THESIS FOR THE DEGREE OF M. SC.

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"THE DISTRIBUTION, IMPORTANCE AND BIOLOGY OF THE MAIN COTTON PESTS OF MOÇAMBIQUE"

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C O N T E N T S

INTRODUCTION

Up to the second half of the eighteenth century the most important fibres in the world were wool, flax and silk. But the Industrial Revolution in England, together with the invention of the Cotton gin by Whitney in 1793, soon gave cotton the first place amongst all the important fibres in world's textile industry.

Although some attempts were made, both in Angola and Moçambique, to cultivate cotton since remote days — as far back as the American Civil War, when market prices suffered an important rise — no serious efforts were made to grow this crop before the proclamation of the Portuguese Republic in 1910, when some definite legislation was passed to encourage the development of this culture.

But the needs of the national industry were everincreasing and the production remained low. The money spent on cotton imports was so heavy on the national budget that the Government had no alternative but to establish a National Cotton Board in 1938, aiming at the co-ordination of the production and distribution of cotton produced in the Portuguese Overseas Empire. Nevertheless this was not sufficient and it was felt that if the productions were to be increased still further and in accordance with the national needs, the cotton culture would have to be thoroughly studied in all its aspects. It was decided then that only a research institute would serve the purpose, and a new branch of the National Cotton Board — The Cotton Research Centre — was therefore created in 1943, to work exclusively on the multiple and important problems of cotton.

The description of the organisation of this Centre and the results of its activities do not fall under the scope of this work. It is interesting however to note that whereas in 1930 Moçambique and Angola supplied only 4% of the needs of the mother--country, in 1951 both territories supplied 96% of the Portuguese Textile Industry.

As an Entomologist of this Centre I am in charge of the study of the occurrance, distribution, biology and control of all the cotton pests, as well as of the organisation of a collection representing not only the cotton pests but also the entomological fauna of Moçambique.

The present work has been done under the direction of Professor Doctor Aurélio Quintanilha, to whom I pay my greatest respects and give my thanks for all the encouragement, comradship and good advise given to me during the last three years.

I am also deeply indebted to Messrs. M. Carvalho, J. Gomes Pedro and D. G. Gouveia, all of this Centre, for their collaboration, respectively on the statistical, botanical and paedological fields; to Messrs. M. Rebelo and A. Cabral for their help in connection with the photographical work, to Miss L.H.Aires, for colouring some of our drawings, and finally to Miss M. D. Gomes da Costa for her most efficient and excellent typing.

I - <u>SHORT DESCRIPTION OF MOÇAMBIQUE</u>


Palma
Maniamba
Vº Cabral
Macomia
PORTO AMELIA
Montepuez
NAMPULA
MOÇAMBIQUE
TETE
QUELIMANE
Chinde
BEIRA
INHAMBANE
Pafúri
Vº de João Belo
LOURENÇO MARQUES
PORTUGAL
OVERSEAS PROVINCE
OF
MOÇAMBIQUE
SCALE 1-10.000.000

A) - THE SITUATION, AREA, LIMITS AND PERIPHERIC CONDITIONS

Moçambique is one of the Provinces of the Portuguese Overseas territories and is situated in South East Africa. Its coast is 2759 Kms long and it stretches from 10° 27' S (the estuary of the Rovuma River) to 26° 52' S (Ponta Ouro).

The maximum width of the territory is 1003 Kms (along the parallel 15° S) and its minimum width is 50 Kms (along the parallel in which Lourenço Marques is situated).

The total area of the territory is 771,125 square Kms, and it is confined within the area shown in the attached map. To the North it is bound by the territory of Tanganyika; to the West by Nyasaland, Northern and Southern Rhodesia, the Transvaal and Swaziland; to the South by the Province of Natal.

Its Northern frontier runs for 690 Kms, following the Rovuma River until it meets the Messinga, and from then on it follows the parallel 11° 34' 28" S, up to the point where the river Tchuindi flows into Lake Nyasa.

The Western border runs for 3.340 Kms, sometimes following rivers and the sides of lakes, sometimes following the lines of mountain ridges. Otherwise, the frontier is determined by conventional marks, established by mutual agreement of international delimitation committees.

Travelling from South to North along the coast one comes upon Delagoa Bay, where the port of Lourenço Marques is built at the mouth of the Espírito Santo River. Further north we find

Ponta Zavora, the Bay of Inhambane, Cape S. Sebastian, the Bay of Mazanzane (where the Port of Beira is situated), the enormous delta of the Zambezi, Ponta Sancul, the Bay of Moçambique, the enormous bay of Fernão Veloso (where the new port of Nacala is under construction), the wide Bay of Porto Amélia and Cape Delgado.

Not far from the coast there are various islands and small archipelagos such as Inhaca (with its biological station), Xefina, Bazaruto, Chiloane, Primeiras, Angoche, Moçambique, Quirimba, Ibo and many others.

E) - CLIMATIC CONDITIONS AND MACROCLIMATIC ZONES

The Northern part of this Province lies on the meteorological area of the monsoons. The Southern part is subjected to the cyclonic and anti-cyclonic centres of the middle latitudes. The Central area of the Province can be considered a zone of transition.

In the Northern zone the rainy monsoon of the NE occurs from October to March and the dry SW monsoon from May to August, while April and September are months of transition.

In the Southern zone the hot rainy season occurs from October to March and the cool showery season from April to September. The transition between the two seasons is rapid.

The temperature, in a general way, increases from South to North from 22° to 26° C or a yearly average, with annual variations of 8° C in the South and 5° C in the North. The daily variation is very high in the South, especially during the cool season, and very small in the North.

The warm current of the Moçambique Channel is an external factor to take into consideration, as it increases the temperature means of the coastal areas, where the latitude factor should justify a more gentle climatic facies, such as that of Lourenço Marques or Durban.

In relation to altitude it can be said that a rise of 200 metres corresponds to a decrease of approximately 1° C in temperature.

The average annual figure for relative humidity varies between 70-80 % and the monthly average between 65-80 %. The climate can therefore be classified as "moderately humid". This may be misleading because the averages result from the representative figures of a normal state of "estraordinary humidity" combined with very short "estraordinarily dry" periods.

The density of the rain increases in the south of the Province as far as the 17th parallel, and then diminishes up to the extreme north.

Rainfall on the south coast is about 800 mm annually; on the central coast 1.300 to 1.400 mm, and on the north coast about 1.000 mm. It increases from the interior to the coast and with heights up to 1.000 metres, but it decreases again above that figure.

The annual average for atmospheric pressure in the southern zone is 764.5 mm with deviations of ± 4.0 mm, diminishing towards the North. The average in July is 768.5 mm and in January 760.0 mm, with two daily minimums (4 and 16 hours) and two maximums (8-9 hours and 23-24 hours).

According to Dr. Oliveira Boleo (1951) Moçambique can be divided into the following macroclimatic areas:

1) - Marginal tropical climate - This covers the whole of the Sul do Save districts and includes a hyperthermic marginal belt and a sub-zone formed by the Limpopo-Chengane and Incomati Valleys.

In the former the average temperature is 22-23° C, with strong daily variations, the relative humidity 68-72 %, rainfall 750-1.000 mm, and prevailing winds South and East.

In the sub-zone the average annual temperature is 23--24.5° C, relative humidity 72-74 %, rainfall 500-600 mm but only 318.3 in the Pafuri region.

2) - <u>Tropical-litoral climate</u> - This covers all the territories between the Save and Ligonha Rivers, except the regions of medium and great altitude. The average annual temperature is 24-25° C, the relative humidity 71-74 % and the average rainfall 1.250 mm. The hot or rainy season lasts from November to April and the dry season from May to October. The prevailing gentle winds are SE. In the sub-zone of the Zambezi Valley the temperature is higher, the relative humidity lower and the rainfall much lower.

3) - <u>Tropical monsoon climate</u> - This covers the whole area of low altitude from the Ligonha River to the Rovuma River. The average annual temperature is 25-26° C with small variations, the relative humidity 70-72 %, the average rainfall 1.000 mm, of which 90 % falls during the rainy season (October-April). The hottest month is December (32.5° C) and the coolest month is July (22.5° C).

4) - <u>Mesothermic climate of high altitudes</u> - This includes a series of small separate areas above the 1.000 metres mark, such as the Espungabera, Chimanimani, Mavita, Manica, Milange, Gurué, Angónia and Vila Cabral areas. These are the best areas for permanent colonisation. According to the altitude and latitude, the average temperatures vary between 18° and 21° C, the relative humidity between 64 % and 77%, the rainfall between 1.000 and 1.500 mm.

C) - GEOLOGICAL STRUCTURE

The nomenclature used for the geological description of Moçambique is, for standardisation purposes, the same used in South Africa.

Briefly we may refer to the following systems constituting the geological structure of this territory:

I) - Primitive Systems - These cover almost two thirds of the territory especially to the north of the Save River, and they consist of ancient granite and quartz brougt to the surface by erosion. These rocks belong to the Laurentian type (lower pre--Cambrian). The system, in Swaziland, includes the Macequece series (mica, talc and oxichlorinous schists and greenstones); the Vengo series (schists, sandstones, quartz with haematite, etc.); and the Chimanimani series (argillaceous and siliceous schists, inserted with quartz and siliceous sandstones).

II) - The Umkondo System - This system consists of argillaceous schists with an overlayer of sandstone, affiliated substances and quartz. Examples of this type are rare (Espungabera and Chimanimani).

In Moçambique the Witwatersrand, Ventersdorp, Transvaal--Nama and Koeisberg systems do not occur. This shows that our territory was cut off for a long period during which the Primitive Systems were separated from the Umkondo.

III) - The Karroo System - Large deposits of Karroo are found in Alto-Rovuma, Amaramba and Zumbo, as far as the Lower Nyasaland. There are also small quantities elsewhere.

The Karroo system includes four series: Dwyka, Eeca, Beaufort and Stormberg. The series most seriously prospected for coal is the Eeca. This system ends in great volcanic eruptions which provide areas of lava, dolerite-basalt, certain porphyries, etc. This may be seen at Luia, Lupata, Milange, Morrumbala and other places.

In the South the mountain range of Libombos is post-Karroo and pre-cretaceous, perhaps coming from the Liassic age.

IV) - The Cretaceous System - This system consists mainly of masses of compact limestone, sandstone and argillaceous schists. The greatest deposits are to be found from the Sábiè to Pafuri, at the Buzi River and on northern coast of the Province.

V) - The Tertiary System - This system includes the basalt crown of the Pequenos Libombos mountains, the marshy limestone of Chimanimani and Buzi, the zone which runs along the northern coast of the Province and greater deposits to the south of the Save River and near Lourenço Marques.

VI) - The Quaternary System - There are vast tracts of new lands. Differential types are still not to be found in places, as its ages vary from the Cretaceous to the Modern. One can find surface sandstones, red sand, white sand, swamp land (machongos), etc., on most of Sul do Save and Manica and Sofala districts as well as on the Rovuma area, besides the sandy formations at the estuaries and along the river banks of most rivers.

D) - THE SOILS

According to D. Gouveia and A. Azevedo (1949 and 1950) the soils of Moçambique have provisionally been classified as follows:

A) - Leached Soils:

1 - Red Soils.
2 - Orange, pale-orange and yellow soils.
3 - Brown and yellowish brown soils.
4 - Grey soils.
5 - Macondes soils.
6 - Urrongas red soils.
7 - Inhaminga soils.
8 - Coastal sand belt soils.

B) - Non-leached Soils:

1 - Tropical black and grey earths.
2 - Guijá grey soils.
3 - Tropical chestnut soils.
4 - Tropical brown, greyish brown and reddish brown soils.

C) - Calcimorphic Soils.

D) - Halomorphic Soils.

E) - Hydromorphic Soils;

1 - Bog soils.
2 - "Machongos".
3 - Vlei soils.
4 - Dambos soils.
5 - Bottom clays.

F) - Regosols and Lithosols.

G) - Alluvial Soils.

A) - Leached soils - Groups 1 to 4 of these soils are subjected to laterization processes, and it is possible to distinguish within each of them lateritic, lateritic ferruginous and ironstone lateric types, the first without iron concretions, the second with iron concretions, and the last one with ironstone.

These soils occur associated in catenas (G. Milne, 1936) in the dissected peneplain of the granite-gneissic complex corresponding to about two thirds of the territory. The red soils occur in the higher, generally well-drained areas, the orange and pale-orange on the slopes, and the yellow soils bordering the low areas of impeded drainage, which are occupied by the grey soils.

The red lateritic soils are deep soils, clayey but friable, without or, when present, with very rare and small iron concretions. They occur in the wet high lands of Vila Cabral, Gurué, Nhamarroi, Tacuane, Angónia, and so on, with a rainfall above 1200 mm and relatively low temperatures (average annual below 20° C).

Groups 5 to 8 of these soils are generally sandy soils and they are found in the plateaux of Macondes, Macomia, Cheringoma (Inhaminga), Urrongas region and, with interruptions, in the litoral and sub-litoral regions.

B) - Non-leached soils - The tropical black earths have a shallow upper horizon, clayey, of granular structure, lying on heavy clays, very compact, with wide cracks and lime concretions. They are generally related with limestone materials, in dry and very hot areas (rainfall below 800 mm and mean annual temperatures above 25° C) as, for instance, at Quissanga, Porto Amélia, Memba, Baixo Chire, Urema-Zangue, and so on.

Apparently similar to the subtropical Black Clays (Van der Merwe) or Black Turf of the Transvaal are the Moamba black clays. They occur not only at Moamba but also in Baixo Mossurize and semi-arid regions, on basaltic rocks.

Tropical grey earths, similar to the black earths except in colour, occur in the Baixo Chire, Muianga and Maringa.

In the Guijá region there are grey soils which have a thick loose sandy layer on a light grey, very compact (sometimes cemented) thick horizon, this overlying another grey, sandy-clay, rich in lime concretions.

The Tropical Chestnut Soils of semi-arid climates (rainfal less than 600 mm and temperature above 25° C) were only identified near Metuge (Porto Amélia) and Lúrio (Memba), on Cretaceous limestone. They present chestnut, sometimes reddish chestnut horizons, clayey, of prismatic structure, with lime concretions.

The brown to reddish-brown soils occur in regions of rainfall below 800 mm and mean annual temperature above 26° C, as, for instance, at the Alto Limpopo region and Tete district.

C) - Calcimorphic Soils - In Moçambique, two different types of calcimorphic soils were identified:

a) - Red calcimorphic - sandy-clay to clayey, compact, in Guijá, Chemba and, related to pleistocenic limestones of the coast, in Sofala, Maganja da Costa, Fernão Veloso and Cabo Delgado.

b) - Black calcimorphic - generally skeletal in the Beira district, derived from numulitic limestones.

D) - Halomorphic Soils - Two categories of halomorphic soils were distinguished:

a) - Continental - along the Changane River (Sul do Save), and in dispersed spots in Guijá, Urema-Zangue, depression and a coastal belt of Sofala.

b) - Tidal clays - The continental type shows a top soil with a characteristic reticular network and black and/or white saline incrustations. In some profiles a columnar structure has been observed.

E) - Hydromorphic Soils - Among the hydromorphic soils the following different groups were identified:

a) - Bog soils - at about 2.000 metres of altitude, on Chimanimani Mountain, with a turf layer relatively thick (0.6 to 1.0 m) formed mainly by undecomposed residues of Sphagnum sp.

b) - Machongos - are peat soils of the depressions of the coastal sand belt of the Lourenço Marques and Inhambane Districts. They are very rich in organic matter and waterlogged.

c) - Vlei soils - these soils have a brown, dark brown or black upper horizon, clayey, of coarse granular structure, overlying a layer generally brown, heavily clayey, very compact, with cracks when dry, and rich in iron concretions and lime nodules. They occur in depressions with impeded drainage in Baixo Chire, Guijá, and are the last members of the Montepuez catena.

d) - Dambos soils - have a grey top soil on a yellow, sandy-clay to clayey underlying horizon, mottled and rich in iron concretions. They occur in bottom or flat lands of impeded drainage and they are very often the last members of some catenas. The Dambos of Amaramba are very characteristic.

e) - Bottom clays - these are grey, greyish brown or yellowish brown clays, very compact, cracking when dry, mottled, with iron concretions. They are badly drained and in some regions locally known as Tandos, as the Tandos of Marromeu, Gorongosa, Buzi, Govuro, and so on.

F) - Regosols and Lithosols - The Regosols are sandy soils whose profiles do not show any characteristic pedogenic process, being found on some sands and sandstones of the Karroo, Cretaceous and Tertiary. The sandy soils of Cádzi (Tete district), of Machaze, Mucheve and Maxaíla are good examples. The coastal sand dunes are considered to belong to this group.

Lithosols, skeletal, or grit and coarse material rich soils, are scattered through the territory.

G) - Alluvial Soils - These soils are very important for the agricultural point of view, occupying the main valleys of the territory, such as the Zambezi, Chire, Buzi, Limpopo, Incomati and

Umbeluzi Valleys. These soils constitute some of the most suitable soils for the cotton culture.

E) - THE VEGETATION, IN RELATION TO THE COTTON CULTURE

The culture of cotton, in Moçambique, has been carried out in the most varied aecological conditions, that is, in areas primitively occupied by very different types of vegetation.

Nowadays, however, and as a consequence of an important and vast aecological survey(J. Gomes Pedro et al. 1946-1949) there is a tendency to abandon the less suited areas and to intensify the culture in favourable regions.

Until recent years, while the cotton culture was submitted to a vast generalization aiming at a high production at all cost, the most typical and larger areas were probably those occupied by populations that the above author generalized under the name of "Brachystegia-Isoberlinia open woodland". Especially in the Zambezia and Niassa Districts (Quelimane, Nampula, Cabo Delgado and Lago), cotton took the place of numerous tracts of Brachystegia-Isoberlinia forest, occupying enormous areas. To-day, many of these areas are being abandoned as unsuitable for the culture, especially the very humid ones.

The areas that show better conditions for the cotton culture, in the above Districts, are the valley formations, either the thorny open forest type, especially those where Acacia campylacantha is dominant, or the deciduous forest of the Adansonia digitata - Sterculia appendiculata type. The former, as a rule, indicates the best suited soils, while the latter shows the most favourable microclimates for the development of the cotton plant.

In the Manica and Sofala Districts, the most suitable areas to cultivate cotton are situated on the banks of the Zambezi and its tributaries, especially in the Chemba, Sena, Marromeu, Cheringoma and Gorongoza regions, in the phytochorologic zone of Adansonia digitata, as well as in numerous savannahs and prairies, all climatically similar but edaphically different, that can be classified as associations of the Adansonion alliance.

Still in the Sofala region, and namely on both sides of the Buzi River, the cotton culture has been carried out in woodland and deciduous parkland of Pterocarpus angolensis, Burkea africana, Amblygonocarpus obtusangulus, etc., but with a marked ill--effect on the economy of the local forests. As a consequence there is a tendency to switch the culture into areas nearing the river banks or into transitional areas occupied by deciduous forests of Adansonia digitata - Sterculia appendiculata, or by thorny parkland of Acacia spp. (A. nigrescens, A. karroo), Combretum spp., and so on.

In the Sul do Save Districts (Inhambane and Gaza), the cotton culture was considerably extended into areas of woodland of the Brachystegia spiciformis type, into forests (only recognisable by individuals or residual tracts) of Ficus spp., Chrysosophyllum sp., Dialium schlechteri, Afzelia quanzensis, etc., and still into secondary savannahs of Sclerocarya caffra, Trichilia emetica, Albizzia spp., all occupying various tracts of the coastal sand belt.

To-day, in these districts, there is a tendency to intensify the culture in the areas previously occupied by Adansonia digitata, Cordyla africana or Chlorophora excelsa, still on the coastal sand belt. But this tendency is especially noticeable in the Middle Limpopo banks, in alluvial formations occupied by associations of Sclerocarya caffra or allied ones, namely in the Guijá, Bilene and Chibuto regions. In this area there are various formations that define suitable conditions to grow cotton, but they can all be classed as associations of the Sclerocaryon alliance.

