PESTS OF THE COCONUT PALM

Pests and diseases are particularly important among the factors which limit agricultural production and destroy stored products. This publication concerns the pests of the coconut palm and is intended for the use of research workers, personnel of plant protection services and growers

Descriptions are given for each pest (adult or early stages), with information on the economic importance of the species the type of damage caused, and the control measures which have been applied (with or without success) up to the present time. The text deals with 110 species of insects which attack the palm in the field; in addition there are those that attack copra in storage, as well as the various pests that are not insects

This is the first of a series of publications on the pests and diseases of economically important plants and plant products, and is intended primarily to fill a gap in currently available entomological and phytopathological literature and so to assist developing countries.

PESTS OF THE COCONUT PALM

FAO Plant Production and Protection Series *No. 18*

PESTS OF THE COCONUT PALM

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome 1969

First printing 1969
Second printing 1979

P-14
ISBN 92-5-100857-4

Printed in Italy

FOREWORD

Shortage of food is still one of the most pressing problems in many countries. Among the factors which limit agricultural production and destroy stored products, pests and diseases are particularly important. When left unchecked, they are liable to cause such serious losses as to discourage further attempts to grow certain crops. The application of rational control measures requires thorough knowledge of the biology and behavior of the pests and diseases, but only too often the necessary basic knowledge is lacking in the very countries in which it is most needed.

The Food and Agriculture Organization of the United Nations (FAO), fully aware of this problem, is producing a series of publications on the pests and diseases of economically important plants and plant products, primarily to fill a gap in currently available entomological and phytopathological literature and so to assist developing countries.

The first of these publications concerns the pests of the coconut palm (*Cocos nucifera*) and is intended for the use of research workers, personnel of plant protection services and growers. Its objective is to present an account of the principal species — both invertebrate and vertebrate — that are harmful to the coconut palm, and to do so for the whole of the tropical belt. To this end, the description of each pest (adults or early stages) has been made as brief as possible, to allow space for information on the economic importance of the species, the type of damage caused, and the control measures which have been applied, with or without success, up to the present time. It is hoped that the work thus planned will satisfy the requirements of those for whom it is intended; readers who are less familiar with the entomological problems of the coconut palm will find in the Introduction definitions of the principal technical and scientific terms used in the text.

In the course of the preparation of this work it has become apparent that numerous insect species recorded over many years in the literature as coconut pests are merely casual feeders on coconut or cause only minor and occasional damage. It has therefore seemed desirable to omit such species, in order to avoid overloading the text with names whose value in the present context is doubtful. The monograph of Lepesme (1947) mentions no less than 750 species of insects associated with the coconut

palm, and indicates that over one fifth of these are specific to it. In the present work, 110 species of insects which attack the palm in the field are dealt with; in addition, there are those that attack copra in storage; as well as the various pests that are not insects.

Most of the pests of the coconut palm will readily attack other species of palm. Many of the insects known as coconut pests in various parts of the world have also attacked the oil palm of West Africa which is now cultivated in Asia, tropical America and elsewhere. The alternative host plants of coconut pests are, in general, still very inadequately known.

The bibliographical references incorporated in the text are a selection of the very large number of published works concerning pests of the coconut palm. To illustrate the wealth of the literature on this subject, it suffices to mention that the study by Gressitt (1953) of the single species *Oryctes rhinoceros*, in one relatively small area of the Pacific, contains no less than 310 bibliographical references.

ACKNOWLEDGMENTS

The author is indebted to many persons for help in the preparation of this work. Special thanks are due to J.P. Doncaster, Keeper of Entomology, British Museum (Natural History), London, and to various members of his staff to whom problems of nomenclature have been referred; to E.O. Pearson, Director of the Commonwealth Institute of Entomology, London, for identification of species by his staff and for kindly permitting the reproduction of illustrations already published in the *Bulletin of Entomological Research;* and to the Anti-Locust Research Centre, London, especially to Sir Boris Uvarov, Fellow of the Royal Society, for information on the Orthoptera.

The author also wishes to record his gratitude to the following specialists: W.E. Bain (Imperial Chemical Industries), J.A. Freeman (Ministry of Agriculture, United Kingdom), A.H. Green (Unilever, Ltd.), R.W. Paine (formerly entomologist in Fiji), J.J.H. Szent-Ivany (formerly entomologist, Department of Agriculture, Papua and New Guinea), G.E. Tidbury (Commonwealth Bureau of Horticulture and Plantation Crops), J. Walton (Lever's Pacific Plantations Pty, Ltd.), A. Wattanapongsiri (University of Missouri, United States) and F.N. Wright (Department of Technical Co-operation, United Kingdom).

