126.

148.

- Southwood, T.R.E. and Scudder, G.G.E., 1957: The immature stages of the Hemiptera - Heteroptera associated with the Stinging nettle (*Urtica dioica* L.). Ent. Mon. Mag., 92, 313-325.
- Stys, P., 1964: The morphology and relationships of the family Hyocephalidae (Heteroptera). Acta Zool. Hung., 10, 229-262.
- Sweet, M.H., 1960: The seed bugs: a contribution to the feeding habits of the Lygaeidae (Hemiptera: Heteroptera). Ann. Ent. Soc. Amer., 53, 317-321.
- Sweet, M.H. and Slater, J.A., 1961: A generic key to the nymphs of North American Lygaeidae (Hemiptera: Heteroptera). Ann. Ent. Soc. Amer., 54, 333-340.
- Theobald, F.V., 1906: Notes on African cotton insects. Entomologist, 39, 27-30.
- Thorsteinson, A.J., 1960: Host selection in phytophagous insects. Annu. Rev. Ent., 5, 193-218.
- Vayssiere, P. and Mimeur, J., 1925: Les Myriapodes et les Hemipteres nuisible au Cotonnier en Afrique Occidentale Francaise. Agron. Colon. No.19, 20-44.
- Vrijdagh, J., 1930: Tableau Systematique des insectes nuisibles aux plantes cultivees du Congo belge. Annales de Gembloux (1930), 425-434.
- Whellan, J.A., 1958: Report of the Chief Entomologist for the year ending 30th September, 1956. Rhodesian Agric. J., 55, 302-313.

149.

- Wigglesworth, V.B., and Gillet, J.D., 1934: The function of the antennae of Rhodnius prolixus (Hemiptera) and the mechanism of orientation to the host. J. Exp. Biol., 11, 120-139.
- Willcocks, F. and Baghart, S., 1937: The insect and related pests of Egypt. Royal Agric. Soc., Vol.1, Part 2, 1-30.
- Willie, H.P., 1950: Untersuchungen über Psylla piri L. und andere Bimblattsau gerarten in Wallis. Doct. Thesis, Tech. Hochschule, Zurich, 1-113.
- Withycombe, C.L., 1924: Factors influencing the control of Cotton Stainers (Dysdercus spp.). Bull. Ent. Res., 15, 171.
- Woodward, T.E., 1949: Notes on the biology of some Hemiptera - Heteroptera. Entomologist's Mon. Mag., 85, 193-206.
- Woodward, T.E., 1952: Studies on the reproductive cycle of three species of British Heteroptera, with special reference to the overwintering stage. Trans. R. Ent. Soc., Lond., 103, 171-218.
- Woodward, T.E., 1962: A new genus of Rhyparochrominae (Hemiptera: Lygaeidae) from Queensland. J. Ent. Soc. Qd., 1, 46-49.
- Youdeowei, A., 1966: Laboratory studies on the aggregation of feeding Dysdercus intermedius Distant (Heteroptera: Pyrrhocoridae). Proc. R. Ent. Soc. Lond.(A), 41, 45-50.
- Youdeowei, A., 1967: Observations on some effects of population density on Dysdercus intermedius Distant (Heteroptera: Pyrrhocoridae). Bull. Ent. Soc. Nigeria, Vol.1, Part 1, 18-26.

150.

- Youdeowei, A., 1967: The reactions of Dysdercus intermedius (Heteroptera: Pyrrhocoridae) to moisture, with special reference to aggregation. Ent. Exp. and Appl., 10, 194--210.
- Youdeowei, A., 1968: The behaviour of a Cotton Stainer Dysdercus intermedius (Heteroptera: Pyrrhocoridae) in a temperature gradient and the effect of temperature on aggregation. Ent. Exp. and Appl., 11, 68-80.
- Youdeowei, A. and Calam, D.H., 1969: The morphology of the scent glands of Dysdercus intermedius Distant (Hemiptera: Pyrrhocoridae) and preliminary analysis of the scent secretions of the fifth instar larvae. Proc. R. Ent. Soc. Lond.(A), 44, 38-44.

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7.

APPENDIX

Percentage Relative Humidity (Monthly data) at
Legon in the savanna locality.

1974	Oct.	81	
	Nov.	79	
	Dec.	81	
1975	Jan.	76	
	Feb.	80	
	Mar.	82	
	Apr.	77	
	May	82	
	Jun.	82	
	Jul.	86	
	Aug.	84	
	Sept.		} Data not yet available
	Oct.		