II - THE MAIN COTTON PESTS OF MOÇAMBIQUE

In 1948 Hargreaves published a list of over seven hundred insects recorded as affecting cotton all over the world. Fortunately only a small percentage of these occur in Moçambique and amongst the several insects which have been collected on our cotton fields it can be stated that the vast bulk of the damage, up to now, is confined to five main pests, which are the following:

A) - The Red or Sudan Bollworm - <u>Diparopsis castanea</u> Hampson (Lep., Noct.)

B) - The Spinny or Spotted Bollworm - <u>Earias</u> spp. (Lep. Noct.)

C) - The Cotton Jassids - <u>Empoasca facialis</u>, Jacobi (Hem., Jass.)

D) - The Cotton Stainers - <u>Dysdercus</u> spp. (Hem. Pyrrhoc.)

E) - The Cotton Seed-bug - <u>Oxycarenus hyalinipennis</u> Costa (Hem. Lyg.)

The five pests are confined to Africa although some of the genera to which they belong attack cotton elsewhere in the tropical regions. With the exception of the Cotton Jassids, these pests attack the reproductive parts of the plant and do not affect its structure. The Jassids, on the other hand, attack the vegetative parts of the plant and may therefore prevent or delay the formation of bolls.

We shall, from now on, deal with each one of these pests in separate.

A) - <u>THE RED OR SUDAN BOLLWORM</u>

I - <u>NAME AND DISTRIBUTION</u>

The genus *Diparopsis* is confined to Africa and its type - *D. castanea* - , from Lourenço Marques, was first described by Hampson in 1902, in the following way:

"Proboscis moderate; palpi obliquely upturned, twice diameter of eye; second joint a little longer than first joint; third joint a little less than one-half of second, narrow and pointed; all joints covered with loose scales; frons with a pointed process, hollow on underside and terminating in three short, pointed lobes; a slightly projecting ridge below it (this process is almost hidden in the scales); eyes rounded; antennae bipectinated, tapering towards apex; longest pectination in ♂ about three times shaft, in ♀ almost twice shaft; prothorax with a small crest, metathorax with a large tufted crest; tegulae also tufted with scales; abdomen with a small crest at base, otherwise covered with scales; legs smoothly scaled with slight fringes of hair; hind tibia with four spurs; outer spur two-thirds of inner, both abnormally long. Forewing: rather broad, termen well arched, hardly crenulated, costa and inner margin arched; cell over half of wing; R_1 from three-fourths of upper median; R_2 and R_3 on a stalk of one-third of R_3 and from middle of origin of R_1 and upper angle; R_4 and R_5 on a stalk of one-fifth of R_4; R_3 and R_4 anastomosing from free part of R_4 to nearly middle of free part of R_3, thus forming a long areole; M_1 remote from areole; M_2 remote from lower angle; upper DC incurved; C_1 twice as far from M_3 as M_2 is; C_2 from beyond two-thirds of lower median; A_2 almost straight. Hindwing: subtriangular with termen strongly arched, costa slightly so, apex well rounded, tornus broadly rounded, termen slightly undulating; frenulum strong; cell nearly half of wing; Sc anostomosing for a little distance at one-third of upper median, leaving a long basal areole; Rs and M_1 from a point; M_2 weak but present and from a little below middle of DC; uper DC very weak; M_3 remote from but slightly approximated to C_1; C_2 from three-fourths of lower median; A_2 and A_3 straight. ♂ Genitalia: abdomen coremata; uncus rather slender, curved, suddenly pointed, without hairs; tergite moderately broad, only well chitinised along the edges; sternite moderately broad, slightly thickening at base; subscaphium absent; valve sole-shaped, bulging at middle on costa and strongly bulging at inner margin at one-third; inner marginal area at base most heavily chitinised and gradually forming a broad-based harpe, which terminates in a rounded process with a short-pointed process from three--fourths of harpe; tumen oblique, tornus well rounded; innerside moderately covered with rather stiff hairs, outerside densely covered with hair-like scales and hairs mixed; aedoeagus short and very stout, only narrow at base; vesica without cornuti."

Until very recently the genus was thought to consist of only two species, D. castanea Hmps. (from South, East and North Africa) and D. tephragramma B. - Bkr. (from Angola). But Clements (1951) based on differences noticed on the frons process (cocoon-

II - DESCRIPTION

1) - The Egg (fig. 1) - The egg of the Red Bollworm is spheroid in shape slightly flattened in the poles, with a diameter of 0.6 mm, and its external wall is highly sculptured and reticulate, with short chitinous processes. The egg, when recently laid is pale whitish-green or whitish blue but it turns slightly darker and greyish, as the embryo develops within.

2) - The larva - After birth, the small first instar larvae are about 1.0 mm in length. The body is very pale cream with slightly darker patches, where setae occur. The head, which is very large compared with the rest of the body, the thoracic and anal plates are very dark brown, almost black.

The second stage larva is characterised by the appearance of rose-coloured markings on each segment, and seen dorsally these marks resemble a broad arrow with the point cut off, and pointing towards the head. These red markings are a diagnostic character of the Red Bollworm. The head and the thoracic and anal plates maintain the same appearance.

The third-stage larva shows a remarkable increase in size, measuring about 5 to 10 mm in length. The red markings are more pronounced and at this stage the Red Bollworm can easily be confused with the Pink Bollworm (Platyedra gossypiella Saund. - Lep., Gelech.) not only in general appearance but also in size. But these two insects can easily be recognised due to the different colour of their thoracic legs: dark brown or almost black in D. castanea Hmps. and light brown or yellow in P. gossypiella Saund. The "crochets" of the pseudolegs of D. castanea Hmps. are also a diagnostic character (fig. 2). The head and thoracic and anal plates show a slight discolouration, being now chestnut in colour.

II - DESCRIPTION

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From now on, until the larva attains its maximum length at the 5th instar, the appearance is always very similar, except for the increases in size, from stage to stage. The fully grown larva can measure up to 25 or 28 mm in length. The ground colour is pale yellow or pale greenish-yellow (fig. 3).

In the last stage the red markings are somewhat fused together at first, and as it approaches its fully grown condition, the trilinear dorsal marking disappears, giving place to a transverse red flush on each segment, on a green or creamy ground. The head and thoracic plates remain chestnut, but the anal plate turns whitish, with a median black longitudinal mark.

In the Petri dishes, just before pupation, the larvae become motionless, with the ventral surface upwards and become almost colourless.

3) - <u>The Pupa</u> - When complet growth is attained the larva descends to the ground, to a depth of about 8 cm, where it constructs an earthen cell, within which the pupa is formed (fig. 4 and 5). This is of a light chestnut colour, sometimes with a greenish tinge, and measures about 13 or 15 mm in length (fig. 6).

4) - <u>The Adult</u> - The moth of the Red Bollworm is very characteristic and once seen there will be no difficulty in recognising it again (fig. 7). The moth measures between 15 and 18 mm in length and has a wing span of about 30 mm. The main colouration is a reddish brown, but there is a considerable range of colouring, varying from deep mauve, a brick pink, to more rarely straw. These pale forms, seen in both sexes, occur in a very small percentage.

In the humeral angle of the forewing there is a reddish brown triangular patch and towards the distal edge of the wing, and more or less parallel to it, there are two bars crossing the wing, the inner being darker than the outer and brownish in colour. These three markings are very characteristic and through them the moth of D. castanea is very easy to recognise. The hind wings are creamy or white in the males and somewhat darker in the females. The head is reddish brown. The thorax is brown and slightly darker in front than at the back. The abdomen is yellow-greyish.

III - LIFE HISTORY

1) - Oviposition, Incubation Period and Hatching - The eggs are laid during the evening and as a rule separately. They are laid in many parts of the plant, such as the leaves, stem, branches, buds or bolls. But they are found more frequently on the upper part of the plant, especially at the base of new leaves and new squares or buds.

As far as my observations are concerned no eggs are laid, to any significative extent, on the cotton plant until de appearance of the first squares.

Cotton is sown in Moçambique during the second half of November, except in the Niassa region where this takes place a month later. The first squares occur, respectively for the two regions, during January and February, and, with them, we have the first egg laying from a first generation of moths which have emerged from long-termed pupae of the previous season. Each female can lay about five hundred eggs before death occurs.

The period of incubation varies greatly with the temperature and can take from three to eleven days, being shorter when the temperature is high.

When the egg is ready to hatch the larval head can be noticed through the egg's wall. At first a gentle heaving of the wall above the head can be seen, and after five to ten minutes the wall is broken. Then, after an irregular period of struggling during which the larva is seen to use its mouth parts widening the exit hole, we can see the small larva emerging from the egg-shell.

2) - The larvae - After hatching, the young larvae lose no time looking for their first meal. They move very rapidly away from the egg-shell and look for either a square or a young boll, where they penetrate with astonishing speed. As a rule this is attained within half an hour from birth. Under laboratorial conditions they have been seen to move for endless hours and if food is not provided, they eventually spin a web and die.

The mechanism to enter the bud or boll is the following: the young larva starts biting the bud, after penetrating the bracts. The bitten pieces are thrown away, and the irregular entrance hole is increased. When eventually the larva penetrates the bud, the entrance is marked by a litter of bud or boll material (fig. 8). After the interior of the bud has been eaten the young larva can move to another bud and yet another until full growth is attained. The damage to the buds or bolls is complet. If a damaged boll is opened it can be observed that its contents have been destroyed and it appears brown or black and full of excreta (fig. 9). By this one can differentiate from a boll injured by American Bollworm (Chloridea obsoleta Fabr. - Lep. Noct.), which usually leaves most of its body, and therefore its excreta, on the outside. Damaged buds or bolls are shed very often after the exit of the caterpillar.

Similar damages are caused by larvae of all stages until they reach the 5th instar (two to five weeks after birth), when they eventually leave the plant to form the pupae on the soil. The first two instars are usually found feeding on buds, flowers or very young bolls; as the larvae grow older they tend to select older fruits for food. Feeding experiments on the laboratory show that a single larva can consume five or six buds before it reaches maturity; but if the small larva enters a normal fair-sized boll this will be enough to carry it up to the 5th instar (fig. 10).

The larvae of Diparopsis, as a rule, don't leave the boll they are eating until it is completely consumed. This habit is very important as it reduces to a minimum the time they are exposed either to parasites or predators, insecticides or climatic influences. But under very adverse food conditions we have observed (Gorongosa, 1952) almost fully matured larvae walking on the branches, looking for food.

Normally not more than a larva is found within a boll. But again, under adverse food conditions, we have observed (Chemba, 1950) two larvae feeding on the same boll, in two cases. These cases are, however, very exceptional.

When the infestation is high, damages can be very severe with losses of 50 % or much more. As a matter of fact we have observed gardens on the Zambezi banks, during a year of floods, where I could not find a single boll that was not attacked or damaged by the Red Bollworm. Fortunately these cases are very exceptional and the average infestation is much lower.

3) - Host Plants - D. castanea feeds on all cultivated varieties of cotton which constitute by far the most important, and almost exclusive, foodstuff of the Red Bollworm. In Moçambique it feeds also on one species of Cienfugosia, viz., Cienfugosia hildebrandtii Gurke, which occurs in fair numbers in a region quite near Lourenço Marques, between the Umbeluzi Valley and Moamba, and also near the Zambezi mouth. The other alternative host-

-plant is wild cotton which in this territory is Gossypium herbaceum var. africanum and occurs in all Southern Moçambique, up to the Save River, and in the Tete district.

D. castanea has also been reported to feed on Hibiscus calycinus (Parson, 1927), Cienfugosia Gerrardi Haw. (Hutchinson, 1936), Hibiscus cannabinus (Monteil, 1934), but none of these cases have been observed in Moçambique.

4) - The Pupa - When the caterpillar descends to the ground it burrows down for a short distance and makes a small cell for itself in the earth. Then it excretes a large quantity of saliva around it, and afterwards it spins a web which lines the cell walls. When this is finished it becomes very still until the formation of the pupa. The depth of the cocoon below the surface goes down to 8 cm.

We come now to a very important point in the life-cycle of the Red Bollworm: the duration of the pupal stage. This is remarkably elastic and can last from two weeks to almost a year, under laboratorial conditions. In nature the same sort of phenomenum takes place and we are therefore faced with a case of coexisting short-termed and long-termed pupae, that is, in presence of a typical diapause.

The mechanism of this duality is still unknown. The problem has been studied by several authors but no definite explanation has been found.

There are two main hypotheses put forward to explain these phenomena: in one the arrest is regarded as due to temporary absence of the factors or hormones necessary to maintain growth; in the other, growth is thought to be inhibited by some chemical constituent accumulating in the body.

The first hypothesis has been proved in the case of some insects (e.g. Rhodnius - Hemip.).

The second hypothesis is especially due to an idea developed by Roubaud who regards diapause "as a kind of developmental fatigue (asthenobiosis) which occurs cyclically after a number of active generations and results from an intoxication of the tissues by a surcharge of excretory products which may be transmitted from one generation to the next. It is supposed that this intoxication disappears during a prolonged resting stage at low temperatures (athermobiosis) during which metabolism is much reduced while excretion proceeds". This conception is based entirely on hypotheses.

In the case of Diparopsis castanea, although no definite answer has been found to explain the formation of the two kinds of pupae, one thing has been established: the nature of the pupal period is determined before the pupa is formed. This was conclusively demonstrated by incubating at constant temperatures batches of pupae collected in the field: individuals continued to show widely differing pupal periods.

Pearson and Mitchell (1945) demonstrated that the formation of long termed pupae was not affected by the temperature or moisture conditions in the soil during the pre-pupal stage, that is, the period in which the larvae are in the soil constructing the cell prior to pupation.

It is therefore necessary to go back to the larval stage in the search for factors inducing the formation of the long termed pupae.

These factors can be external, such as temperature, humidity and food supply, or internal, such as genetic and somatic factors.

So far, none of these factors in itself has been sufficient to explain the phenomenum thoroughly, and the general trend is to accept that diapause is due to a combination of all of them or, at least, some of them acting independently.

But whatever the causes are the fact itself is of extreme importance, as the long termed pupae are the only means by which, at least in Moçambique, Red Bollworm reestablishes its populations in the cotton fields, from season to season.

In fact, in this territory, there is no cotton plant in the soil from August to November, and the first squares only appear in late January or February. Therefore only long termed pupae can give rise to the moths that appear in great numbers with the first squares.

Bearing this fact in mind, and wishing to maintain the population of Red Bollworm as low as possible, the only way to achieve it to a certain extent is to cut down its food supply: therefore a clean period or closed season was established, so that the number of annual generations was cut down to four instead of the possible five that we have observed.

Knowing, on the other hand, that late in the season, when the weather is quite cold and the bolls are almost mature, the percentage of long-termed pupae is far higher that at the beginning (when almost all pupae are short-termed), we came to the conclusion that the sooner cotton was uprooted the fewer long-termed pupae were found and therefore fewer individuals would appear at the beginning of the next season.

As the fifth generation appears by the end of August or September (as observed near Milange in 1950) we established that all cotton should be uprooted by the 31st of July, eliminating thus this generation altogether.

But the fourth generation, derived from eggs laid in late June or July, can be partly avoided, as the life-cycle of our varieties allows cotton to be mature before that date. Farmers are therefore strongly advised to uproot the plants as soon as the fibre has been picked and never to wait for the final date to do so.

By eliminating thus as many carrying-over pupae as possible we try to maintain the population of Red Bollworm at a low level.

5) - The Adult - The emergence of the moth takes place in warm weather or after rain, and it is remarkable how the moth tends to emerge at the same time, about the date of appearance of the first squares, that is, at the end of January or February. The period of emergence extends over about five months, with a very pronounced decrease in numbers towards the end, certainly due to the very high percentage of long-termed pupae formed at that time.

After leaving the ground the moth as a rule sits on the nearest plant, sometimes on weeds, where eggs have been found. In most cases, however, they look for a cotton plant to sit on.

Egg-laying takes place for an hour or two after sunset, and this goes on for seven to ten successive nights. Each night fourty to fifty eggs are laid and, under laboratorial conditions, a maximum of 476 eggs laid by one moth during nine days has been recorded.

After laying its eggs the moth settles to rest and it may remain on the cotton plant, where it hides itself on the foliage, or it can be found sitting on grass or on nearby bushes. The first case is the most usual one. The position of the wings is very typical, when at rest, being folded tight against the body, with the dorsal margins touching.

It was thought for a long time, and until very recently, that the Diparopsis moth could not fly over a distance of five miles, for reinfestation purposes. It was thought therefore that a belt of five miles of uncultivated country would be enough to protect a new region opened to cotton from Red Bollworm infestation.

In a conference held in Blantyre (Nyasaland) during 1950 for the control of Red Bollworm and in which we took part as one of the Portuguese representatives, this problem was discussed in connection with the Red Bollworm position in the Lower Shire Valley, where annual infestations went up to one hundred per cent.

English and Portuguese technicians agreed then to carry some experiments on the subject, which can be shortly described as follows:

With centre at Makanga and within a radius of five miles (including therefore Portuguese territory), no cotton plant, cultivated or wild, would be left during a whole season. Complementary, some radial fields would be planted in non-cotton areas, at different distances, to find out how far could the moth fly, in case the five miles radius proved to be too short a distance.

In fact, on the following year, the usual high infestation occurred at Makanga, and one of the radial infestation fields in a non-cotton area twenty five miles to the north, towards Cholo, showed also Red Bollworm infestation.

It is proved, thus, that the moth can fly at least twenty five miles in its annual infestation flight.

6) - Biological control - No parasites have been found on the eggs, larvae or pupae of Diparopsis.

Similarly no predator has been found, except that in the laboratory some ants eat both larvae and pupae kept in glass jars. In Nature, however, as the larvae spend their lives within the boll, ants have very little opportunity to attack them. As far as the pupae are concerned, a certain amount of control might be attained by ants, at least during the period in which the larvae are building their earthen cell, lying therefore unprotected.

Yet, whether it is adverse environmental conditions, or some unknown parasites or predators, or some unknown disease, the fact is that the great majority of the Red Bollworm individuals bred annually do not survive, the populations being kept down at their normal level.

B) - THE SPINY OR SPOTTED BOLLWORM

The genus Earias is African but some of its species occur in Asia, Australasia as well as Southern Europe. In Moçambique and, I think, in most territories of this continent two species occur: Earias insulana, Boisd. and Earias biplaga, Walk.

The Spiny or Spotted Bollworm is universally known as one of the worst enemies of cotton, but in Moçambique, probably due to its wide range of wild and cultivated hosts, its status as a cotton pest is far less important than that of the Red Bollworm. However, it still constitutes one of the main enemies of cotton in this territory, covering all the regions of cotton and inflicting severe damages to the annual productions.

The two local species are very much alike both in their morphology and biology, and are often mixed together. Some constant characters, however, allow the separation of the two species.

We shall deal therefore with some of these morphological characters and give an account of their geographical distribution..

I - EARIAS INSULANA, BOISDUVAL

a) - Synonymy - The variation in colour of the wings has caused several authors to give this species many different names, such as:

Tortrix insulana Boisd.

Earias smaragdinana Zell.
Earias frondosana Wlk.
Earias simillina Wlk.
Earias chlorion Rmbr.
Earias gossypii Fran.
Earias anthophilana Snell.
Earias tristrigosa Butl.
Earias dorsivitta Stand.
Acontia xanthophila Wlk.

b) - Geographical Distribution - According to Willcoks (1937), *E. insulana* is probably indigenous to Egypt, but no further evidence has been found to confirm the fact. *E. insulana*, however, is a very widespread species as it is found in Southern Europe, Africa and Asia.