The Verlag für Recht und Gesellschaft A.G., Basle, has permitted the citation of certain passages from *Pests of crops in warm climates and their control*, 1962, by R. Wyniger; Longmans, Green and Co. have allowed the reproduction of a sketch of a coconut from *Plant life in Malaya*, 1954, by R.E. Holttum; the n.v. Uitgeverij W. van Hoeve, The Hague, the Netherlands, and P. Lechevalier, Paris, have authorized the reproduction of photographs and the redrawing of illustrations already published in L.G.E. Kalshoven, *De plagen van de cultuur-gewassen in Indonesië*, 1950-51, and in P. Lepesme, *Les insectes des palmiers*, 1947, respectively. Photographs of coconut palm pests and their damage have been received for publication from the Institut de recherche pour les huiles et les oléagineux (IRHO), Paris, France; from the Royal Tropical Institute, Amsterdam, the Netherlands; from the Institut national de la recherche agronomique (INRA), Station de recherches de lutte biologique et de biocœnotique, La Minière, Versailles, France; from P. Grison and B. Hurpin, of the above-mentioned INRA

station; from C. Kurian, Central Coconut Research Station, Kayangulam, Kerala, India; from M.J. Way, Imperial College of Science and Technology, Sunninghill, Ascot, Berks., England; from K.J. Marschall, insect pathologist, at present specialist for the United Nations Development Program/Special Fund-FAO-South Pacific Commis sion project, Research on the control of the coconut palm rhinoceros beetle, Apia, Western Samoa; and from F.Q. Otanes, National Research Council, Manila, the Philippines. Several photographs of locusts and of the rhinoceros beetle have been provided by FAO.

The author also expresses his thanks to his wife, a former student of the Slade School of Fine Arts, London, for certain sketches included in the text. He also records that it is a pleasure to acknowledge his indebtedness to that unknown band of abstractors who, over many years, have provided in the *Review of Applied Entomology*, *Horticultural Abstracts* and *Tropical Abstracts* invaluable summaries of entomological papers and indexes of pests. He is similarly grateful to the staffs of the libraries in London of the Commonwealth Institute of Entomology, the British Museum (Natural History), the India Office, the Commonwealth Relations Office, the Department of Technical Co-operation, the Ministry of Agriculture, and the Tropical Products Institute.

NOMENCLATURE

Recent changes in nomenclature

In recent years, the scientific names of certain of the insects and other animals associated with the coconut palm have been changed in the light of revisions of the genera concerned. These changes, so far as they have become known to the author, are indicated in the appropriate places in the text; most of them involve the generic name only. Further reference to such changes will be found on page 5.

Similarly, the names of certain of the plant species which are alternative hosts of some of the pests of the coconut palm have been changed; the royal palm, for example, known in the past as *Oreodoxa regia*, must now be called *Roystonea elata*.

Popular and scientific names of palms of economic importance

In order to avoid unnecessary repetition in referring to palms of economic importance which are alternative host plants of coconut pests, only the generic names of these palms are used in the text. The popular and the full scientific names of the more important of the palms in question are listed below:

Areca palm	*Areca catechu*
Date palm	*Phoenix dactylifera*
Nibong	*Oncosperma tigillaria*
Oil palm	*Elaeis guineensis*
Palmyra	*Borassus flabellifera*
Rattan palm	*Calamus* spp.
Royal palm	*Roystonea elata*
Sago palm	*Metroxylon* spp.
Sugar palm	*Arenga pinnata*
Swamp palm	*Nypa fruticans*
Talipot	*Corypha umbraculifera*
Toddy palm	*Caryota urens*