In Europe its occurrance has been signaled from Spain, Southern Italy, Sicily and Crete. In Asia it has been reported from the Near East, India, Burma, Siam, Indochina, Formosa, Borneo and the Philippines. In Africa it occurs in Egypt, the rest of North Africa, French Equatorial Africa, West Africa, Sudan, Somaliland, Eritrea, Uganda, Tanganyika, Southern Rhodesia, Nyasaland, South Africa and Moçambique. According to Willcoks (1937) this species does not occur naturally in the Americas but it was accidentally introduced to Rio de Janeiro in 1883.

c) - The Egg (fig. 11 and 12) - The eggs are very beautiful, have a diameter of 0.5 mm, are spheroid in shape and slightly flattened at the poles, with longitudinal sculptures, from pole to pole. They can be easily differentiated from those of the Red Bollworm, on account of a sort of crown that exists at their superior pole. Just before hatching, the embryo can be seen through the egg-shell.

When laid, the egg is bright turquoise in colour, being very conspicuous on the plant. Later, they become whitish-green and show a very characteristic brown ring just below the crown. Finally, shortly before the young larvae hatch out, the eggs become dusky to greyish and very difficult to see on the plant.

d) - The Larva - The small larvae, immediately after hatching (fig. 13), measure about 1.0 mm, and their ground colour is very light yellow, almost white. The head is very voluminous in relation to the body, and is bright black. The thoracic plate, in the pronotum, is brown and semicircular, with the base towards the head. The anal plate is darker, subtriangular in shape and has long black setae, inserted in tuberculae. Setae also occur in all body segments.

At the end of the first phase, the bollworm is about 2 mm long. The body is pallid or yellowish and glistening.

Second Instar - At the beginning of the second stage the larvae measure about 2.5 mm. The head and body plates are black and look polished. The hairs are paler than in the first instar.

During this stadium a number of brown markings appear in the body segments, especially in the second and third thoracic, and in the second, third and fifth abdominal ones.

The ground colour is still whitish or pale yellow. At the end of this instar the larvae measure between 4 mm and 5 mm.

Third Instar - The larvae measure now from 5 mm to 6 mm in length. At his stage, the fleshy spine-like tuberculae, with a seta inserted, become very conspicuous, especially on the thoracic segments. This is a characteristic feature of this bollworm.

The tuberculae are dorsally placed on the thoracic and first abdominal segments, whereas on the other abdominal segments they are dorso-laterally placed.

The head has two large chitinous black plates in the cephalic region, but the frons region is brown. The thoracic shield is now also brown, except at its posterior margin and for a transverse line at its centre, which are darker. The anal plate is still black.

On the nineth abdominal segment, and over the median dorsal line, a small triangular shield can be seen, with its base at the posterior margin of the segment. The colouring is now pale to ivory with a light reddish brown and denser areas of reddish brown forming a distinct pattern. Towards the end of this stage an orange colouration develops at the base of the tuberculae. At the end of the stadium the larvae measure about 8 mm in length.

<u>Fourth Instar</u> - At the beginning of this stage the larvae measure about 9 mm in length. During this stadium no striking changes take place but the markings already described become more conspicuous.

The pale transverse band at the front of the head becomes more marked. The thoracic plate becomes paler but now the posterior margin shows no darker colouration. The median transversal darker line persists. The anal plate becomes also less densely coloured. The reddish-brown colouring turns now into a purplish-brown. There is, however, at this stadium a fairly pronounced variation in tint of the colouring. At the end of the stage the larvae measure about 10 mm in length.

<u>Fifth Instar</u> - At the beginning of this stage the larva measures about 12 mm in length (fig. 14) and is quite thick in front and tapering posteriorly. There is little change in appear-

ance following the fourth moult. The ground colour is paler but remains ivory.

The head is dark brown and the transversal ivory band of the frons shows very well, with its posterior margin not well marked. The pronotum is now very light in colour and has two ivory transverse bands, each with a brown line at its posterior margin. The pronotum has no tuberculae but has two black stigmata.

All the other body segments carry four tuberculae, each bearing a seta at the top. Sometimes the first abdominal segment carries six tuberculae but this is not very common. The tuberculae are placed in the following way: two are adjacent to the median dorsal line and the other two are laterally placed. Some of the tuberculae are greyish-purple, others are light in colour, especially those of the second and third thoracic segments which have yellow-orange bases. Each thoracic segment has four brownish-grey spots, of which two are placed between the dorso-lateral tuberculae and the other two between the dorso-lateral and the lateral tuberculae. Each spot has a light-brown hair at its centre.

All abdominal segments carry also four brownish spots, with a light-brown hair in the centre; the size of these spots varies considerably, those of the second, third and fifth segments being the larger.

The fully grown fifth instar larva measures up to 16 mm in length. The thoracic legs are light brown. The pseudolegs are creamy and their "crochets" are disposed in a wide arch, opening outwards.

c) - <u>The Pupa</u> (fig. 15) - The pupa has 9 - 11 mm in length. The outline of the head, wings and legs is light brownish-yellow, whereas that of the thorax is darkish brown. The abdomen is brown and lighter than the thorax.

Prior to the formation of the pupa the fully grown larva forms a cocoon, over the plant or in the soil, with a very typical shape: it looks like a small boat with the keel turned upwards (fig. 16), within which the pupa will be formed. The cocoon measures 10 mm to 13 mm in length and its outside is ivory or amber in colour. The inside is almost white.

f) - The Adult (fig. 17) - The moth has a wing span of about 22 mm and is 9 mm in length. Its colours are very variable with the time of the year. They can be bright green, yellowish-brown and the winter forms can be very pale yellow, almost white. The most common type, however, has the head, thorax and forewings of a bright pea-green. The fore-wings have, as a rule, three brownish waving lines (submarginal, median and submedian), running across its width. The hindwings are usually whitish or greyish, with a brownish marginal area. The abdomen is also whitish or greyish, with a brownish marginal area. The abdomen is also whitish or greyish.

MORPHOLOGICAL DETAILS

1) - Labial palps (fig. 18) - Turned upwards and forwards with three articles. The first is subclaviform, with a length three times its maximum width. The second is arched, subcylindrical, twice as long as the first. The third is also subcylindrical, with a slight thickening at the tip, and slightly shorter than the second.

2) - Wings - The forewings are subtriangular in shape, with a distal anterior angle of about 60°. The hindwings have a length slightly inferior to the double of their maximum width.

3) - Legs - The tibiae of the first pair (fig. 19) have a large pointed spur, with a length slightly superior to half of that of the tibiae. The tarsi are double the length of the ti-

biae. The tibiae of the second pair have a pair of long narrow spurs. In the male of this species, both femurs and tibiae of this pair of legs have long and abundant setae (fig. 20). The tarsi are slightly longer than the tibiae. The third pair presents two pairs of spurs in the tibia. Tarsi are longer than the tibiae (fig. 21).

II - EARIAS BIPLAGA, WALK.

a) - Synonymy - Although there is also a great variation in the colouring of the moth, there are very few synonyms for this species:

Earias fusciciliana, Snell.
Earias maculana, Snell.
Earias plaga, Feld.

b) - Geographical Distribution - This species has a much smaller distribution and appears to be entirely African. It has been reported from almost all cotton areas of this continent, namely from the French Sudan, Sierra Leone, Nigeria, Guinea, Togo, Belgian Congo, Uganda, Tanganyika, Southern Rhodesia, Nyasaland, South Africa and Moçambique. Apparently it does not occur in Egypt.

c) - The Egg - The egg of this species is similar to that of E. insulana and can in no way be differentiated from it.

d) - The Larva - It is very difficult to differentiate the larvae of the two species. Up to the third stadium they are so similar that we could not find one true distinctive feature.

On the fourth, but especially on the fifth instar there are some differences that can be used as diagnostic characters.

The ground colour is orange-grey or almost orange, with brownish spots.

The head is dark brown, with ivory bands near the sides of the antennal-postfrontal sutures and a double crescent transverse band, ivory in colour, occupying the genae and the apex.

The pronotum is light yellow in colour and has a small shield formed by two brown transverse bands joining at the sides, the interior of which is occupied by a white transverse band. The stigmata, which are black, are placed laterally and at the meeting point of the two brown bands.

The second thoracic segment is very light in colour. It has four tuberculae, two being dorsal and having a purplish hairiness, the other two being laterally placed and with a whitish hairiness, the hairs being shorter than in the dorsal pair. The third thoracic segment is darker and carries four tuberculae similar to those of the second and in the same position. The base of all thoracic tuberculae is orange in colour.

But it is in the abdominal segments that we found a very interesting difference between the two species: while in E. insulana all abdominal segments carry always, or almost always, four tuberculae per segment, in E. biplaga the first six abdominal segments have six spiny tuberculae, the seventh and the eighth have only four, the ninth has six again and the tenth has four reduced ones. This character is definitely a diagnostic one.

The thoracic legs are black externally and greyish on the inside. The pseudolegs are very similar to those of E. insulana.

e) - The Pupa - The pupae are very similar in the two species, as well as the cocoon but this, in E. biplaga, is more yellowish in colour.

f) - The Adult - The moth has a wing span that can vary from 20 to 25 mm and is 10 mm to 12 mm long. The colour of the head, thorax and forewings is very varied with the time of the year, and it ranges from ocraceous yellow to bright green. In all cases the distal margin of the forewings is well marked with a purplish-brown band across the width of the wing. This marginal band of the forewing has never been observed in E. insulana and can serve, therefore, as another diagnostic character. Very often the forewings have a large brown spot with angular sides, occupying two thirds of the width of the wing (fig. 22). Hence the specific name. In some of the dry season forms, three transverse brown lines appear across the forewings, with more marked angles than in E. insulana, where the lines are more undulating than angular.

The hindwings are whitish or greyish in colour. The abdomen is also whitish or greyish.

MORPHOLOGICAL DETAILS

1) - Labial palps - Three articles. The first is subcylindrical, with a length about three times its maximum width. The second is claviform with a rounded anterior margin. It has a length three times its maximum width, and is about one third longer than the first. The third, in the female, is subcylindrical, with a rounded distal end and approximately as long as the first (fig. 23). In the male this article is very short, egg-shaped, about as long as one third of the second, and inserted in it at the ventral face of its distal quarter (fig. 24).

2) - Wings - The forewings have a subtriangular shape and are twice as long as wide. The distal anterior angle measures about 80°. The hindwings have a length twice the width.

3) - Legs - The tibiae of the first pair (fig. 25) have a thick short spur, inserted at its middle. The tarsi are twice as long as the tibiae and their first article is as long as the following three together.

The second pair is identical in both sexes and this differs from E. insulana where the legs differ with the sexes. The first article of the tarsi is slightly shorter than the other four together (fig. 26).

In the third pair the first article of the tarsi is as long as the following three together (fig. 27).

III - LIFE HISTORY OF EARIAS SPP.

As these two species of Earias have a very similar biology we shall deal, from now on, with them together.

1) - Oviposition, Incubation Period and Hatching.

The first Spiny Bollworm eggs are found on the cotton plant about the middle of January, that is, a month or a month and half after the sowing dates.

At the beginning, before the appearance of the first fruiting branches, the eggs are found at the end of the main stalk or in some of the new and tender branches, and very often on the leaf petioles.

With the appearance of the flower buds and small bolls, however, we find them mainly on the peduncles, the bracts of the epicalyx, the petals or on the bolls themselves.

In insectaries numerous eggs are found in a single flower bud or boll, but in Nature only a limited number of eggs is found together over the same plant organ, giving the impression that the moth flies from organ to organ, or even from plant to plant, while laying its eggs.

The incubation period of the egg varies with the time of the year, temperature being a very important factor, and is shorter during the warm months. From February to April incubation takes from two to four days but in the great majority of cases recorded it takes only two days. From May onwards it takes from three to six days but in most cases it takes five days. All these results were obtained under laboratorial conditions.

When hatching is about to take place the egg has a very characteristic appearance, showing the brown ring, already referred to, very distinctly. This brown ring is the embryo seen by transparency. The young larvae, when hatching, bite the chorion at no special place and make a small hole which they gradually enlarge until they can leave the egg-shell. The process takes thirty to fourty minutes altogether, including the resting periods while the hole is being enlarged. Some 100 to 200 eggs are laid by each female.

2) - <u>The larvae</u> - After hatching and as in the case of the Red Bollworm, the young larvae show immediately a period of great activity. But instead of looking straight away for their first meal, as in the case of the Red Bollworm, the larvae have a more or less prolonged wandering period over the plant. In fact if the eggs are laid on a flower bud or on a young boll, the lar-

vae on hatching do not try to make their way in immediately, but walk over it for a certain time and sometimes abandon it and look for another one.

This is a very important fact in the life-cycle of the Spiny Bollworm, as it turns its young larvae, in contrast with those of the Red Bollworm, very vulnerable to possible enemies, parasites or predators, or even to chemical control.

If when the young larvae hatch the plants carry neither bolls nor flower buds, then they attack the terminal bud of the shoot or of the branches, by eating its meristemetic tissue. Sometimes they even enter the shoot by making a longitudinal tunnel, which can be seen full of excreta. But in most cases they only eat the bud, after which they look for another one. Again the larvae are exposed to their natural enemies as well as to chemical control.

But as soon as the plant has fructiferous bodies the larvae show an immediate and complete preference for these, and they attack squares and young flowers by making an orifice at their base and eating their way up. Both squares and flowers are eventually shed (fig. 28).

When finally the bolls appear the larvae show again a preference for these and attack them in all stages of development, the bolls being eventually shed.

The caterpillar enters the boll by digging a hole at its exterior wall, which is steadily increased until the larva has built a gallery big enough to enter it completely (fig. 29). The excreta can be seen on the outside, often kept together by the bracts. The galleries opened by the larvae of the Spiny Bollworm, have an irregular shape.

The larvae eat everything within the boll but show a marked preference for the seeds, of which they eat the interior. They move from loculus to loculus, often without finishing up the contents of any particular one. They move too from one boll to the other, showing again this ambulatory character so different from the larvae of the Red Bollworm. This character is present in larvae of all stages.

Two larvae have been found in the same boll but this fact is most uncommon. If a boll is shed with a larva on the inside, the boll will be abandoned and the larva will climb the cotton plant looking for more food.

The bolls attacked by the Spiny Bollworm, even if not shed, which happens quite rarely, are completely lost for all purposes as their interior is practically eaten up or destroyed..

The duration of the larval stadia varies with the time of the year and is sensibly shorter in the warmer months, temperature apparently being again an important factor.

We found that it can range from eight days to twenty days. At the beginning of the year it lasts about ten to twelve days while later, during the winter, it lasts fifteen to eighteen days. These results were all obtained in the laboratory.

3) - Host Plants - Earias spp. have a great range of hosts especially amongst the Malvaceae. Amongst others we have found them in all species of Gossypium and many Hibiscus (H. esculentus, H. cannabinus, H. rosa-sinensis) as well as on the genus Abutilon (A. grandiflorum, A. indicum) and on the genus Sida (S. spinosa). Earias insulana has also been found in Zea mays.

The behaviour of the Spiny Bollworm has not been studied for all these hosts except for Abutilon grandiflorum, where it behaves very much in the same way as in the genus Gossypium.

4) - The Pupa - The pupa can be found in many different places. Pupation may occur on the organ where the larva has been feeding, on a healthy boll, on the internal face of the bracts of the epicalyx, sometimes on leaves, on the main stem, on branches, at the surface of the soil and even on fallen parts of the plant where the larva had been feeding. In India, R. D. Mihra (1935) observed that pupation could occur under the soil surface, at a depth of five to twenty five centimeters. This case has never been observed in this territory but it is very probable that it occurs quite often as one does not see many cocoons in the field.

In the laboratory, on Petri dishes, pupation occurs everywhere but especially on the feeding material or on the angle formed by the base and walls of the dish.

When the larvae of the fifth instar are fully grown they leave their last feeding place and have a migratory prepupal stage. This migration can be short or relatively long as the larva may go from one plant to another before pupating. Again the ambulatory character of these species.

Just before pupation the larvae become sluggish and show very little activity. The spinning of the cocoon is very interesting but very difficult to describe. The "skeleton" of the boat is first built and attached to a support on the plant or wherever pupation occurs, and then the walls are spinned and closed over the larva within.

The duration of the pupal stage again varies with the time of the year. In the laboratory it ranges from seven to twenty four days. At the beginning of the year the moth often emerges after eight or nine days. But in July, for instance, the pupation period often last sixteen, eighteen or even more days.

The Spiny Bollworm has only one kind of pupae, diapause never been observed by us or reported elsewhere, in contrast with the Red Bollworm. The annual infestation of the cotton fields derives from normal generations that go on feeding on the numerous wild host plants, right through the year.

5) - The Adult - The adult is essentially an insect with nocturnal habits, although some moths may be seen flying in the cotton fields at sunset. During the day the moth is very seldom seen and it remains hidden under the foliage, on the bracts of the epicalyx and on the branches. Mating occurs during the night but in the laboratory I have observed one case of copulation during the day.

Egg laying starts at sunset and goes on for a few hours, with intermediate resting periods at irregular intervals. The number of eggs laid by a single female is very difficult to be accurately counted as the eggs are laid separately and sometimes in different plants. In the laboratory the maximum number of eggs laid by one female was 271, at a temperature of about 26° C, during five successive nights.

R. D. Mihra, in India, reports that E. insulana and E. fabia lay from 400 to 450 eggs during the week that follows copulation. I have never observed such high numbers under local conditions.

The longevity of the adult, under laboratorial conditions, ranges from twelve to thirty three days, when fed with a sugar solution. Willcoks reports from Egypt that the moth of E. insulana can live up to sixty days when fed with honey and water. No data was found on the longevity of the adult in the field.

6) - Natural control - Most individuals of the six annual generations of Earias spp. must die before their life-cycle is completed or otherwise at the end of one season we should have an immense number of Spiny Bollworms, and this does not happen. Therefore there are some natural factors that keep their numbers at theirusual level, as a stable population.

Although some Authors mention both predators and parasites of the Spiny Bollworm we have never been able to find them on the thousands of eggs, larvae and adults delt with. In any case, the Braconid parasites referred to by those Authors do not achieve any real control as only a very small percentage of larvae seemes to be parasitised. It is possible on the other hand that some birds and fowl act as predators, especially at the periods when the larvae move from one feeding place to another, but again I do not think that any significative control is achieved in this way.

It is therefore possible that the high mortality of Earias individuals is mainly due to lack of food material and to accological factors.

In fact, when in a vast territory like Moçambique cotton is all uprooted at once, the food situation for millions of individuals should become extremely difficult, inspite of all the wild hosts that exist in nature. The mortality must therefore be very high when uprooting takes place, and the following generations should constitute a much smaller population. The following cotton season should provide again enough food for the building up of a large population which, due to the same causes, should be cut down in numbers at the end of the season. And so we ought to have a cyclic chain of large and small populations in accordance with the food available.

But the climatic conditions should also play a very important part in keeping the populations of Spiny Bollworm at their normal balanced numbers. T. Ahmad and G. Ullah, working with E. insulana in the Punjab, found out that the temperature of 40° C is a vital limit for the preadult stages and that the first larval stages need a high hygrometric condition.

If in Africa the temperature conditions are the same, and they very probably are, there are regions where the Spiny Bollworm will certainly be affected as the temperature raises above that limit, and it should be expected that the preadult stages should die in great numbers.

The higrometric conditions of most of our cotton areas should, on the other hand, be quite favourable to the normal development of the Spiny Bollworm as the humidity is normally very high.

This part of the biology of Earias spp., however, requires further studies which will be done in the future.

C) - THE COTTON JASSID

The Cotton Jassid of Moçambique and of the neighbouring territories belongs to the genus Empoasca (Hem., Hom., Auch., Cicad., Jass.) and the local species is E. facialis, Jacobi.

Until quite recently the Cotton Jassid was an extremely important limiting factor of the cotton culture in Southern Africa due to the very considerable damages caused to American Upland cotton, Gossypium hirsutum, normally the only cultivated species, south of the Equator. In fact, Jassid damages were so high that the cultivation of cotton was not an economical crop until Parnell in 1935 bred Jassid resistent varieties at Barberton. This breeding work was of extreme importance and Parnell based it in the hairiness of the plant: the hairier the plant the greater the resistance to Jassid. Through this extremely good piece of work Jassid is no longer a pest of great importance to the crop.

DESCRIPTION

1) - Synonymy - We have only found one synonym for the Cotton Jassid which is Chlorita facialis Jac.

2) - Geographical Distribution - Empoasca facialis Jac. has been reported from the French Sudan, Southern Mauritania, Senegal, Togo, Belgian Congo, Southern Rhodesia, Nyasaland, South Africa and Moçambique, where it occurs in all cotton areas. It is possible that it might occur in other african territories but we have no available data on the subject.

3) - The Egg - During the last three years we have examined thousands of leaves and have made serial cuts of leaf petioles as well as of leaf veins. Unfortunately and in spite of this we have not yet been able to find a Jassid egg. According to Leroy (1936), the eggs are greenish white in colour, translucent, cylindrical but slightly curved and are 1.0 mm in length.

4) - The Nymphs - The study of the nymphs was made in Petri dishes, under laboratorial conditions, at a room temperature of about 26° C. Fresh leaves were daily placed in the dishes and each dish contained one single nymph which was kept under close observation. There are five nymphal stadia that can be described in the following way:

First instar - The first instar nymph (fig. 30) is almost colourless and measures 1.0 mm in length. They show very little activity but when disturbed move rapidly sideways.

Second instar - The nymphs of the second stadium (fig. 31) measure at the beginning of this stage about 1.2 mm and are very pale green in colour. Soon, however, they become completely green or yellowish-green. They show quite an intense activity moving rapidly sideways on the undersurface of the leaf. At the end of the stage the young nymphs measure about 1.5 mm in length.

Third instar - At the beginning of this stage the nymphs are about 1.6 mm long (fig. 32), and again show the same discolouration, but soon become green or yellowish-green. This discolouration is observed at the beginning of all stages. The third instar is characterised by the appearance of the wing rudiments, respectively at the meso and metathorax. The nymphs are very active and at the end of this stadium they measure about 1.9 mm.

Fourth instar - The nymphs at the beginning of this stage (fig. 33) measure approximately 2.0 mm in length. The eyes show a slight purplish colouration which is also noticed in all the posterior phases. The wing rudiments reach the posterior limit of the second abdominal segment. At the end of the phase the nymphs are about 2.3 mm long.

Fifth instar - The nymphs attain now a length of about 2.8 mm (fig. 34) and the wing rudiments reach at this phase the fifth abdominal segment. All nymphs show the characteristic lateral movement, as soon as they are disturbed.

5) - The Adult (fig. 35) - The adult is elongate, delicate and pale green in colour, and measures up to 4.0 mm. The elytra are transparant and much longer than the abdomen. The wing veins are as in fig. 36. The genital valve is wanting in the male. The female has a saw-like ovipositor (fig. 37). The head has a faint line that runs from the centre of its posterior margin to the end of the frons and the antennal flagella are composed of numerous joints. The tips of the tarsi and of the rostrum are brown. The tibiae of the hindlegs have a double row of large spurs.

6) - Life-cycle - According to Leroy (1936) the eggs are laid in the petiole or the leaf veins in a plan parallel to the leaf blade. The incubation period lasts from six to eight days. According to Cowland (1947) each female lays an average of 250 to 300 eggs.

The nymphal stages last from six to thirteen days and the duration of each stage, according to the results obtained under laboratorial conditions, can be summarised as follows:

First phase	1 to 2 days
Second phase	1 to 2 days
Third phase	1 to 2 days
Fourth phase	1 to 3 days
Fifth phase	2 to 4 days
Total	6 to 13 days

But in most cases the nymphal stages observed last from eight to ten days, after which the adult emerges. The nymphs are very mobile and keep almost always to the undersurface of the leaves, where they feed. It seems also that sunlight has an harmful effect on them as in nature one never sees them exposed to the sun.

The adult can be seen flying early in the morning or towards sunset but otherwise is almost always observed on the underside of the leaves. It can fly very swiftly but never for considerable distances, often landing on the same plant or on the neighbouring ones. The adult seems to be very timid because as soon as we touch the plants it flies immediately away.

The duration of the adult stage is very variable but in the laboratory we kept a female alive for fourty seven days; we can state quite safely, however, that the average adult lives from two to five weeks.

The adult, but especially the nymphs, feed by sucking the sap from the peticle but mainly from the leaf veins. This mechanical action blocks the leaf vessels and interferes with the translocation of the plant fluids. Parnell (1927) thought that while sucking the sap this insect also inoculated some poisoning substance very harmful to the plant, but this has not been confirmed.

The feeding action of the Jassid has, nevertheless, a very bad effect on the cotton plant and if the attack is very severe the plant might even be killed.

The first symptons of the damage caused by a Jassid attack which were observed on old U4 varieties of very little pubescence, are a slight yellowing of the leaves towards the margin, which is often limited on the inner side by the veins. As this yellowing process becomes more pronounced the leaves curl with the edges turned down (fig. 38). At this stage several nymphs will be found on the underside of the leaves, together with some adults. Soon a general redening takes place, from the periphery inwards, followed by the shedding of the older leaves, while the younger leaves do not develop properly and remain small with the margins of a brown dried up colouration. If the attack is very rapid and severe most leaves will turn brown and dry up in the plant, and the plant itself might be killed, but this happens very seldom.

In the normal sort of attack, however, redening of the leaves is followed by an arrest of the plant development and shedding of buds and young bolls occurs. Well developed bolls will either dry up or give fibre that can hardly be used for any purpose.

Under normal conditions Jassid does not appear in any number on the cotton fields before January, that is, a month or a month and a half after sowing with the first rains and therefore well beyond the seedling stage. When cotton is sown early, Jassid attacks are less severe. This is due to the existence of young leaves from an early date, allowing a gradual establishment of the Jassid populations.

The attacks under normal conditions become conspicuous towards the end of February and if the plants are not sufficiently hairy the crop can be seriously hampered through shedding of squares and bolls of all ages.

It is very important to notice, on the other hand, that if cotton is sown before the first rains, that is, under partial irrigation (the case of some long-cycled, non-pubescent Egyptian varieties which are under trial at one of our stations), the establishment of large Jassid populations, about the same date, i. e. towards the end of February, does not seem to have a significant effect on the final production. In fact, when we compare the figures for the productions of unprotected plants and plants treated with 10 % D.D.T., we have the following results:

TABLE I +

VARIETY - BAR - 4/16

Sowing date	Total wt. of seed-cotton per plant in grams		Difference of productions expressed as a percentage of the untreated production.
	Treated with 10% DDT	Untreated	
22/10/51	269.5	244.1	+ 10.4
22/11/51	182.5	148.4	+ 23.2
22/12/51	84.0	30.7	+ 173.6

\+ These results, still unpublished, were obtained from trials carried out at one of the stations of this Centre (Limpopo Valley), together by the Departments of Agronomy and Entomology.

TABLE II

VARIETY - BLR - 14/25

Sowing date	Total wt. of seed-cotton per plant in grams		Difference of productions expressed as a percentage of the untreated production.
	Treated with 10% DDT	Untreated	
22/10/51	170.4	158.3	+ 7.6
22/11/51	165.7	131.1	+ 26.4
22/12/51	90.5	26.1	+ 246.7

It can therefore be stated that cotton sown before the rainy season, that is, under partial irrigation although non-pubescent, has acquired enough strength by the time of the main Jassid infestation inasmuch as to have a final production practically identical to that of treated plants.

If, however, the non-pubescent varieties are sown at the usual time, that is, with the first rains, Jassid infestation has a very important effect on the final production, which decreases conspicuously with late sowing, as seen in the above table.

In Moçambique, therefore, where so far only rain cultivated cotton is used, only Jassid resistent varieties can assure economical results and a high production.

If we consider, on the other hand, the number of leaves attacked by Jassid, and the number of Jassid nymphs per leaf, on a total of ten plants (five treated with 10% D.D.T. and five untreated) from each of the five Egyptian varieties under trial, we get the results of Tables III - IX.

TABLE III

SOWING IN 22/10/51

VARIETIES		DATE OF COUNTS									
		27/2/52		29/3/52		30/4/52		30/5/52		28/6/52	
		Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs
BLR 14/25	Treat.	3	4	6	92	5	8	1	1	0	0
	Untreat.	1	5	27	78	47	158	18	31	0	0
BAR 4/16	Treat.	5	8	5	7	7	9	0	0	0	0
	Untreat.	10	21	32	60	43	127	22	10	0	0
X 1730-A	Treat.	5	5	18	28	9	13	2	2	0	0
	Untreat.	4	7	32	50	46	131	29	46	1	1
BAR 1730-4	Treat.	4	5	10	14	6	10	1	1	0	0
	Untreat.	5	7	38	112	43	150	31	62	1	1
BLR 14/16	Treat.	2	2	1	1	8	12	0	0	0	0
	Untreat.	7	7	29	62	37	96	25	49	2	2
AVERAGES	Treat.	3,8	5,8	8	28,4	7	10,4	0,8	0,8	0	0
	Untreat.	5,4	5,4	31,6	72,4	43,2	132,4	25,0	39,6	0,8	0,8

TABLE IV

SOWING IN 22/11/51

VARIETIES		DATE OF COUNTS									
		27/2/52		29/3/52		30/4/52		30/5/52		28/6/52	
		Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs
BLR 14/25	Treat.	2	2	2	3	6	8	2	2	0	0
	Untreat.	9	14	38	105	43	123	21	30	0	0
BAR 4/16	Treat.	3	5	6	7	6	11	2	2	0	0
	Untreat.	9	11	39	102	46	164	32	39	1	1
AVERAGES	Treat.	2,5	3,5	4	5	6	9,5	2	2	0	0
	Untreat.	9	12,5	38,5	103,5	44,5	143,5	25,1	34,5	0,5	0,5

TABLE V

SOWING IN 22/12/51

VARIETIES		DATE OF COUNTS									
		27/2/52		29/3/52		30/4/52		30/5/52		28/6/52	
		Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs
BLR 14/25	Treat.	2	3	16	41	16	25	0	0	0	0
	Untreat.	16	36	47	243	49	297	22	69	3	3
BAR 4/16	Treat.	12	19	11	15	9	16	4	4	0	0
	Untreat.	3	3	46	129	46	261	25	30	5	5
AVERAGES	Treat.	7	11	13,5	28	12,5	20,5	2	2	0	0
	Untreat.	9,5	19,5	46,5	126	47,5	279	23,5	149,5	4	4

TABLE VI

SOWING IN 22/1/52

VARIETIES		DATE OF COUNTS									
		27/2/52		29/3/52		30/4/52		30/5/52		28/6/52	
		Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs
X 1730-A	Treat.	1	1	12	14	9	14	6	6	0	0
	Untreat.	3	4	28	57	49	180	41	102	4	4
BAR 1730-L 1	Treat.	3	6	7	9	7	10	0	0	0	0
	Untreat.	8	13	42	148	46	190	37	95	4	4
AVERAGES	Treat.	2	3,5	9,5	11,5	8	12	3	3	0	0
	Untreat.	5,5	8,5	35	102,5	47,5	185	29	98,5	4	4

TABLE VII

SOWING IN 22/2/52

VARIETIES		DATE OF COUNTS									
		27/2/52		29/3/52		30/4/52		30/5/52		28/6/52	
		Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs
X 1730-A	Treat.	-	-	5	8	7	10	4	4	0	0
	Untreat.	-	-	4	4	50	211	45	109	3	3
BAR 1730-L 1	Treat.	-	-	7	10	10	20	2	2	0	0
	Untreat.	-	-	22	39	50	247	39	105	4	4
AVERAGES	Treat.	-	-	6	9	8,5	15	3	3	0	0
	Untreat.	-	-	13	21,5	50	229	42	109	3,5	3,5

TABLE VIII

SOWING IN 22/3/52

VARIETIES		DATE OF COUNTS									
		27/2/52		29/3/52		30/4/52		30/5/52		28/6/52	
		Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs
BLR 14/16	Treat.	-	-	-	-	9	16	4	4	0	0
	Untreat.	-	-	-	-	49	189	41	83	4	4

TABLE IX

SOWING IN 22/4/52

VARIETIES		DATE OF COUNTS									
		27/2/52		29/3/52		30/4/52		30/5/52		28/6/52	
		Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs	Nº of leaves	Nº of nymphs
BLR 14/16	Treat.	-	-	-	-	-	-	3	3	0	0
	Untreat.	-	-	-	-	-	-	38	90	4	4

It is therefore to be concluded from these experiments, that the later the cotton is sown the higher the influence of Jassid is on the final production, and that Jassid is an extremely important limiting factor of the crop if non-resistent varieties are used on a rain cultivation system, as it is entirely done in this territory.

As non-pubescent Egyptian varieties, on one side, only started being experimented during the last season, and, on the other hand, the economic position of the native farmer (practically the only cotton grower in Moçambique), does not allow him to buy insecticides, it is evident that, so far, only resistent varieties can be grown in this Province. And, as Parnell proved (1949), if resistence to Jassid is conferred by the hairiness of the plant, then all varieties to be used in this territory must be of this type.

The Indian School of Thought, as stated by Husain and Lal (1940), Lal (1941), Afzal (1941), Afzal and Manzoor (1944) and Lal and Husain (1945) does not seem to regard the hairiness of the leaves as the factor conferring cotton resistence to Jassid. Lal (1938) went as far as suggesting that "resistence to Jassid attack is due to some peculiarity of the leaf veins that prevents oviposition". But the work of Parnell is so conclusive that no doubts can exist as to the factor conferring resistence to Jassid. In this territory, <u>in all cases</u>, only highly pubescent strains are satisfactorily resistent to <u>Empoasca</u>.

The mechanism of the resistence conferred by hairiness is not yet fully understood, although the hairiness and the length of the hair itself have shown to be of prime importance; highly densed leaves, where the hairs are short, do not show a high degree of resistence. The ideal pubescence is that that combines a good density of hairs with a good length.

According to Hanna (1950) the splashing of mud from the soil onto the lower sides of the leaves has a controlling effect on Jassid populations. In this territory nothing similar has been observed, either because the rains are not sufficiently strong to lift soil particles to such an extent as to give protection to the leaves or because the soils have a different texture.

7) - Host Plants - Cotton Jassid has been found on many Malvaceae, namely on all species of Gossypium, on Hibiscus (H. esculentus, H. cannabinus), and Abutilon (A. grandiflorum); it has also been found on Euphorbiaceae - Ricinus communis, and Solanaceae - Solanum tuberosum, as well as on many Gramineae and Leguminosae. As cotton is all uprooted by the 31st of July, Empoasca must spend the close season on the other host plants and, from what I have observed, especially on the Gramineae.

8) - Biological control - Neither parasites nor predators have been found in the thousands of individuals delt with, except that in a few cases ants were seen carrying nymphs away. It is doubtful, however, whether this constitutes a normal proceeding or just an accidental case but I am inclined to the latter on account of the very few cases observed.

D) - THE COTTON STAINERS

The Cotton Stainers belong to the genus Dysdercus (Hem., Heter., Gymn., Pyrrhocoridae, Pyrrhocorinae). This genus possesses a fundamental difference from the other genera of the subfamily, as pointed out by Stål, in having the wing complete and without a hook. Its species are very abundant and widely distributed, and found throughout the tropical and subtropical regions of the world.

In Moçambique three species occur attacking cotton, namely:

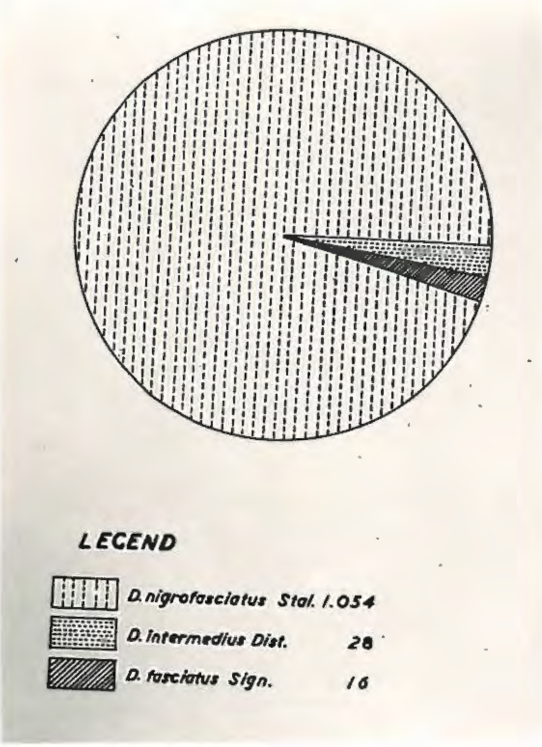
- Dysdercus fasciatus Signoret
- Dysdercus nigrofasciatus Stål
- Dysdercus intermedius Distant

Pierre Lesne (1930) refers to the occurrance of D. superstitiosus Fabricius, in great numbers in the Chemba region (Zambezi Valley). In our numerous trips to that region, however, we have never collected this species and never seen it in any other region of Moçambique. J. E. Baptista (1945) also never mentioned this species in his paper. Further, the only specimen we have ever seen of D. superstitiosus F. exists in the collection of the Moçambique Department of Agriculture and comes from the Union. As P. Lesne did not leave a specimen in any collection, and did not even describe the species, we consider D. superstitiosus F. as not occurring in Moçambique until it comes on record.

1) - Geographical Distribution - The three species occur in all the cotton areas of Moçambique but their abundance varies

greatly with the different regions. In a general way it can be stated that D. nigrofasciatus is by far the most abundant species up to the Limpopo, whereas to the north of this river D. fasciatus is the dominant form. D. intermedius occurs everywhere but almost always in small numbers, except in the Gorongosa region of Manica and Sofala Districts, where we have observed twice (in 1950 and 1951) large and dominant populations of this species.

To give an illustration of the differences in numbers in which the three species occur we drew the following graph, representing the population of each species collected during January in Lourenço Marques:



2) - Interspecific Coupling - Very little success was attained in coupling trials. All possible modalities were tried but little was achieved. A male intermedius had intercourse with a female nigrofasciatus, but the female never laid eggs.

It is interesting to notice, however, that we collected a specimen of one Abutilon grandiflorum which showed characters in common with D. nigrofasciatus and D. fasciatus, and these characters were the following:

a) - The colour of the hemi-elytra and the transverse band of the posterior margin of the pronotum resemble those of D. nigrofasciatus.

b) - The markings of the anterior and lateral margins of the pronotum are similar in colour to those of D. fasciatus, but resemble D. nigrofasciatus in shape and dimensions.

c) - The transverse bands of the abdominal sternites of this specimen are different in shape and colour and more or less intermediate between those of D. nigrofasciatus and D. fasciatus (fig. 39).

This specimen is kept in the collection of this Centre and it might represent the cross between the two above mentioned species, but the existence of a single specimen does not allow a definite conclusion. No other special case was ever observed.

3) - Specific Determination - According to Baptista's dichotomic Key (1945) the adults of the three species can be distinguished in the following way:

I) - Posterior margin of the pronotum with a black transversal band. Nineth abdominal segment of male more or less spherical - II) or III)

- Posterior margin of the pronotum with no black transversal band. Nineth abdominal segment of male with a projecting keel.

DYSDERCUS INTERMEDIUS DISTANT (fig. 40)

II) - Band of the posterior margin of the pronotum uniformly thick. Rostrum reaching the second visible abdominal segment. Tubercles of the posterior lobes of the nineth abdominal segment of the male are separate:

DYSDERCUS NIGROFASCIATUS STÅL (fig. 41)

III) - Band of the posterior margin of the pronotum thicker at the middle than at the sides. Rostrum reaching the posterior margin of the third visible abdominal segment. Tubercles of the posterior lobe of the nineth abdominal segment of the male are united:

DYSDERCUS FASCIATUS SIGNORET (fig. 42)

To this we add the following diagnostic character:

a) - Coxa, trochanter and femur bright red:
D. intermedius

b) - Coxa, trochanter and femur orange-red:
D. nigrofasciatus

c) - Coxa, trochanter and femur black:
D. fasciatus

4) - Life-cycle - The study of the life-cycle of the three species of stainers was made on the laboratory, from December to April. The room temperature was about 26° C and the relative humidity very high, reaching 100% in the Petri dishes.