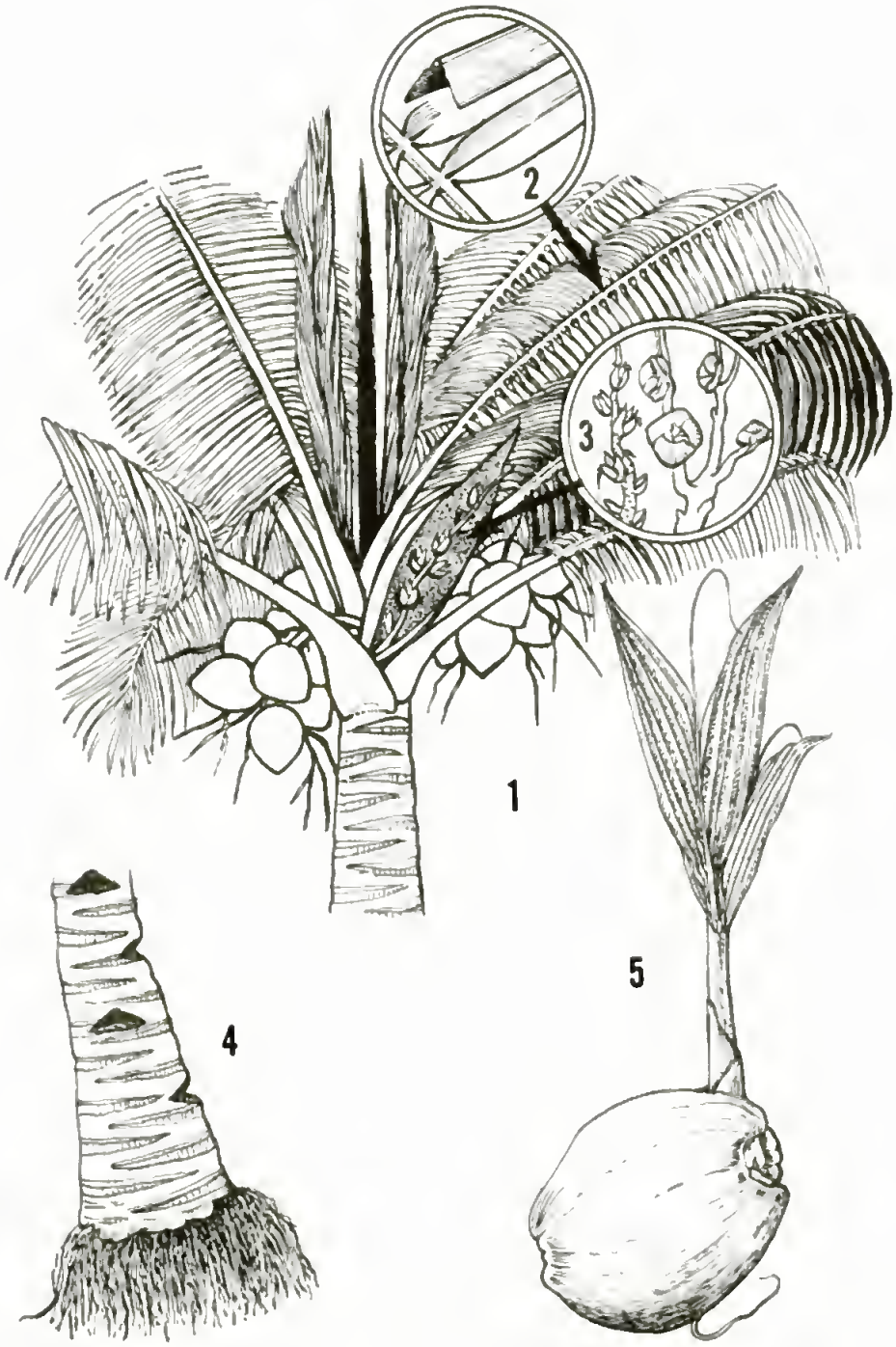
CONTENTS

INTRODUCTION

Description of the coconut palm

There is considerable variation in both the size and the period of development of the palm in the wide tropical belt where it thrives. The leaves, also called fronds (Figs. 1 and 2), reach a length of 4-6.5 meters; each has 200-250 leaflets or pinnae, which are about 1 meter long. On average, the tree produces 12-16 new leaves per year and carries 25-35 open leaves at any one time. The upper surface of the leaflets is smooth and is covered with a waxy layer; the lower surface also is smooth but is without wax, and it is on this surface that most of the insect pests, whether biting or sucking, live. At the center of the crown of the palm, the young developing leaves are tightly compacted into an elongate terminal shoot, called the spear or cabbage; severe injury to this growing point usually results in the death of the palm. Each leaf has a very strong midrib (rachis), flat above and convex below, which is attached to the trunk by a broadened base. At the junction with the trunk there are sheets of brown fibrous tissue. The positions of the bases of the old leaves which have fallen off are marked by prominent scars which are permanent characteristic features of the trunk (Figs. 4 and 6).

The coconut palm is monoecious, i.e., both male and female flowers are present on the same inflorescence (Fig. 7). The latter, which is called a spadix, develops within 2 stout sheaths or spathes, of which the inner continues growing after the outer has ceased and therefore splits it and emerges from it. A new spadix is formed every 20 to 25 days, so that there are about 16 per year. The spadix is branched; it is composed of a central axis with the branches, or spikes, disposed spirally, and each branch carries female flowers on its basal part and male flowers apically. Of the 15-20 female flowers produced on each spadix, only 4 or 5 set; these are initially small mushroom-like objects, commonly called buttons, and they rapidly grow to become pointed acorn-like nutlets (Figs. 3 and 7). Each spadix bears 250-300 male flowers, small in comparison with the females, and within about 2 weeks these fall off, 3-6 days before the female flowers on the same spadix become receptive to pollen. The receptive period lasts 4-6 days. Thus, crossfertilization from a spadix opening later is



FIGURES 1-5. - *Cocos nucifera* Linnaeus, the coconut palm. Crown (1) with details of the leaflets or pinnae (2) and of male and female flowers (3), base of the trunk and root apron (4), and a germinating coconut (5). According to Leong Hong Tim, redrawn.