The Dysdercus couples were placed on glass jars covered with gauze and Petri dishes, inside which cotton seed, bolls in different stages of development and wet cotton wool were also placed. For the daily observations two or three nymphs were isolated and observed under the binocular lens, fully alive or under the influence of chloroform.

a) - The egg (fig. 43) - The eggs of the three species are identical and practically impossible to be differentiated. They are oval in shape, have a smooth, bright surface, are white in colour and measure about 1.5 mm in length. On the third or fourth day the egg becomes pearl-yellow in colour. There is always a small percentage that remains white and from these there is no emergence of nymphs. The incubation period for the three species varies between four and nine days.

b) - The nymphs - Cotton stainers have metamorphosis of the hemimetabolic type, and have five nymphal stages.

First Instar (fig. 44) - During the first stadium the nymphs of the three species cannot be differentiated. When recently hatched, they all measure about 1.5 mm and there is no visible difference between the thoracic and abdominal segments. The tibiae and tasi of all legs are colourless and translucent. The femurs, antennae and rostri are slightly pigmented but also translucent. The head, thorax and abdomen are uniformly toasted-yellow and the compound eyes are red. The first three articles of the antennae are all practically of the same size and the fourth, which is club-shaped, is as long as the other three together.

On the second day the nymphs turn to an orange-red colouration and the antennae, rostri and femurs become more pigmented. During the third day the nymphs become frankly red and on this last day of the first instar they measure about 2.0 mm in length. During the last twenty four hours of this stadium the dorsal odoriferous glands of the abdomen become slightly visible near the posterior margin of the third, fourth and fifth segments. The rostrum reaches only the base of the hindlegs.

Twelve to fifteen hours before ecdysis the nymphs become motionless until they reach the second stadium.

Second Instar (fig. 45) - During five or six hours after ecdysis the nymphs of the three species show a pronounced discolouration at the end of which the normal colours reappear. This discolouration is observed at the beginning of every phase.

During the second stadium the nymphs have a slightly closer resemblance to the adults. The three thoracic segments are now a little differentiated from the abdominal ones. The first three articles of the antennae which, during the first stage, were practically identical are now different, the first and the second being fairly longer than the third but still shorter than the fourth.

The rostrum is now much longer, reaching the abdominal region, and in D. fasciatus it reaches the posterior margin of the fifth abdominal segment.

At the end of this stadium the nymphs of D. nigrofasciatus and D. intermedius measure about 3.5 mm, whereas those of D. fasciatus measure about 3.8 mm. The general colouration of the nymphs is red and in all three species the head is blackish-red, being darker in D. fasciatus. The dorsal odoriferous glands of the abdomen are now quite conspicuous and are black on D. nigrofasciatus and D. intermedius but quite light in colour in D. fasciatus.

While D. nigrofasciatus and D. intermedius have the thorax uniformly red, D. fasciatus has four black spots, two in the mesonotum and two in the metanotum, situated where the wing rudiments will appear during the next stage. The edges of the coxal cavities of D. fasciatus show also by now a whitish colouration not seen on the other species.

Third Instar (fig. 46) - After the second moult the nymphs of the three species show a much closer resemblance to the adult, this stage being characterised by the appearance of the wing rudiments, respectively at the meso and metanotum, where they are latero-posteriorly placed.

The odoriferous glands of the abdomen are now much more conspicuous than at the end of the previous stage. The general colouration is still red, D. fasciatus being darker than the others.

In D. nigrofasciatus the head is black and the antennae, rostrum and legs are black with pomegrenate reflections. In D. intermedius the head is reddish-black and the antennae, rostrum and legs are very dark red. In D. fasciatus the head, antennae, rostrum and legs are very black but have red reflections.

The pronotum of D. fasciatus has on either side of its median longitudinal line a black rounded spot which does not show on the other species.

During this stadium, the abdominal sternites of the three species show white transversal bands at their posterior margins, but while the posterior margin of the pronotum in D. nigrofasciatus and D. intermedius shows a white band, this does not occur on the other species.

The edges of the coxal cavities in the three species are now white and at the end of this stage the nymphs of the three species measure about 6.0 mm.

Fourth Instar (fig. 47) - The thorax of the three species is now conspicuously differentiated from the abdomen, with the wing rudiments quite developed, the first pair partially covering the second.

The general colouration of D. nigrofasciatus and D. intermedius is at this stage yellowish-red, while in D. fasciatus it remains pure red.

In D. nigrofasciatus the head is black but the antennae, rostrum and legs still show pomegranate reflections. In D. intermedius the head, antennae, rostrum and legs are black with reddish reflections, whereas in D. fasciatus the head is frankly black and the antennae, rostrum and legs are black with wine-red reflections.

The white markings in the three species are becoming more conspicuous. The transverse white bands of the posterior margin of the abdominal sclerites are much more visible, but only D. nigrofasciatus shows complete white bands across the sternites. The abdominal tergites show also white markings at their posterior margin, and the odoriferous glands are now very conspicuous.

The pronotum of the three species is now more vividly marked although it keeps the same shape. D. fasciatus still shows the two black spots that do not occur in the other two species, but they disappear slowly before the end of this stadium.

At the end of this stage the nymphs of D. nigrofasciatus are about 8.0 mm long, whereas those of the other two species measure about 8.5 mm in length.

Fifth Instar - During this stage the nymphs acquire quite a different aspect, closely resembling the adults (fig. 48).The thorax is now completely differentiated, the pronotum and the scutellum pratically showing their deffinite form. The wing rudiments are now very developed and reaching the third abdominal tergite. The odoriferous glands are now much larger and very black.

The white markings of the three species are now very pronounced and are:

In D. nigrofasciatus - The anterior margin of the prothorax, the posterior margin of the pronotum, the edges of the coxal cavities, the posterior margin of the abdominal segments and the posterior margin of the epimeron.

In D. intermedius - are similar, except the posterior margin of the pronotum which is whitish-rose.

In D. fasciatus - are similar except the anterior margin of the pronotum which is yellowish-white.

At the beginning of this phase the sixth and seventh abdominal sternites of the three species show small black chitinous plates that disappear gradually before the end of the stadium. The posterior margin of the eigth abdominal sternite is partially chitinized, whereas the nineth is all chitinized.

The rostrum of the three species reaches the 4th abdominal sternite, and at the end of this stage the nymphs of D. nigrofasciatus and D. intermedius measure about 12.0 mm in length whereas those of D. fasciatus are about 13.0 mm long.

c) - The Adult - The three species are represented in figs. 40, 41 and 42 and their diagnostic characters have already been described.

We made some observations on the longevity of the adults, working only with D. nigrofasciatus, by far the most abundant species in Lourenço Marques. For this work we divided the adults into males and females on one side, and into virginal and coupled individuals on the other.

The longevity of the adults varies considerably, the minimum period observed being 17 days and the maximum 144 days.

The recorded observations were the following:

Coupled males: 47, 34, 58, 36, 64, 54 days
Virginal males: 29, 17, 23, 19, 30, - days
Coupled females: 36, 25, 51, 33, 28, 29 days
Virginal females: 19, 29, 144, 21, 32, - days

The number of observations is small but some conclusions could be drawn on the relation between longevity and sex on one hand, and between longevity and sexual condition on the other. Let us see what happens with the males:

MALES

	Coupled		Virginal		
	47		29		
	34		17		
	58		23		
	36		19		
	64		30		
	54		--		
Total	293	+	118	=	411
Mean	48.8		23.6		

TABLE X

	Degree of freedom	Sum of squares	Mean square	F
Between sexual condition	1	1737	1737	18,09
Within sexual condtion	9	864	96.0	-
Total	10	2601	--	-

To the value of $F_{(1;9)}$= 18.09 corresponds a probability lying between 1.0 % and 0.1 %; the difference between the longevity of the coupled males and of the virginal ones, according to our figures, is therefore highly significant, and is of 25.2 $\pm$ 5.93 days in favour of the coupled males.

Now, the case of coupled individuals from both sexes:

COUPLED INDIVIDUALS

	Males		Females		
	47		36		
	34		25		
	58		51		
	36		33		
	64		28		
	54		29		
Total	293	+	202	=	495
Mean	48.8		33.7		

TABLE XI

	D.F.	S.Sq.	M.Sq.	F
Between sexes	1	690	690	5.93
Within sexes	10	1164	116.4	
Total	11	1854	-	

The corresponding probability is between 5.0 % and 1.0 %. The difference of the means is therefore significant, and is of 15.1 ± 14.8 days in favour of the males.

The mean corresponding to the virginal females is not significant owing to the exceptionally long life of one of its individuals. This fact does not allow the analysis of the data as a whole, which would allow us to verify whether the relative behaviour of males and females would be the same between coupled and non-coupled individuals.

In any case, the longevity of the adults can vary considerably as seen from the recorded data.

According to the maximum and minimum periods observed for each stage of the three species of stainers, their life-cycle can be summarised in the following way:

Incubation of the egg	4 to 9 days
First nymphal stage	3 to 4 days
Second nymphal stage	3 to 11 days
Third nymphal stage	4 to 14 days
Fourth nymphal stage	6 to 11 days
Fifth nymphal stage	9 to 17 days
Adult stage	17 to 144 days
From the adult stage to first egg laying	5 to 9 days

5) - <u>Biology</u> - The adults of the three species of stainers are easily seen walking and feeding on the cotton plants as well as on many of its alternative hosts. They can also be seen flying individually from plant to plant, making a characteristic noise. No mass migration has ever been observed.

Two to six days after reaching the adult stage, stainers begin coupling. Copulation is continuous and prolonged and only ends about twelve hours before the first eggs are laid. During copulation the female, which is considerably larger than the male, drags the latter while walking or feeding (fig. 49).

The females, on the cotton fields, lay their eggs in a small hole that she opens on the soil surface, near the plants.

The hole is later carefully covered with earth, for protection purposes. In the Petri dishes the eggs are laid at random, that is, on the glass walls, on the bracts of the epicalyx or on the wet cotton wool. But if half the bottom of the Petri dish is covered with earth, then eggs are always laid on the earth and never anywhere else.

The females, as a rule, lay more than one hundred eggs per batch, and the number of times eggs are laid varies from one to eight. The maximum number of eggs recorded for one batch was 147 (D. nigrofasciatus) and the minimum 39 (D. fasciatus). The maximum number of eggs laid by a single female was 829 (D. nigrofasciatus in eight batches.

We have recorded two cases where females of D. nigrofasciatus laid eggs twice without a second copulation. In one instance the female laid 81 eggs of which 58 hatched. Egg laying by virginal females was never observed although Vrydagh (1942) recorded such cases.

On hatching, the chorion of the egg splits longitudinally and the head of the nymph is the first part to emerge. Then, by slow movements of the antennae, rostrum and legs the nymph gradually becomes free from its involucre (fig. 50). These slow movements, which are interrupted every now and then as if to give the nymph a rest, last ten to fifteen minutes, at the end of which the nymph is completely free.

After leaving the egg-shell the nymphs increase the movements of the antennae, rostrum and legs and, after approximately five minutes, they try their first steps (fig. 51).

Roughly three hours after hatching the nymphs approach the wet cotton wool and it seems that they draw some water from it. The nymphs, however, were never seen to touch food during the whole of the first stage.

From the second instar onwards the nymphs are seen to feed on bolls of all stages of development and on seeds of open bolls.

Stainer damage is caused by the introduction of bacteria and spores of fungi, especially yeasts, when the rostrum is introduced in the boll, during the action of feeding.

The mouth parts are typical of the heteropterous Hemitera and the rostrum is quite long, so that the fibre and the seeds within the bolls are easily reached.

The puncture is hardly seen on the exterior wall of the boll but the results on the internal face are very characteristic (fig. 52). The first symptoms are small circular dull green spots that look like oil stains. Later, small rugosities, which are the product of neoplasiae, can appear in the internal wall of the boll.

The punctures can also be responsible for secondary infections as there are bacteria that can enter the boll through the puncture hole.

When the rostrum is introduced in the boll it passes through the fibre before reaching the seeds. Some of the fungi and bacteria are left on the fibre where they may develop, damaging and staining it to a large extent. Its quality is therefore lowered and its value highly decreased.

But besides damaging the fibre, stainer punctures have a very harmful effect on the seed, to-day a product of high industrial importance for the extraction of vegetable oils. In fact, the puncture of the seed brings internal infection of the kernel, with serious consequences on its germinating power, and the feeding action itself lowers its oil content.

To prove that the internal infection of the kernel is due to the feeding action of Dysdercus spp. as well as other hemipterous pests (e.g. Oxycarenus spp.) we protected numerous flowers, against the attack of all insect, with cellophane bags from the day of anthesis. These seeds could therefore be considered aseptic.

The seeds were then delinted with concentrated sulphuric acid, passed through mercuric chloride, washed in tap water and finally flamed with 90 % alcohol, so as to eliminate any external infection.

After this, we made cultures of these seeds in fourty test tubes containing Saboraud Dextrose Agar, and the results were highly satisfactory as, after eight days, all seeds kept their aseptic condition.

On the other hand, fourty aseptic seeds, obtained in the same way, were subjected to the action of fourty stainers during fifty days. Dead stainers were daily removed and replaced to keep their number constant.

Then, similar Agar cultures were made with those seeds and, after two weeks, thirty five, that is, 87.5 % of the seeds showed a septic condition.

The seeds appeared infected in the following way:

1) - By bacteria only .... 8 tubes
2) - By yeasts only .... 9 tubes
3) - By bacteria and yeast............ 18 tubes

Amongst the yeasts a species of Rhodotorula was identified in six tubes. Amongst the bacteria Xanthomonas malvacearum was identified in one tube.

This experiment shows clearly the importance of stainers in connection with the infection of the kernel (figs. 53, 54,55).

This infection, on the other hand, affects very significantly the germinating power of the seed, and the following experiments were carried out to prove it:

Fourty aseptic seeds were placed on germinators between two layers of cotton flannel which were daily wet to keep up a good moisture content. After three days all seeds had germinated.

Then fourty seeds that had been attacked by Dysdercus spp. during fifty days were placed on other germinators under the same conditions. After three days only twenty six seeds had germinated, which represent only 65 % of the total.

The decrease of the germinating power is therefore very important and undoubtedly due to the feeding action of the "stainers".

The oil content of the seed is also affected by this action (Anthony, K. and Farr, A. J., 1952) and we intend to calculate its decrease as soon as the necessary apparatuses arrive from abroad. In the meantime, we calculated the loss of weight of the seed due to Dysdercus action, subjecting one hundred aseptic seeds to the action of "stainers" during fifteen days and keeping twenty aseptic seeds as witnesses.

The loss of weight due to the action of the insects was 3.94 % of the initial weight, which is not significant at 5.0 %, and this was certainly due to the great variability in weight of the samples. Further work will be done on the subject as with other pests (e.g. Oxycarenus spp.) the loss of weight was significant.

"Stainer" damage is therefore of considerable importance, as seen from the above data.

6) - Host Plants - Cotton stainers seem to have a wide range of hosts and we have collected them on the following plants:

In many Malvaceae, including all species of cultivated and wild cotton, and in numerous species of the genera Hibiscus and Abutilon; in many Sterculiaceae, especially on Sterculia spp., as well as in Adansonia digitata L. (baobab) and Ceiba pentandra Gaertn, (silk-cotton tree), both belonging to the family Bombacaceae. Stainers have also been collected on unidentified specimens.

7) - Natural control

a) - Biological control - Dysdercus spp. have both parasites and predators. The parasites are Tachinid Diptera which belong, in this Province, to the genera Alophora and Bogosiella. Yet, their value as controling agents of the stainers is insignificant as the infestation did not reach 0.5 % in five thousand individuals observed in one of our stations. Further, when the parasites lay their eggs on Dysdercus nymphs, they are discarded with the next moult. The Tachinid flies are therefore of little value as a biological controller.

The predators, on the other hand, are more important and more abundant, and the local ones belong to the family Reduviidae (Het., Hemipt.). The identified forms are Phonoctonus fascialis Pal. Beaw. (P. nigrofasciatus Stål) and Phonoctonus principalis Gerst. (fig. 56), but there are at least two other Reduvid bugs that attack "stainers".

Individually, all predators are of great value as both nymphs of all stages and adults attack nymphal and adult Dysdercus, and a single predator may kill up to three "stainers" in one day. The control, however, is not as important as it might look at first sight, on account of the low biotic potential of the predator in relation to that of the stainer. In fact, while the "stainers" lay up to five hundred eggs, the Reduvid bugs lay between fifteen and twenty five eggs. Further, in the laboratory and at a mean temperature of about 25° C, the number of Reduvid nymphs that reach the adult stage is relatively small, as only about 50 % of the individuals complete the life-cycle. "Stainers" on the other hand, show a very low death rate.

The biological control of the Reduvid predators, therefore, is not as satisfactory as one would hope for but, nontheless, it is important and it certainly contributes to keep the stainer population at a more or less constant level. These predators have a widespread occurrance in Moçambique.

b) - Removal of Host Plants - This practise was followed in the West Indies, apparently with great success. In our case, the problem presents great difficulties, not only on account of the extense cultivated areas and the scattered position of the native gardens, but also due to the great number and variety of host plants, and finally to the manpower required for so vast an operation.

I think, however, that removal of host plants, whenever possible, especially around concentration of gardens, which is now being aimed at, are strongly advised.

c) - Use of Resistant strains - Some investigators (Boga Baduei et al. - 1945) have worked on the development of resistent varieties to boll rot due to *Dysdercus* punctures but apparently with no success as no further data on the suject has been published so far.

-------- oOo --------

Under the present conditions we think that the best way to keep "stainer" damage as low as possible is to maintain the large *Dysdercus* populations for the shortest period on the cotton plant.

The main invasion of the cotton fields by "stainers" takes place from early May onwards. The best solution appears, therefore, to be the use of short-cycled varieties, sown at the earliest possible date. Under these conditions, when the invasion takes place most bolls will be already mature and the fibre can be picked at an early date, allowing for an early uprooting and burning of the plants. Through these measures together with removal of alternative host plants whenever possible, staining of the fibre will be reduced to a minimum and the seed will be kept as healthy as possible.

E) - THE SEED-BUG

The Cotton Seed-bug belongs to the genus Oxycarenus (Gymn., Heter., Hem.) and the species occurring in this territory are Oxycarenus hyalinipennis Costa, as an almost completely dominant form, and another unidentified species that occurs in very small numbers.

1) - Geographical Distribution - Oxycarenus hyalinipennis Costa is found in all cotton areas of Moçambique, being extremely abundant in all districts (Kirkpatrick - 1923 - in Egypt, estimated that in highly infested cotton gardens there were twenty two million seed-bugs per acre). O. hyalinipennis was also collected at the Lower Shire Valley and Salima, both in Nyasaland, which form a geographical unit with our neighbouring regions. This species has also been reported from Egypt, Sudan, Italian Somaliland, British East Africa, as well as from some mediterranean countries of Europe.

2) - Life-Cycle - The study of the life-cycle of the Cotton Seed-bug was made from January 1950 to May 1951. We had great difficulties in studying the complete development of this bug because, for long periods, the nymphs kept dying after reaching the second stage.

The Oxycarenus couples were placed in Petri dishes where at first only green and mature bolls were used as feeding material. The individuals that had only green bolls to feed upon died in all cases, without exception. This method was repeated numerous times but the nymphs soon died, leaving no doubts that it was always the seed and never the fibre they looked for to feed upon.

The couples that were placed on dishes containing open bolls lived for a few days. The females did lay their eggs, which actually hatched, and nymphs grew up to the second stage. But they never reached the third stage, invariably dying before.

After numerous failures we succeeded at last in having complete cycles, feeding the nymphs and adults of the bug with immature seeds of Abutilon grandiflorum (Malv.), which were much smaller than cotton seeds, and very tender. Some loculi from Abutilon fruits were also placed on the dishes to allow the females to lay their eggs on a natural medium. Wet cotton wool was also placed on the dishes.

The mean temperature of the laboratory was about 25° C and the relative humidity very high, especially on the Petri dishes, where saturation occurred, favouring an abundant development of fungi.

The study of the life-cycle was made from twenty couples which were daily observed under the binocular lens. Mounts of the different nymphal stages were made.

a) - The egg (fig. 57) - The egg is cylindrical in section, with rounded tips, and has a length of about 1.0 mm and a diameter of about 0.27 mm. The chorion is highly striated, with about thirty four longitudinal striae, and is yellowish-white in colour, turning orange as the embryo develops within. The anterior extremity is more round in shape and has six small protuberances, almost invisible.

b) - The nymphs - The cotton seed-bug has metamorfois of the hemimetabolic type and has five nymphal stages.

First Instar (fig. 59) - The nymphs of the first instar measure 1.1 mm in length, from the anterior margin of the head to the posterior margin of the abdomen. The antennae are quite long in relation to the body length and have four articles. The first three are very light yellow in colour, translucent, practically with no pigments and all have about the same length. The fourth is much longer and is orange-red in colour. The head is dull olive-green, with orange reflections. The compound eyes are bright red. The thorax has the same colouration as the head and shows no sign of differentiation, but in the region corresponding to the metathorax there is a white ring that shows up to the fourth stage. The rostrum is longer than the body length.

The abdomen has a light ground colouration and is light toasted-yellow in colour. The segments show no differentiation but there are two abdominal orange-red bands situated respectively at two-fifths and two sevenths from its anterior limit.

The legs have a greenish-orange colouration resembling that of the head, and have a wine-red spot at the femur-tibia articulation. The tarsi have only two articles.

Second Instar (fig. 60) - The nymphs of the second stadium have a length of approximately 1.5 mm. Except for the length, they resemble very much the first instar nymphs. The head and thorax are maybe slightly lighter in colour and the abdominal transverse bands of a lighter red, but on the whole the colours are duller. The increase in length is particularly conspicuous on the abdomen, which is frankly longer than in the previous stage. A slight differentiation of the thoracic segments is noticeable, with a white metathoracic region. The segmentation of the abdominal segments is still badly defined, but three dorsal odoriferous glands are already present, the first two, which are bright red in colour, occurring close together and approximately in the region of the third and fourth abdominal tergites, while the third shows only as a discoloured round spot. The badly defined abdominal segments, however, do not allow a proper localization of these glands. The rostrum, at this stage, reaches only the third visible abdominal sternite.

Third Instar (fig. 61) - The nymphs of the third instar measure between 2.0 mm and 2.2 mm in length. Although the general aspect is still very similar to that of the last two stages the nymphs on reaching this phase, show a very conspicuous increase in the length of the abdomen.

Now, the body is perfectly segmented. The ground colour, on the whole, is much darker. The head, prothorax and mesothorax are brown with reddish reflections. The metathorax forms a white band. The first three abdominal segments are bottle-green, with the anterior and posterior margins of a dark red colouration. The other abdominal segments are dark green in colour with red reflections, but under certain light effects they seem to be red in colour with green reflections, especially at an advanced phase of this stage. There are four visible odoriferous glands on the abdomen.

The first three articles of the antennae, which had at the beginning of the stage very little pigmentation, show later a brown colouring. The fourth article is very dark reddish-brown.

The femurs are dark reddish-brown but the tibiae, although slightly pigmented, are still very light and translucent.

This stadium is characterised by the appearance of the wing rudiments but these only show clearly at the end of the stage. They are placed respectively on the meso and metathorax. The body hairiness becomes quite apparent.

Fourth Instar (fig. 62) - The nymphs of the fourth stadium measure about 2.7 mm in length. During this stage the colouration remains very much the same but there is a characteristic change of the body shape, which resembles more closely the adult. The width of the nymphs increases considerably, giving the impression that the nymphs become shorter.

The nymph, on the whole, is now brown in colour, with reddish reflections, except the metathorax which remains white. The head, prothorax and mesothorax are darker than the rest of the body, and have blackish reflections. The abdomen has a vague carmine tinge. The wing rudiments are now very developed and well defined, covering laterally the white band of the metathorax. The odoriferous glands are very conspicuous.

Fifth Instar (fig. 63) - At the beginning of this stage the nymph measures between 3.2 mm and 3.4 mm in length. The general ground colour is dark brown, especially the head and thorax which are almost black. The abdomen has carmine and greenish reflections.

The wing rudiments are now very developed and cover the anterior region of the abdomen. The metathorax looses its white aspect to become of the colour of the whole body. The odoriferous glands are very visible under artificial light, quite large, and have carmine reflections. The ventral aspect is uniformily brown and the rostrum reaches the posterior margin of the metasternum. The hairiness is considerably more noticeable. The antennae and legs are dark, almost black, but have reddish or brownish reflections, according to light incidence. At the end of this stage the nymph is 3.7 to 4.0 mm long.

c) - The Adult - After the fifth moult the nymphs reach the adult condition (fig. 64).

Immediately after ecdysis the adult shows a pale-pink colouration but, soon, it takes up the characteristic black ground colour of this stage.

The hemi-elytra as a rule cover the whole of the abdomen and are translucent but have a silvery aspect.

The general aspect of the two sexes is very similar, but for the length. The females are about 4.0 mm long, but large specimens can measure as much as 5.0 mm in length. The males are considerably smaller and the biggest we ever saw did not measure more than 3.9 mm in length. The tarsi of the adults have three articles whereas in all nymphal stages they only had two. The articles of the antennae are black but have dark brown reflections. The tibiae of the second and third pair of legs have a greenish--white central zone while both tips are black. The tibiae of the first pair of legs have the general colouring of the body. The edges of the coxal cavities of the three pairs of legs are all white.

The abdomen of the female is truncate at its posterior end and has an ovipositor (fig. 65) normally at rest on its ventral side. The abdomen of the male is far more narrow and its posterior margin is rounded. The presence or absence of the ovipositor allows for a rapid sex determination of the adult.

According to the maximum and minimum periods observed for each stage of development of Oxycarenus hyalinipennis, its life-cycle can be summarized in the following way:

Incubation of egg	4 to 11 days
Total duration of nymphal stages	11 to 21 days
From the adult stage to first copulation	2 to 3 days

From copulation to first egg-laying	2 to 3 days
Total	19 to 38 days

These results were obtained under laboratorial conditions and with Oxycarenus kept in Petri dishes. On account of the size of this insect, there is no practical way to find out the length of the different stages under natural conditions.

3) - Biology - Two or three days after reaching the adult condition the cotton seed-bug begins coupling (fig. 66). During copulation there is an initial phase, lasting for about four hours, which is followed by a resting period about two hours long, after which sexual activity is renewed. This activity lasts for about another day. The female, which is much larger than the male, during copulation is seen to drag the latter around, while looking for food. Coupled individuals as a rule hide on sheltered places, and on the Petri dishes we seldom see them, as they normally are inside one of the empty loculi, placed there for this purpose.

On the cotton plant, although sometimes we see a few pairs on the superior face of the leaves, most times they hide on the interior of mature bolls, on the bracts of the epicalyx or, more rarely, on the undersurface of the leaves. Coupling is continuous and prolonged, except for the resting period already referred to.

As a rule the first eggs are layed two days after copulation, and inside the loculi of open bolls. The number of eggs layed each time is quite variable as well as the number of egg--laying periods. Normally, the female goes on laying eggs at irregular intervals, after which there is a resting period, sometimes followed by a new copulation, from which a new laying period results. The minimum number of eggs recorded was six and the maximum sixty three in two series: the first with twenty nine and the second with thirty four eggs. The two egg-laying series were observed during a period of fourteen days, after the first copulation.

The eggs are layed in clusters of varying numbers, of which, normally, the posterior ends are more or less cemented to the laying surface. During the second day the eggs, which were yellowish-white in colour, become canary-yellow and this colour, with the development of the embryo, changes into pinkish-orange. Incubation, which can last from four to elevan days, normally lasts for about five days.

On hatching, the chorion splits longitudinally and the first part of the nymph to emerge is the head (fig. 58).The nymphs after birth keep close together near the empty egg-shells, and later look for a sheltered place in which to spend their first day. In our case, they normally gather inside the already mentioned empty loculi.

During the second and third day the nymphs become more active and are seen to move around, but were never observed to feed.

From the second instar onwards the nymphs are seen to feed on the seeds, as well as to suck water from the wet cotton-wool.

As a rule no large <u>Oxycarenus</u> populations are observed on the cotton fields before the maturation of the first bolls.But the seed-bug appears on the cotton plants, in small numbers or even forming small populations, before this phase of the plant cycle. At this early stage <u>Oxycarenus</u> is seen sucking the different organs of the plant, especially the tender parts, but as soon as the bolls open they feed exclusively on the seed. It is interesting to notice, on the other hand, that, even before the opening of the bolls, there are cases when Oxycarenus feeds on the cotton seed. This happens when the seed-bug enters the green bolls through the holes made by the different Bollworms. This case was observed several times.

The cotton-bug hardly damages the fibre and due to this it has often been regarded as a pest of little importance. In fact, the only way in which the seed-bug affects the fibre is by becoming intermingled with it after death, lowering therefore the percentage of first grade cotton-fibre.

But the seed-bug is extremely important in relation to the cotton seed, not only through being an infection agent of the kernel, and therefore lowering the germinating power of the seed, but also by decreasing significantly the weight of the seed, through its feeding habits.

Experiments on this field were carried out, exactly on the same lines as those connected with the cotton "stainers", and the following results were obtained:

a) Internal infection of the kernel

Agar cultures of 40 aseptic seeds	100% healthy
Agar cultures of 40 seeds attacked by Oxycarenus during 50 days ..	17.5% healthy

It gives us therefore a high percentage of internal infections (82.5 %), and the seeds appeared infected in the following way:

By bacteria only	21 tubes
By yeasts only	5 tubes
By bacteria and yeasts	6 tubes
By a filamentous fungus ...	1 tube

Amongst the yeasts a species of <u>Rhodotorula</u> was identified in three tubes. The filamentous fungus was a <u>Nigrospora</u> sp.

b) <u>Germinating power of the seed</u>

Agar cultures of 40 aseptic seeds	100% of germinations
Agar cultures of 40 seeds attacked by <u>Oxycarenus</u> during 50 days	80% of germinations

The loss in germinating power of the seed due to <u>Oxycarenus</u> action is not as high as that caused by the cotton "stainers" but, nevertheless, it still represents a loss of 20%.

c) <u>Loss in weight of the seed.</u>

The loss in weight of the seed due to the feeding action of the seed-bug is significant. Five samples of twenty seeds were subjected to the attack of one hundred <u>Oxycarenus</u> during fifty days. One sample of twenty aseptic seeds was used as witness. The following table shows the results obtained:

TABLE XII

	Initial wt. of samples in grams.	Final wt.	Diffe- rence	Natural loss 0.75% of the initial wt.	Loss of wt. due to insects
I	1.9208	1.8958	0.0250	0.0144	0.0106
II	2.0499	2.0242	0.0257	0.0154	0.0103
III	2.5498	2.4947	0.0551	0.0191	0.0360
IV	2.5931	2.5673	0.0258	0.0194	0.0064
V	2.2719	2.2329	0.0390	0.0170	0.0220
IV-VI	2.2125	2.1959	0.0166	0.0166	--

Loss of wt. due to insects	In % of initial wt.
I - 0.0106	0.52
II - 0.0103	0.40
III - 0.0360	1.39
IV - 0.0064	0.28
V - 0.0220	1.31

$X = 3.90$

$\bar{x} = 0.780$

$S(X^2) = 4.1570$

$X\bar{x} = 3.0420$

$S(X - \bar{x})^2 = 1.1150$

$$Sm = \sqrt{\frac{1.1150}{20}} = \sqrt{0.05575} = \pm 0.236$$

$$t_{(4)} = \frac{0.780}{0.236} = 3.305$$

$5\% > P > 2\%$

The mean loss of weight (0.78%) is significant at 5 %. In accordance with the results of our experiments, the mean loss of weight due to the action of the seed-bug, will lie, in 95% of the cases, between the following limits:

$$0.78 \pm 0.665 \% = \begin{cases} 1.445 \\ 0.115 \end{cases} \%$$

The results of these experiments suggest that a greater number of samples (possibly ten) should be used, as well as more than one witness to control the natural loss of weight. Further work will be done on this subject.

In any case, however, the results of our experiments show clearly the influence of this sucking insect on the seed, when the mature bolls are left on the plant for long periods.

4) - Host Plants - Besides all species of wild and cultivated cotton, the seed-bug has been collected in great number of Malvaceae, especially on the genera Hibiscus (H. rosa-sinensis, H. cannabinus, H. esculentus), Abutilon (A. grandiflorum, A. asiaticum, A. africanum) and Paritium spp. Oxycarenus spp. has also been found on Sterculia spp. (Sterculiaceae) and on several species of Acacia (Leguminosae). We are sure, however, that the seed--bug has a much wider range of host plants.

5) - Natural control - Neither parasites nor predators of the cotton seed-bug were found. This actually agrees with the existing literature on Oxycarenus spp.

In some of the cultures made on the laboratory, we observed a number of dead specimens in which there was a strong development of a species of the filamentous fungus Aspergillus. Cultures of this fungus were made and several Oxycarenus placed on them, but not a single individual showed any sign of infection. This, together with the dissection of some specimens, proved that the fungus was only an exoparasite, with no influence on the insect's health and, therefore, with no value in its control.

Although we did not find any form of biological control, a great number of seed-bugs must die during the close season, probably due to adverse food and climatic conditions. In fact, the mortality rate must indeed be very high to keep the Oxycarenus population at a more or less constant number or soon the world would be literally covered with this insect.

Taking into consideration the size of the seed-bug and the density of its populations, once the Oxycarenus is established on a cotton field we can hardly hope to eliminate it from the attacked field.

Under the conditions in which cotton is presently cultivated in Moçambique, and bearing in mind that the large populations of the seed-bug appear only after the maturation of the boll, the only way in which partial control of this bug is obtained is to have a first picking of fibre soon after boll maturation, and a second one as soon as there is again a sufficiently large flush of mature fibre, followed by uprooting and burning of the plants. It is important to notice that this practice is advantageous not only in relation to this pest, but also to all the other serious cotton pests.

Through these prophylactic measures the seed will be kept as healthy as possible, and the seed-bug populations checked down to a certain extent.

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Fig. 41 Dysdercus nigrofasciatus Stål - The Adult. (Coloured plate published in our paper "Estudo Comparativo da Biologia dos Manchadores da Fibra em Moçambique e das medidas para o seu control").

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Fig. 51 The nymphs, after leaving the egg-shell, try their first steps.

Fig. 52 View of the internal face of cotton fruits showing small rugosities derived from neoplasiae and stained fibre.

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Fig. 65 Ventral view of female adult showing ovipositor (Approx. X 13.5).

Fig. 66 O. hyalinipennis Costa - Coupling. The larger female draggs the male, while walking.

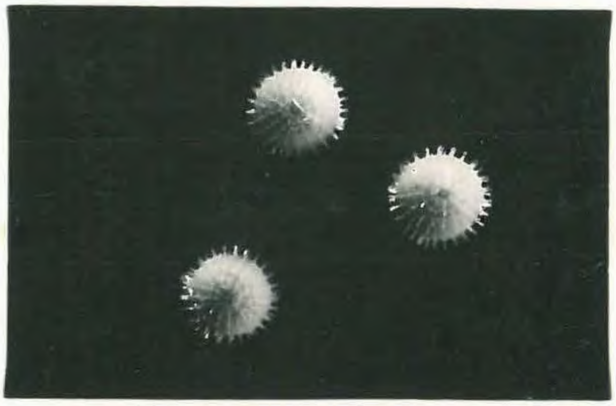

Fig. 1

D. castanea Hmps. - The Egg
(pag. 26). 21.6 X

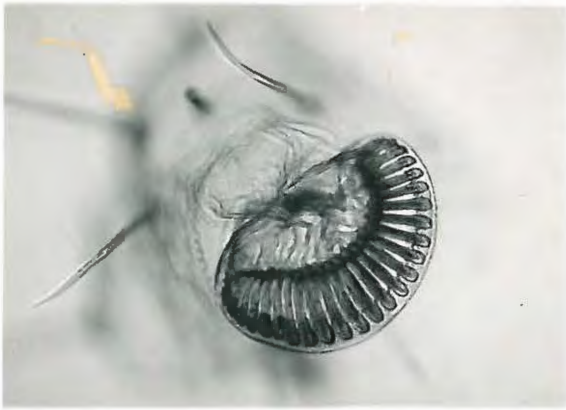

Fig. 2

D. castanea Hmps. - The "crochets"
of the pseudolegs (pag. 26) - From
a Canada Balsam Mount - ± 60 X

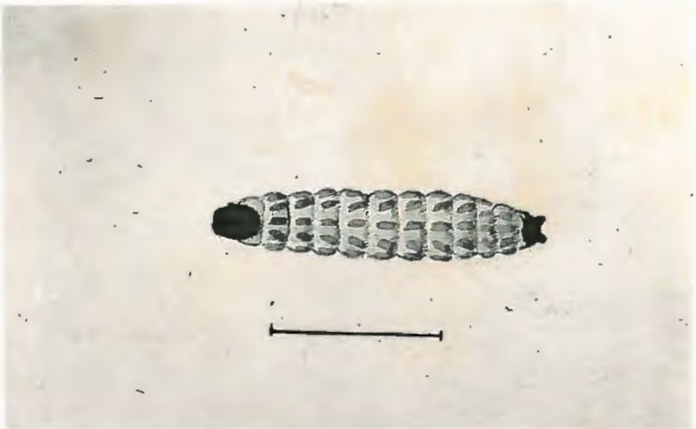

Fig. 3

D. castanea Hmps. - Larva of the 4th instar (pag. 27). From Nature

Fig. 4

D. castanea Hmps. - The earthen cell within which the pupa is formed.(pag. 27) ± 2.6 X

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Fig. 6

D. castanea Hmps. - Ventral aspect of the pupa (pag.27) 3 X

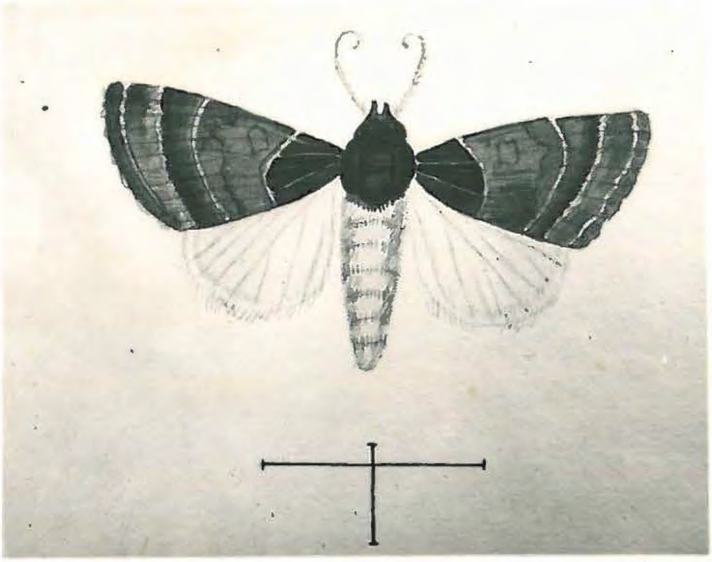

Fig. 7

D. castanea Hmps. - The moth ♂ (pag. 27)

Fig. 8

Green boll showing entrance hole of Red Bollworm with litter of excreta and boll material. (Pag. 29)