FIGURE 6. - *Cocos nucifera* Linnaeus. Scars on the trunk.
(*Photo P. Grison*)

FIGURE 7. - Newly opened spadix, showing female flowers (nutlets) and many male flowers on spikes.
(*Photo M.J. Way*)

ensured. A single palm produces, on average, some 400 female flowers annually.

The trunk of the tree attains a height of 18-21 meters. As in all monocotyledons, there is no cambium and therefore no secondary thickening. During the first few years of growth, the trunk increases in girth but not in height, so that in young palms the bole looks disproportionately large. Upward growth does not begin until some five years have elapsed.

The wiry, fibrous roots penetrate rather shallowly into the soil but nevertheless anchor the tree firmly (Fig. 4). There is no taproot and there are no true root hairs, but the main roots are finely branched. Prolonged waterlogging is inimical but considerable salinity in the soil is tolerated.

The fruit is a drupe, with a thin epicarp overlying a thick, fibrous mesocarp. The fibers of the mesocarp, which are the commercial product called coir, are used to make rope, matting, baskets, etc. Inside the mesocarp is the hard shell-like endocarp which in turn encloses the endosperm; this provides, as the fruit ripens, the white meat or copra, rich in oil, and the watery milk, of the central cavity. About 5,000 coconuts yield 1 ton of copra, and a single ripe nut weighs 2.5-3 kg and attains a length of about 25 cm. The fruit is fully grown in 6 months but requires 3-7 months more to become mature. The coconut palm begins to bear fruit in or about the sixth year and comes into full bearing in about the twelfth year, with a mean annual production on good plantations of some 80 nuts and on particularly well-maintained ones of 150 nuts, but only about 30 in neglected groves. The embryo which develops within the nut fills the central cavity and emerges through one of three pores (eyes) in the shell; the leaves and roots penetrate the outer layers of the fruit in opposite directions (Fig. 5). The cotyledon, unlike a mature leaf, is undivided.

Classification of insect pests of the coconut palm [1]

The body of all insects consists of three parts: head, thorax and abdomen, and adult insects have three pairs of legs and usually one or two pairs of wings, all these appendages arising from the thorax. Spiders, mites and ticks, which are not insects, have a different basic structure. In many insect species the early stages are legless. To reach the adult stage every insect undergoes a series of transformations which are referred to collectively as its metamorphosis. In some kinds of insects, the metamorphosis is said to be complete, because it involves three very different stages after the egg — the larva (also called caterpillar, grub, maggot,

[1] The Orders and Families represented among the pests of the coconut palm dealt with in this work are listed in Table 1, together with notes on selected characteristic features of the Orders (or other major groupings).

TABLE 1. - ORDERS AND FAMILIES TO WHICH THE INSECT PESTS OF THE COCONUT PALM BELONG

Order	Family	Characteristics
Orthoptera	Acrididae Tettigoniidae Gryllidae	Hind legs saltatorial; forewings tough, at rest covering membranous hindwings. Eggs laid in the soil; early stages similar to adults in form and mode of life. (Grasshoppers, locusts, crickets.)
Phasmida	Phasmidae	Body very elongate, stick-like; wings small or absent. Eggs seed-like, laid freely in trees, often dropping to the ground. Early stages similar to adults. (Stick insects.)
Isoptera	Rhinotermitidae Termitidae Kalotermitidae	Social insects living in communities composed of well-marked castes, such as reproductives, workers, soldiers and queens; structure and arrangement of nests vary greatly according to family and species. (Termites or white ants.)
Rhynchota or Hemiptera	Coreidae Pentatomidae Tingidae Aphididae Coccidae Aleurodidae	This order is divided into: Heteroptera (including Coreidae, Pentatomidae and Tingidae) and Homoptera (including Aphididae, Coccidae and Aleurodidae); in the Heteroptera basal zone of forewings thickened, differing from distal zone, wings when at rest flat on back, crossed distally; in the Homoptera, forewings and hindwings, if present, similar and uniformly membranous. Early stages similar in form and mode of life to adults. (Plant bugs, including [Homoptera] aphids, scale insects, white flies.)
Lepidoptera	Amathusiidae Brassolidae Satyridae Hesperiidae Cossidae Cosmopterygidae Cryptophasiidae Agonoxenidae Galeriidae Pyraustidae Phycitidae Psychidae Limacodidae Castniidae Zygaenidae Noctuidae	Two pairs of wings, covered with scales, usually forming conspicuous pattern and/or color. Larvae mostly leaf-eaters and free-living, but some construct webs or bags and others tunnel in trunk, nuts or spadices. Pupae in soil, or in cocoons, or suspended by silken girdle or freely. Early stages entirely different from adults. (Butterflies and moths.)