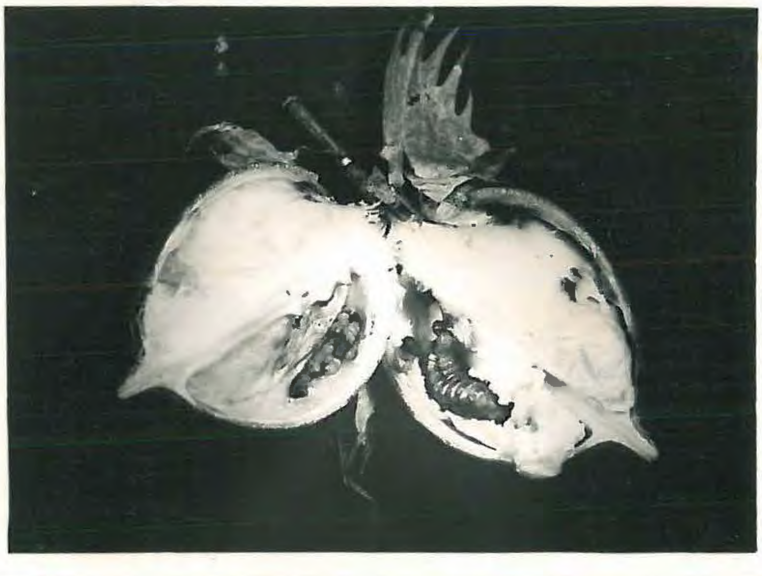

Fig. 9

Attacked boll cut into two halves showing, on one gallery the Red Bollworm, and on the other the typical excreta. (pag. 29)

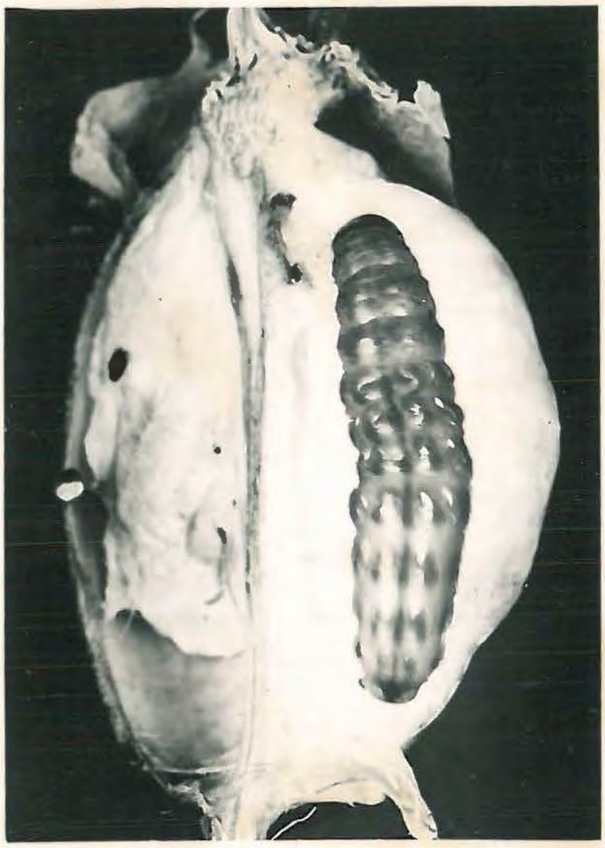

Fig. 10

Almost fully mature larva of *D. castanea* moving out of damaged boll (pag. 30).

Fig. 11

E. insulana Boisd. - Top view of the egg. (Pag. 38) Approx. X 30

Fig. 12

E. insulana Boisd. - Lateral view of the egg showing crown and sculptured nature of walls. Approx. 50 X (pag. 38)

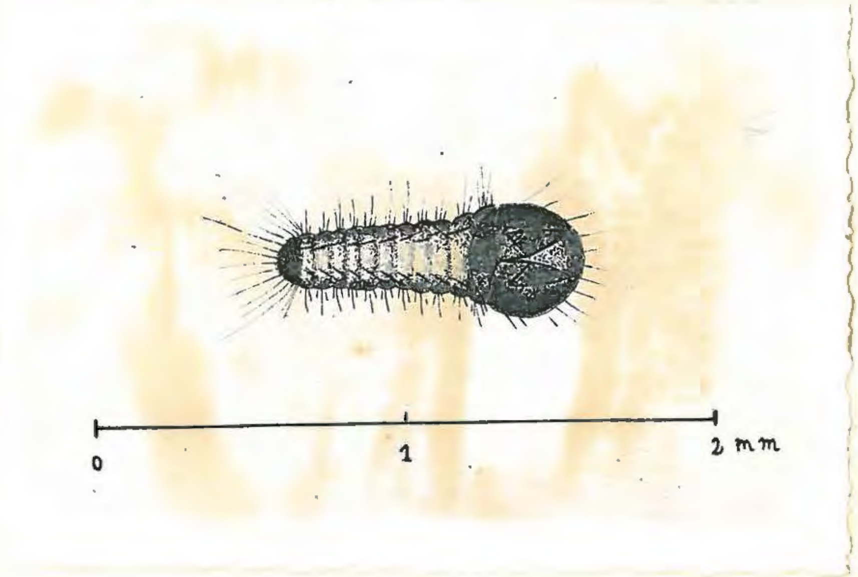

Fig. 13

E. insulana Boisd. - Larva immediately after hatching (pag. 39). Drawing from slide.

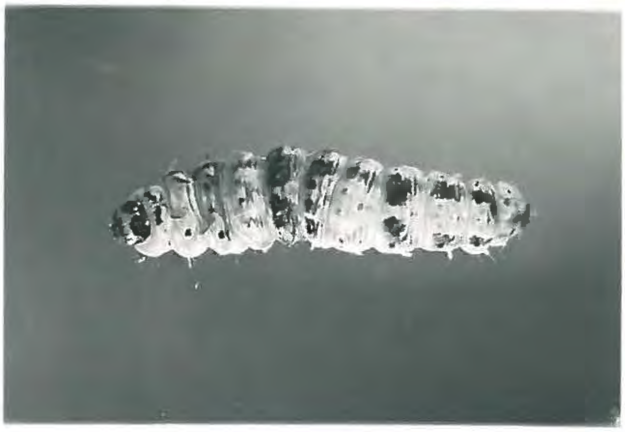

Fig. 14

E. insulana Boisd. - Larva of the 5th instar, from Nature. (pa. 40). About 5 X

Fig. 15

E. insulana Boisd. - Dorsal view of the pupa (pag. 41) 4 X

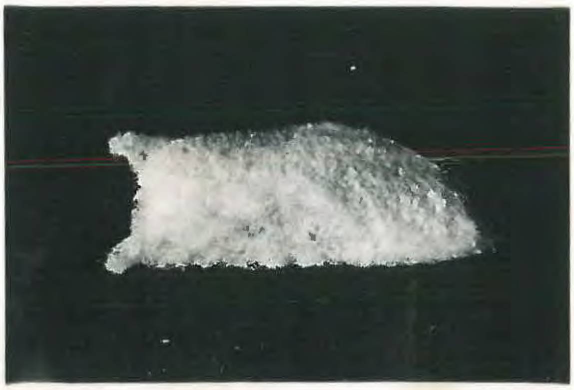

Fig. 16.

E. insulana Boisd. - Cocoon with its typical boat shape. Approx. 3.7 X. (pag. 42)

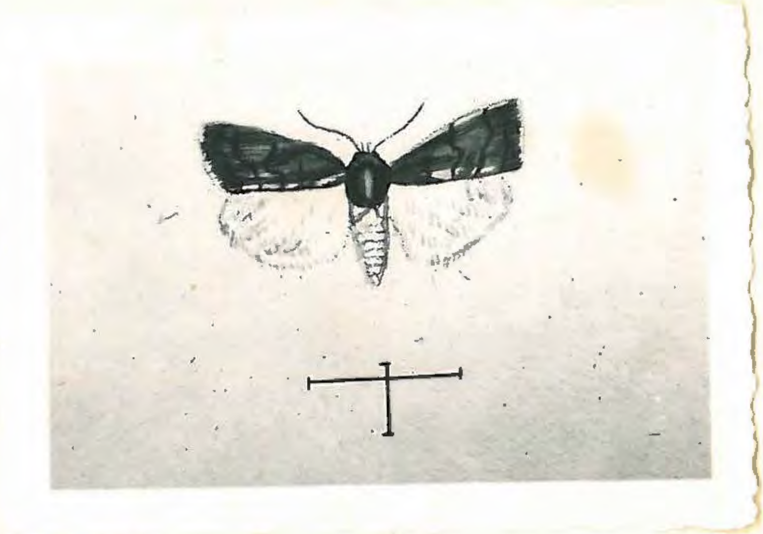

Fig. 17

E. insulana Boisd. - The adult (pag. 42).

Fig. 18

E. insulana Boisd. - Labial palp (pag. 42).

Fig. 19

E. insulana Boisd. - Anterior leg (tibia and tarsus) - (pag. 42).

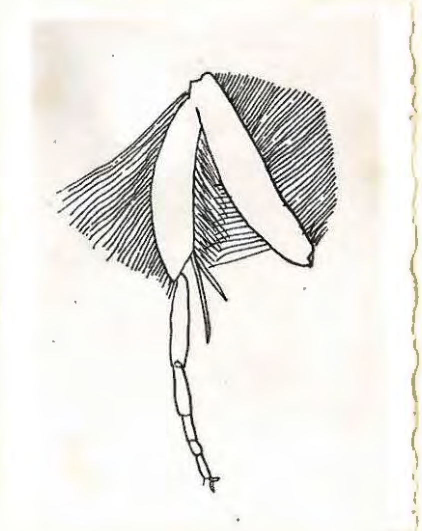

Fig. 20

E. insulana Boisd. - Middle leg of male (pag. 43).

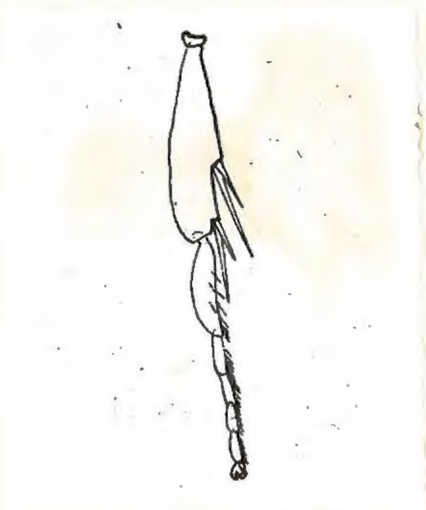

Fig. 21

E. insulana Boisd. - Posterior leg (tibia and tarsus) - (pag. 43)

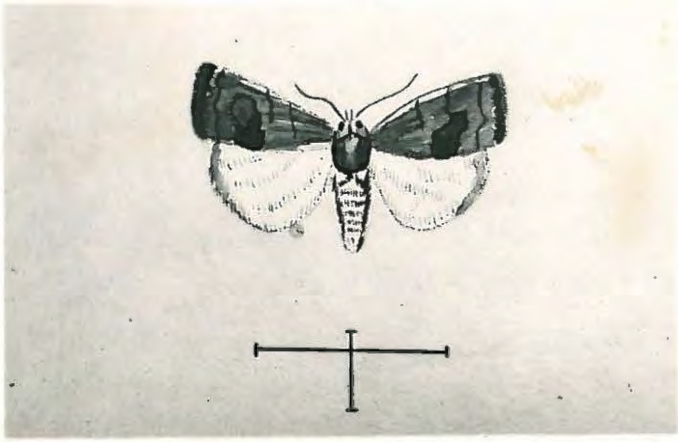

Fig. 22

E. biplaga Walk. - The adult (pag. 45).

Fig. 23

E. biplaga Walk. - Labial palp of the male (pag. 45).

Fig. 24

E. biplaga Walk. - Labial palp of the female (pag. 45)

Fig. 25

E. biplaga Walk. - Anterior leg (tibia and tarsus) - (pag. 46)

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E. biplaga Walk. - Posterior leg (tibia and tarsus) - (pag. 46)

Fig. 28

E. insulana Boisd. - Young larvae of the first stadium feeding on seeds of Abutilon grandiflorum (pag. 48). Approx. X 20.

Fig. 29

E. insulana Boisd. - Larva of the 4th instar entering a new boll (natural size) (pag. 48). From Nature.

Fig. 30

Empoasca facialis Jac. - First instar nymph (pag. 55). 15 X

Fig. 31

E. facialis Jac. - Second instar nymph (pag. 55) 15 X

Fig. 32

E. facialis Jac. - Third instar nymph (pag. 55). 15 X

Fig. 33

E. facialis Jac. - Fourth instar nymph (pag. 56). 15 X

Fig. 34

E. facialis Jac. - Fifth instar nymph (pag. 56) 15 X

Fig. 35

E. facialis Jac. - The Adult (pag. 56). About 16 X

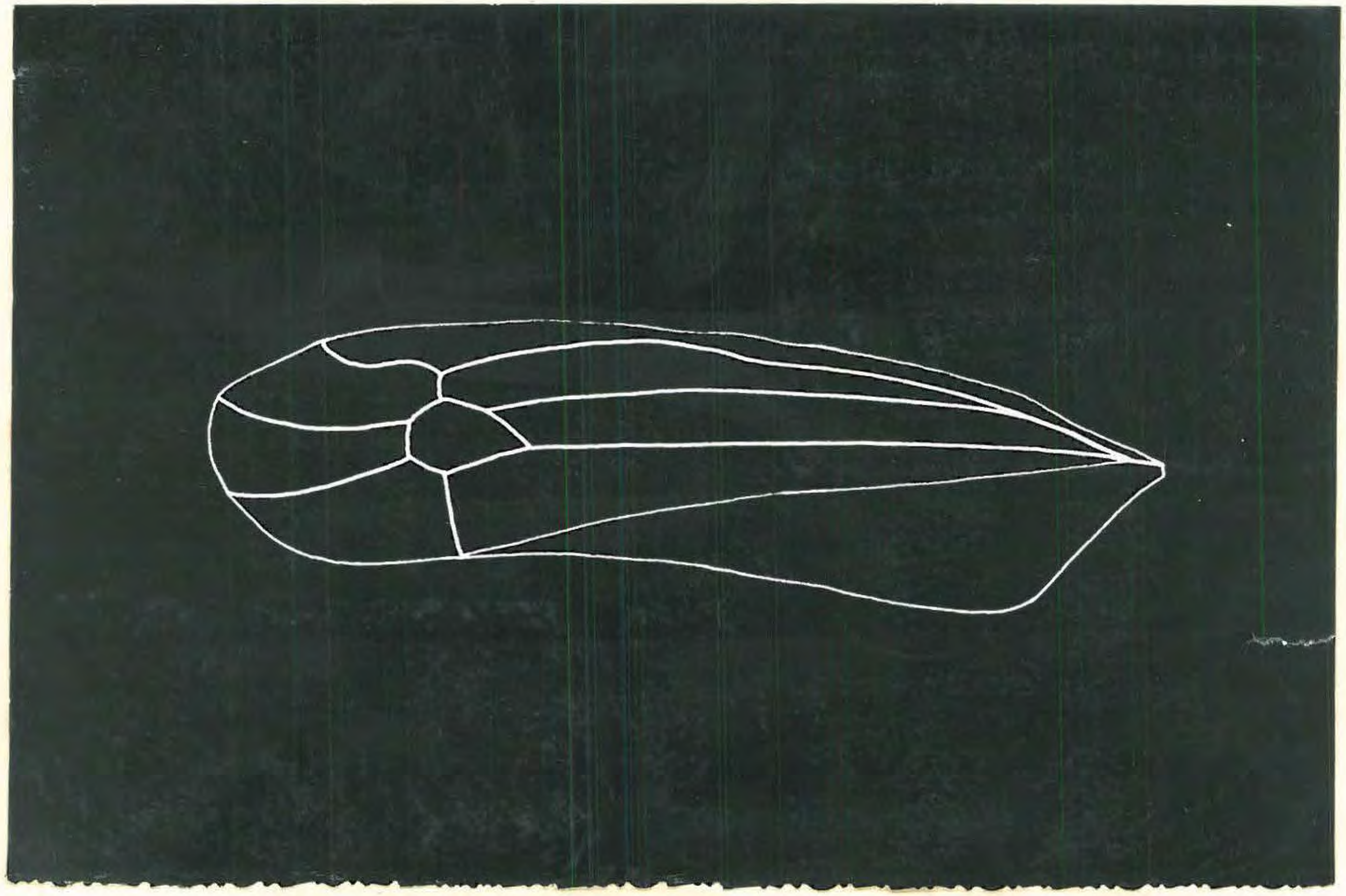


Fig. 36

E. facialis Jac. - The left forewing of the Cotton Jassid (from a Canada Balsam Mount) - (pa. 56).

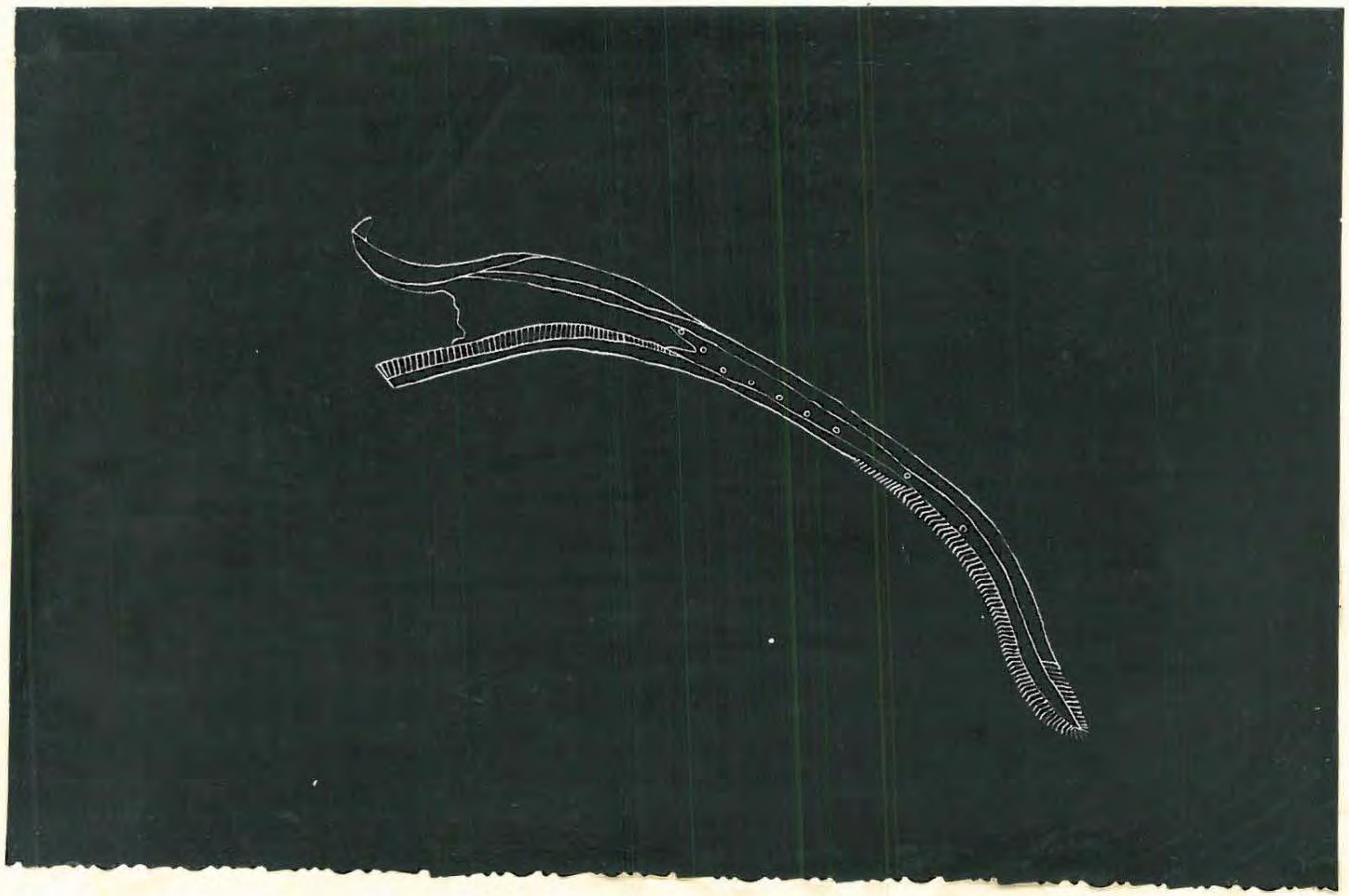
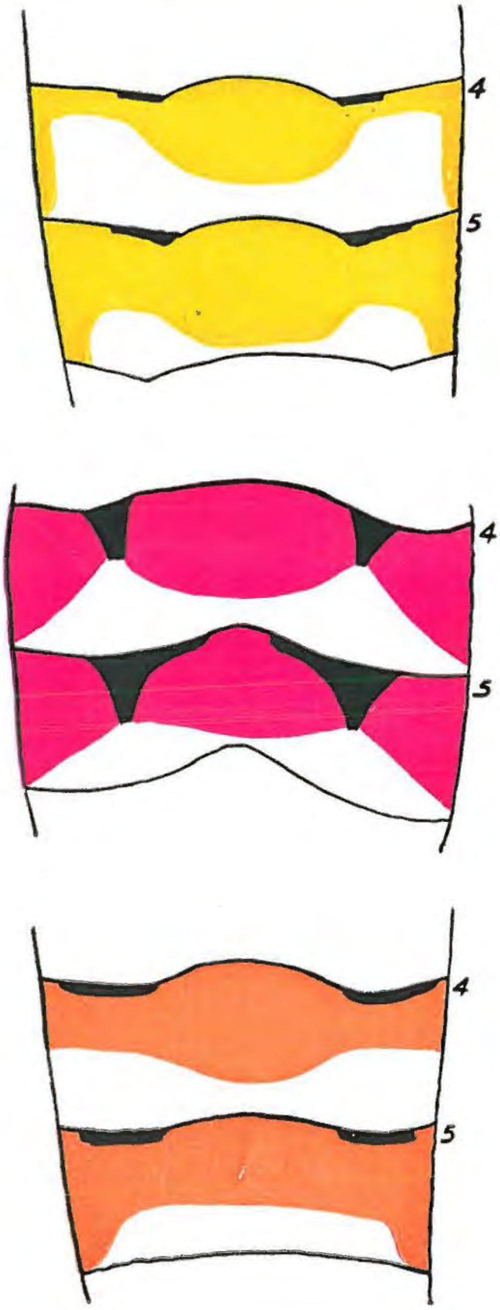


Fig. 37

E. facialis Jac. - Saw-like ovipositor of the female (from a Canada Balsam Mount) - (pa. 56).

Fig. 38

Leaves curled with the edges turned down, due to the feeding action of the Cotton Jassid (pag. 58).