TABLE 1. - ORDERS AND FAMILIES TO WHICH THE INSECT PESTS OF THE COCONUT PALM BELONG (*concluded*)

Order	Family	Characteristics
Coleoptera	Lymexylonidae Hispidae Curculionidae Scolytidae Dynastidae Lucanidae Melolonthidae	Forewings (elytra) tough, opaque, at rest usually covering the membranous hindwings. Larvae with three pairs of legs or without legs. Early stages entirely different from adults. (Beetles.)
Hymenoptera	Formicidae	The ants live in communities organized in castes, in general males, workers and queens. Certain species are beneficial predators. Early stages entirely different from adults. (The order Hymenoptera also contains the bees and wasps, including several families of parasitic wasps, many species of which are beneficial as enemies of coconut pests.)
Diptera	Scholastidae (Ortalididae)	Only one pair of wings. Early stages entirely different from adults. (The order Diptera contains a vast assemblage of flies with only two wings; some of them, notably in the family Tachinidae, are beneficial as enemies of coconut pests.)

nymph, according to the kind of insect), the pupa (also called the chrysalis in the case of butterflies and moths) and then the adult; other examples of complete metamorphosis are provided by the flies, wasps and the beetles. Incomplete metamorphosis, on the other hand, is so called because the early stages after the egg resemble the adult in general form and way of life, except that they are wingless and therefore, unlike most adult insects, cannot fly; examples of types of insects having this kind of metamorphosis are the locusts, grasshoppers and the plant bugs.

The principle of classification which is used throughout the animal and plant kingdoms involves the placing of any particular specimen into its appropriate positions in a series of assemblages of descending status. The insects constitute the Class Insecta, which is divided into several Orders, and each order is divided (often via Suborders and Superfamilies) into Families, each family into Genera, and each genus into Species and, frequently, each species into Subspecies. In practice, every organism is placed directly into the appropriate genus, which is a group of species morpho-

logically and biologically similar to one another. Thus, the so-called rhinoceros beetles, widely distributed in the tropics, can be classified as follows: Class, Insecta; Order, Coleoptera; Superfamily, Lamellicornia; Family, Dynastidae; Genus, *Oryctes;* Species, *rhinoceros* (Asia), *monoceros* (Africa), *centaurus* (New Guinea).

Many species are so variable that well-marked differences warrant division of them into subspecies or into geographical races. An example is provided by a beetle of the genus *Brontispa*, the classification of which is as follows: Order, Coleoptera; Superfamily, Phytophaga; Family, Hispidae; Genus, *Brontispa*; Species, *longissima*; Subspecies, *selebensis* (Celebes), *javana* (Java), *simmondsi* (Bismarck Archipelago), *froggatti* (Melanesia).

Mention is made in this work not only of the pests but also, in the more important cases, of their insect enemies, both parasites and predators. Since the pests are arranged under the names of the families and orders to which they belong, there is no difficulty in classifying them; the natural enemies, however, are named in the accounts of the pests which they attack, and in order that interested readers may know what sorts of insects they are, the family or superfamily name is given in most cases, usually with an indication of a higher group (order) to which the family or superfamily belongs. The names of the families or superfamilies are usually given in full (e.g., *Tachinidae*, *Proctotrupoidea*, *Chalcidoidea*), but the names of the higher groups are abbreviated in a form which will be readily interpreted by entomologists (*Hym.* for *Hymenoptera*; *Dipt.* for *Diptera*). Frequently, however, the family or the superfamily is sufficiently indicated by adjectival terms such as tachinid, coccinellid, braconid and chalcidid, and the higher group similarly by terms such as dipterous, hymenopterous, wasp, fly and beetle.

The scientific names given to animals and plants are not static. Taxonomic studies sometimes show that a species placed in a certain genus has greater affinity with the species of another genus, to which it is therefore transferred with consequent change of its generic name. Thus, a tachinid fly (a beneficial parasitic species) known for some 40 years as *Ptychomyia remota* is now considered by specialists to belong to the genus *Bessa*. Similarly, a common moth pest of copra known for more than half a century as *Ephestia cautella* has recently been transferred to the genus *Cadra*. Changes of specific names must also be made on occasion according to the rules of nomenclature; when it is discovered that another name has previously been given to the same species or that the same name has previously been used for a related species, the name first used and the first allocation of a name take priority. An example in this category is the moth *Tirathaba complexa*, which was for many years referred to in the literature as *Tirathaba trichogramma*. Some of the names used in this work may well require changing in the future.

For purposes of accurate taxonomic identification, it is customary, and indeed necessary, to append to a species name the name (often abbreviated)

of the specialist who described that species under that name. Thus, the moth, already mentioned, whose specific name is *cautella*, was *Ephestia cautella* Walker until it was placed in the genus *Cadra*, when it became *Cadra cautella* Walker. In this volume, the name of the specialist is given at the first mention of each invertebrate species (after the Introduction), but not subsequently. The convention of putting in brackets the names of the authors of those species whose generic allocations have been changed is ignored as being superfluous in a work of this nature, as opposed to a primarily taxonomic work. In certain special instances, however, in which the name now considered correct differs from one by which the species is probably known to many readers (as in the case of *Cadra cautella* already cited) a special note of warning is given.

Insect damage in relation to the environment of the palm

The degree of damage caused by coconut pests can be related to some extent to the conditions of the environment, particularly to the composition of the vegetation associated with the palm and to the microclimate which it engenders, and also to soil and to weather factors (Lever, 1964a).

Effects of neighboring vegetation and of the condition of the food supply

A striking example of the effect of other plants on insect damage is provided by the long-horned grasshopper *Sexava nubila* on coconut estates in the Talaud Islands near Celebes. Franssen (1954) showed that where there are areas of dense coverage of the ground by *Centrosema pubescens*, *Sexava* lays its eggs in such areas rather than in patches of bare soil or in the coconut palms; this facilitates the discovery of the eggs by the egg parasite *Leefmansia bicolor*, with the result that heavy parasitization occurs, sometimes attaining 95 percent, and the *Sexava* population in the palms is much lower than it would otherwise be.

In New Britain it has been shown (Hoyt, 1963b) that the beetle *Oryctes centaurus* is less harmful to coconut palms in places where the palms have been interplanted with cocoa than elsewhere. The same author has also demonstrated (Hoyt, 1963a) that in West Africa burning of the jungle has a more adverse effect on the predators that destroy species of *Oryctes* occurring there than on the beetles themselves.

In 1928, it was observed in the Solomon Islands that attacks on the palms by the beetle *Brontispa longissima froggatti*, which feeds between the unopened leaflets, were invariably less severe in the nursery on young local palms than on corresponding palms of Malayan or Samoan origin (Tothill, 1929).

Later observations showed that this same beetle in New Guinea caused more damage on young palms on which wild vines had been allowed to climb than on those properly tended (O'Connor, 1940).

Since the planting up and maintenance of coconut estates provide artificial pure stands of the one plant species, of which palm-feeding insects in the surrounding jungle can avail themselves, care must be taken to ensure that pests do not establish themselves along the boundaries and spread inward before being noticed. In the Malay Peninsula, the moth *Setora nitens*, whose caterpillars eat the coconut leaves, mainly on young palms, is most troublesome in recently cleared and planted areas adjoining jungle (Corbett, 1932). Similar observations have been made in the Solomon Islands concerning the bug *Amblypelta cocophaga*, which is considered to be a relatively recent invader of the plantations, where it thrives on the extensive and readily accessible food supply (Lever, 1935).

An interesting instance of the effect of diet on a caterpillar pest of coconut palms has been given by van der Vecht (1950), who observed that the life cycle of the moth *Brachartona catoxantha* in the areas in which he worked in Java was consistently longer by 8 days than the 36 days normally recorded, and there was a reduction in the reproductive capacity of the moths and in the proportion of females to males. These effects were attributed to a physiological decline in the health of the trees. Similar observations have been made in the Sangi (Sangihe) Islands, to the north of Celebes, where Reyne (1948) recorded that deterioration of the food supply of a subspecies of the coconut scale insect *Aspidiotus destructor* resulted in a reduction of the fecundity of the female insects and heavy mortality in the early stages.

Effects of climate and weather

The seasonal changes in outbreaks of *Brachartona catoxantha* have been studied in several countries. In the Malay Peninsula and the Philippines, the combined effects of wind and rain on the insects tend to terminate the outbreaks which always begin in the dry season (Gater, 1925, 1926; Merino, 1938), but wind also transports the moths from their normal sites in jungle areas to distant coconut plantations (Gater, 1926).

The effects of relative humidity and rainfall on the development of the beetle *Brontispa mariana* have been studied on Saipan Island in the Mariana group, in Micronesia, where Lange (1950) calculated that the number of generations per year can vary from 3 to 9 according to meteorological conditions, the mean being 5 to 6. In the case of one of the true leaf-mining species of the same family (Hispidae), *Promecotheca coeruleipennis*, which had become a serious pest of coconut palms in the relatively dry Lau Islands of Fiji, it was concluded by Taylor (1937) that, while the low rainfall was a dominant factor in the outbreaks, its effect was nevertheless indirect.

The precipitation in Lau (about half that of other parts of Fiji) was not sufficient in the dry season to limit, as it did elsewhere, the multiplication of an unintentionally introduced parasitic mite, *Pyemotes ventricosus*, with the result that the mite completely destroyed the larvae and pupae of *Promecotheca*, and their indigenous parasites, in the mines of the leaves, leaving only the adult beetles. The onset of the rainy season then caused a sudden reduction in the mite population to a very low level, thus enabling the beetle to multiply without hindrance.