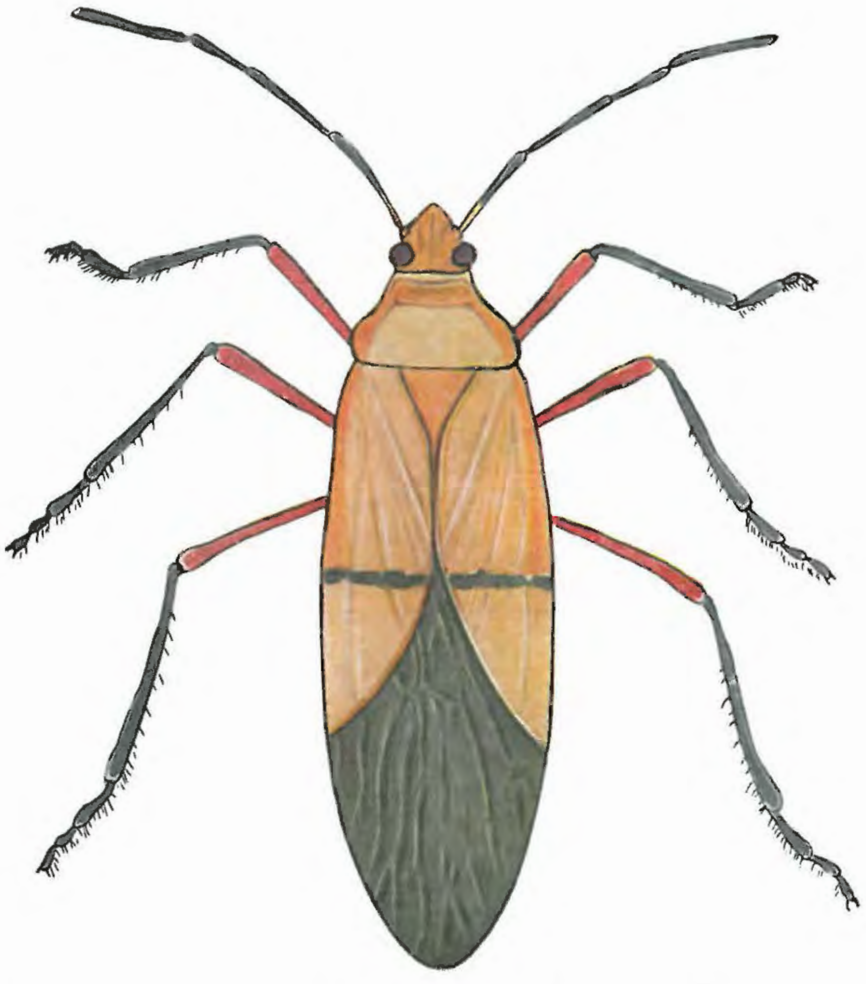
D. nigrofasciatus

D. fasciatus

Dysdercus sp.

Fig. 39

Transverse bands of the abdominal sternites of D. nigrofasciatus, D. fasciatus and Dysdercus sp. (coloured plate published in our paper "Estudo Comparativo da Biologia dos Manchadores da Fibra em Moçambique e das medidas para o seu control") - (pag. 72).

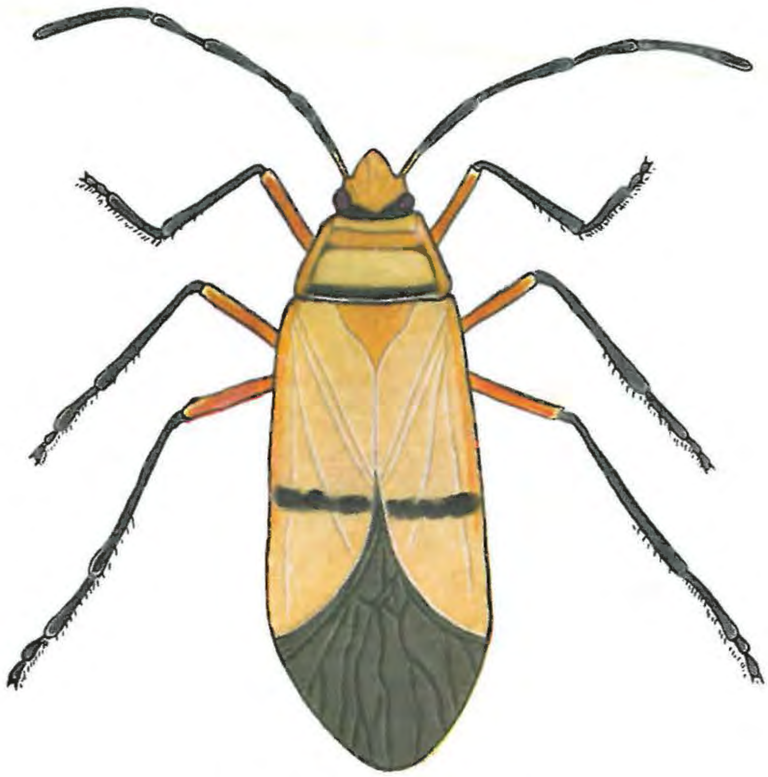


Dysdercus intermedius Dist.

TAMANHO NATURAL

Fig. 40

Dysdercus intermedius Dist. - The adult (coloured plate published in our paper "Estudo Comparativo da Biologia dos Manchadores da Fibra em Moçambique e das medidas para o seu control") - (pag. 73).

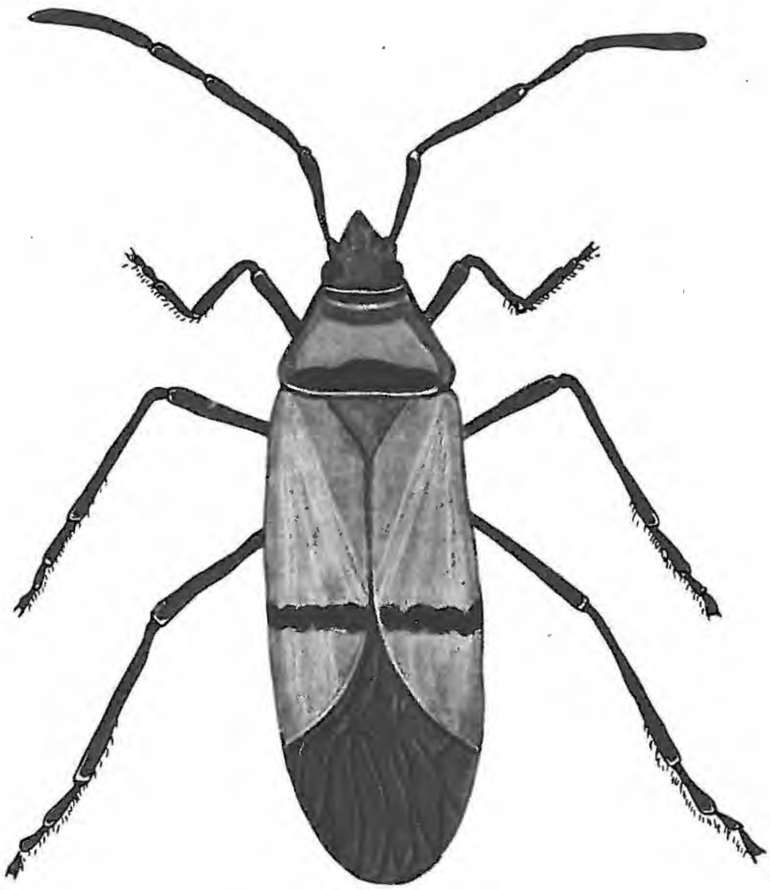


Dysdercus nigrofasciatus Stäl.

TAMANHO NATURAL

Fig. 41

Dysdercus nigrofasciatus Stäl - The adult (Coloured plate published in our paper "Estudo Comparativo da Biologia dos Manchadores da Fibra em Moçambique e das medidas para o seu control") - (pag. 73)



Dysdercus fasciatus Sign.

TAMANHO NATURAL

Fig. 42

Dysdercus fasciatus Sign. - The adult (Coloured plate published in our paper "Estudo Comparátivo da Biologia dos Manchadores da Fibra em Moçambique e das medidas para o seu control") - (pag. 73).

Fig. 43

D. nigrofasciatus Stål - The eggs (pag. 74). Approx. 7 X

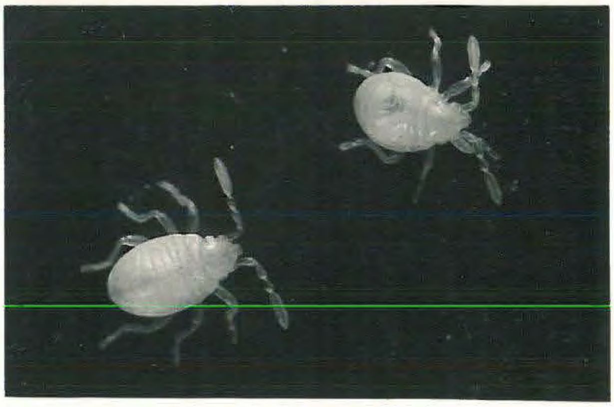


Fig. 44

D. nigrofasciatus Stål - The nymph of the first stadium (pag. 74). Approx. 13 X

Fig. 45

D. nigrofasciatus Stål - The second stadium nymph (pag. 75). Approx. X 8.5

Fig. 46

D. nigrofasciatus Stål - The nymph of the third stage (pag. 76). Approx. 5 X.

Fig. 47

D. nigrofasciatus Stål - The nymph of the fourth stadium (pag. 77). Approx. 4 X

Fig. 48

D. nigrofasciatus Stål - The nymph of the fifth stadium (pag. 78) Approx. 3 X

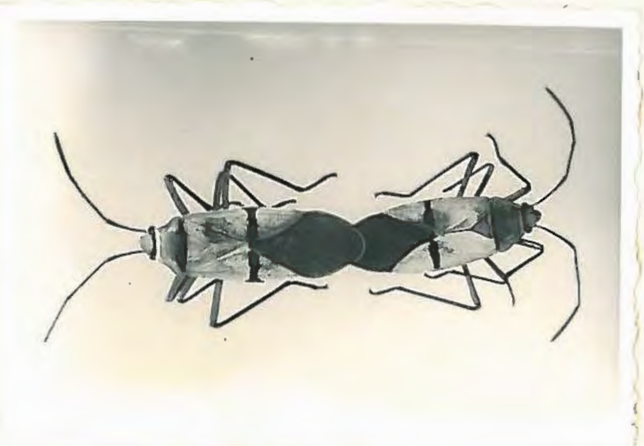


Fig. 49

D. nigrofasciatus Stål - Coupling (pag. 82) Note the larger female dragging the male. About natural size.

Fig. 50

The nymphs, through slow movements of the antennae, rostrum and legs gradually become free from their involucre (pag. 83)

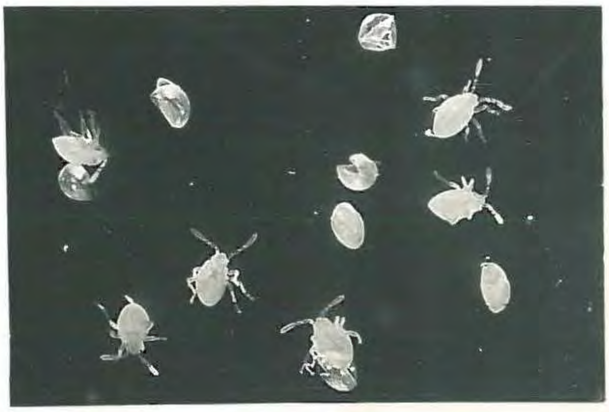


Fig. 51

The nymphs after leaving the egg shell try their first steps (pag. 83)

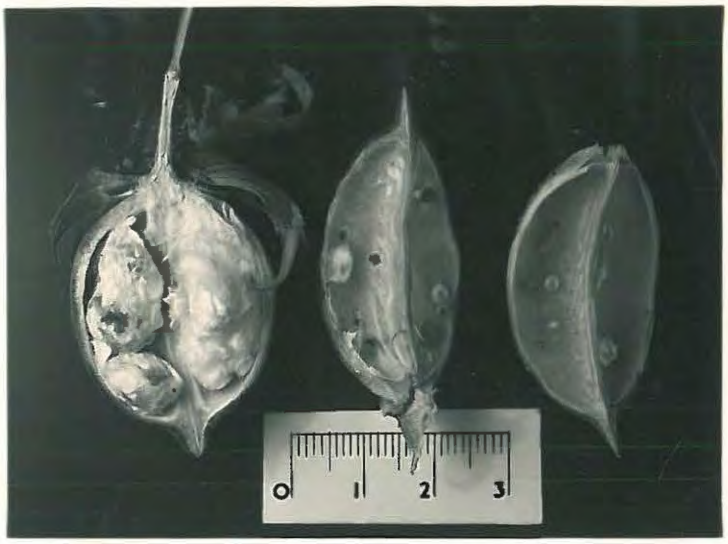


Fig. 52

View of the internal face of cotton fruits showing small rugosities, derived from neoplasiae, and stained fibre. (pag. 84)

Fig. 53

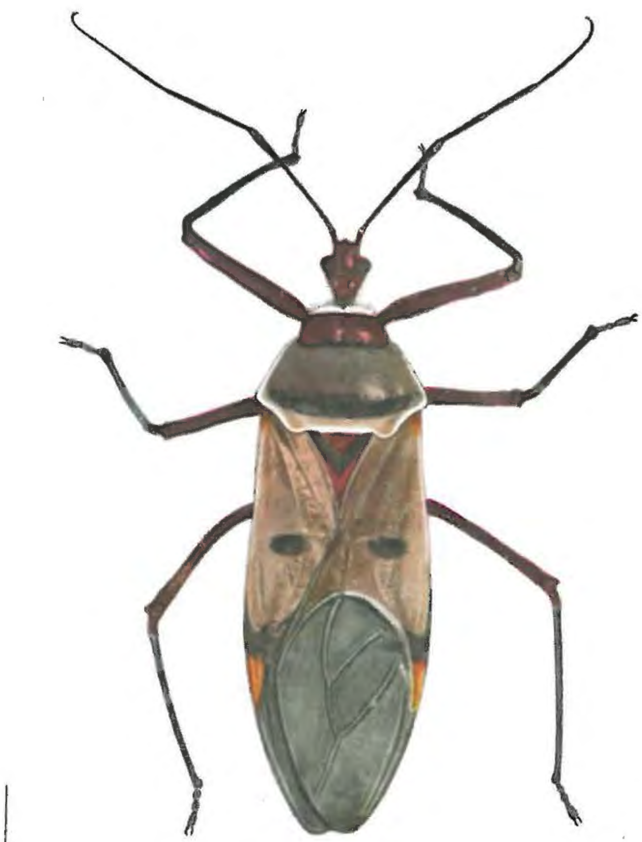
Longitudinal cut of a cotton seed, showing the structure of normal embryo (pag. 86).50 X

Fig. 54

Longitudinal cut of cotton seed, showing an embryo infected with bacteria, introduced by the rostrum of the stainers (pag. 86). 50 X

Fig. 55

Colony of bacteria developing over the rest of the endosperm, between the embryo cotyledons (pag. 86). 420 X



Phonoctonus principalis Gerst.

Fig. 56

Phonoctonus principalis Gerst. (Red.) - A predator of the stainers (Colour plate from our paper "Estudo Comparativo da Biologia dos Manchadores da Fibra em Moçambique e das medidas para o seu control") - (pag. 88)

Fig. 57

Oxycarenus hyalinipennis Costa - Eggs on fruit of A. grandiflorum. Notice the longitudinal striae. (pag. 91) - 24 X

Fig. 58

O. hyalinipennis Costa - Nymph leaving the egg-shell (pag. 97). (Approx. X 18)

Fig. 59

O. hyalinipennis Costa - Nymph of the first stadium (pag. 92) (Approx. X 12)

Fig. 60

O. hyalinipennis Costa - Nymph of the second stadium (pag.92) Approx. X 12

Fig. 61

O. hyalinipennis Costa - Nymph of the third stadium (pag. 93) Approx. X 20

Fig. 62

O. hyalinipennis Costa - Nymph of the fourth stadium (pag. 94) Approx. X 13

Fig. 63

O. hyalinipennis Costa - Nymph of the fifth stadium (pag. 94) Approx. X 16

Fig. 64

O. hyalinipennis Costa - The adult (pag. 94) Approx. 13.5 X

Fig. 65

Ventral view of female adult showing ovipositor (pag. 95) Approx. X 13.5

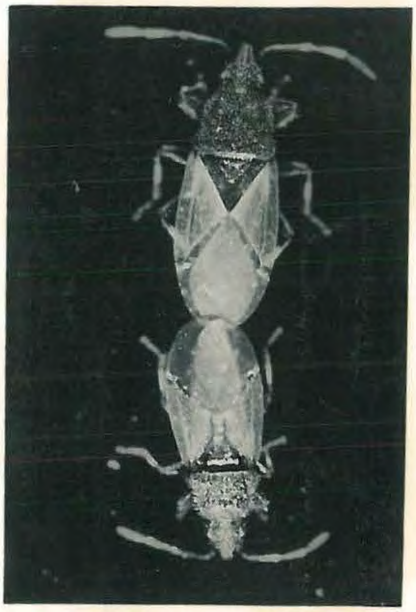


Fig. 66

O. hyalinipennis Costa - Coupling (pag. 96). The larger female draggs the male, while walking.

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