In India and Ceylon, it has been observed that outbreaks of the moth *Nephantis serinopa* are occasionally terminated by abnormally heavy rains causing the death of the leaf-eating caterpillars in their silken galleries and favoring the development of pathogenic fungi and bacteria. The heaviest infestations occur during the hot, dry months, and it is the onset of the monsoon season that results in the reduction of the caterpillar population to a low level (Nirula *et al.*, 1951b).

In the Fiji Islands, coconut palms growing in swampy ground were particularly prone to severe infestation by the scale insect *Aspidiotus destructor*. This led to a belief that ill-nourished palms were more favorable to the insect than healthy ones, but it was later concluded that the factor favoring it in such sites was that they were sheltered from strong winds (Taylor and Paine, 1935).

Hurricanes can give rise indirectly to outbreaks of pests. An increase in the population of the beetle *Strategus* that occurred in Puerto Rico after a particularly severe hurricane was due to the abundance of food provided by the fallen palms. In many of the islands of the Pacific, hurricanes have had the same effect on infestation by *Oryctes rhinoceros*.

Effects of soil composition and manuring

Soil factors also can be responsible for damage to coconut palms by insects. A notable example of this is afforded by the beetle *Melittomma insulare* in the Seychelles, which is reported as occurring only on islands of granitic origin, not on those derived from coral (Vesey-Fitzgerald, 1941b). This beetle became a pest at the time when coconut palms, which are not indigenous to the islands, were first cultivated there on a commercial scale; previously its host plants there were indigenous palms of the genera *Stevensonia* and *Nephrosperma*. The same group of islands provides another instance of the nature of the soil as a factor in insect infestation, in that the damage caused by the scale insect *Ischnaspis longirostris* is more severe on palms growing in alluvial soils than on those in coral sand or eroded ridges. A somewhat similar case of limitation of habitat occurs in the extreme southwest of India, where the beetle *Leucopholis coneophora* favors sandy soils, especially those in which root crops such as tapioca, yam, sweet potato and *Colocasia* are grown

(Nirula *et al.*, 1952). This beetle is one of the few primary pests of the roots of coconut palms; it did not become serious until 1952.

In India and Ceylon, the termites *Odontotermes obesus* and *O. redemanni* attack seedling palms commonly in lateritic soils, rarely in sandy soils (Nirula *et al.*, 1953).

Like all trees, the coconut palm responds to manuring and, in general, is less severely damaged by pests when healthy than when unhealthy. In Fiji, outbreaks of the moth *Agonoxena argaula* were checked by spraying with malathion to kill the caterpillars, but it was observed that the adverse effects of the insects on the health of the trees persisted longer in areas where no fertilizer had been applied to the soil and no draining or weeding had been practiced (Hinckley, 1961). In Ceylon, the caterpillars of *Nephantis serinopa* often cause serious damage, but only those palms growing on poor and ill-drained soils are actually killed (Nirula *et al.*, 1956b).

It is most important to give seedling palms a good start by avoiding harsh treatment during transplanting (Barrett, 1928). Care should be taken not to damage the roots, either mechanically or by exposing them too long; otherwise the plants will be severely checked in growth and weakened, in which condition they are highly vulnerable to termite attack and to the ravages of other pests.

The shedding of immature nuts

This phenomenon, commonly referred to as "immature nutfall," must be briefly mentioned, since the primary purpose of coconut growing is the production of ripe nuts. This is a complex problem involving the agronomist, soil chemist, geneticist and entomologist.

The term "nutfall" is used rather loosely to include: firstly, the fall of young nuts, usually less than four months old, which results from attack by plant bugs, caterpillars, weevils or rats, and which is discussed under the appropriate headings: *Amblypelta*, *Pseudotheraptus*, *Axiagastus*, *Tirathaba*, *Diocalandra* and rodents; and secondly, natural or "button nutfall," which occurs within two months from the opening of the spathe and is due to factors other than insects or rodents. Natural nutfall can be due to the shedding which must inevitably occur merely because the tree cannot nourish all the fruits which are set, as in the case of the shedding of young apples and young cotton bolls; temporarily adverse physiological factors, such as drought or flooding; or permanently adverse environmental factors, such as waterlogged soil, or hardpan preventing adequate root development, or shortage of salts (usually potash). In addition, the female flowers may fall off without setting, owing to abortion of the stigma, or to inviability of the pollen or lack of pollinating insects. There are almost certainly causes

of premature shedding which are still unknown. Various authors have estimated that, of the flowers which set, only 25-30 percent yield ripe nuts.

Recently, in India, the application of hormones to the trees by spraying has given encouraging results. An aqueous solution of 2-4-dichlorophenoxyacetic acid at 30 parts per million, plus the same volume of coconut milk or cow's urine, has led to retention of nuts and an increase of 35-160 percent in the weight of copra produced.

For many years the problem of nutfall has been studied on an *ad hoc* basis, with or without its entomological aspects, and it is encouraging to note that it is now receiving comprehensive attention as a full-time investigation. Details on this subject can be found in the literature by the following authors: Dwyer (1937); Gadd (1923); Gangolly *et al.* (1956); Simmonds, H.W. (1938); Tammes (1937); Taylor (1930).

Current needs and research trends

The uncontrolled utilization of modern, highly toxic insecticides of long residual effect, in place of the older products such as arsenicals, nicotine and kerosine emulsion, constitutes a very serious threat to the beneficial parasitic and predatory insects which contribute greatly to the suppression of many insect pests. The destruction of these natural enemies of harmful insects enables the latter to multiply. It is to be hoped that coconut growers will not have to face the same difficulties in this respect as those which have afflicted fruit growers in Europe and North America. It is essential to avoid the destruction of beneficial insects, and this can be achieved by careful selection of the insecticides to be used, proper timing of application and, in general, by controlled and knowledgeable use.

The recent establishment (in 1961) in Tahiti of the beetle *Brontispa longissima*, which attacks the young unopened coconut leaves, illustrates the necessity for strict quarantine measures. The arrival of this pest to an island situated some 5,000 km from its probable source, New Caledonia, constitutes a grave menace to the production of coconuts in a vast region of Polynesia, but fortunately there are good prospects of its control by chemical or biological means. It appears that there was also a movement in the opposite direction of another pest, the very harmful scale insect *Aspidiotus destructor*, which arrived at about the same time (probably from Polynesia) in New Caledonia and the New Hebrides. The appearance of *Oryctes rhinoceros* in Mauritius in 1962 and in the Tokelau Islands, north of Samoa, in 1963 affords further examples of recent accidental introductions of dangerous insects.

With expanding air services and the use of ever faster aircraft, it can be expected that pests such as scale insects and leaf miners will be transported

increasingly, in coconut leaf baskets that are in common use wherever the palms are grown, unless rigid quarantine is enforced at all places where planes land. A classical example of disastrous transportation of a highly undesirable insect is that of the rhinoceros beetle to Samoa from Ceylon in packing cases of rubber budwood in 1911, prior to the establishment of international phytosanitary regulations.

The mere enactment of quarantine measures cannot attain its objective unless it is supported by means of enforcement. In Ceylon, *Oryctes rhinoceros* is still a serious pest more than half a century after the laws designed to control it were promulgated, since they have never been adequately implemented, and similar failure in Samoa to control this beetle has resulted from failure to enforce regulations enacted in 1914.

A recent instance of legislation designed to exclude insect pests is to be found in the U.S. Trust Territory of the Pacific Islands (Anon., 1959), where the introduction of coconut plants and of the nuts themselves (excluding husked nuts) is prohibited unless they have been fumigated with methyl bromide; this particular fumigant is lethal to all insects. Similar measures should be adopted in other countries to ensure mutual benefit.

It is interesting to note that current work on the control of the rhinoceros beetle in Samoa includes a return to the 50-year-old method of using fungal, bacterial and other organisms which cause disease in insects. The program also involves the utilization of parasitic and predatory insects, as well as attractant and sterilant substances and the technique of sterilization of males by irradiation.

Considerable progress has been achieved in research on the coconut palm at the permanent stations that already exist for this purpose in India and Ceylon, where teams of specialists of various disciplines concentrate their efforts on the one plant species.

1. INVERTEBRATE PESTS

INSECTS

Orthoptera

Acrididae

In comparaison with rice, millet, sugarcane and banana, the coconut palm is not much favored as a food plant by the insects (locusts and grasshoppers) which comprise this family. Certain species have, however, caused serious damage. In general, attacks on palms have occurred only at intervals of several years and in relation to meteorological conditions, such as drought, which may cause swarms to settle in the moister areas where palms are grown.

Many species of this family, though liable to occur in large numbers, are habitually solitary-living, while others (which are called locusts) pass intermittently, and in particular circumstances, from the solitary (*solitaria*) phase to a gregarious (*gregaria*) phase via intermediate (*transiens*) forms. These phases have corresponding morphological and color differences which, in some species, are very striking. The transformation to the gregarious phase takes place in certain areas which, for some species, are clearly delimited, so that they can be referred to as outbreak areas. In other species, the areas where gregarious behavior develops are much less clearly defined and it is more appropriate to speak of outbreak conditions than outbreak areas. In either case, the areas where the initial swarming occurs may be very far from the coconut plantations reached by the migrating swarms. The eggs are laid in patches of bare soil, often in grassy plains, and each female deposits a succession of oothecae (egg pods), each of which contains many eggs and is buried at a depth of several centimeters in the soil (Fig. 8). From the eggs, wingless hoppers emerge, and in certain species and favorable circumstances these form themselves into vast coherent bands which advance on a front that may be more than a kilometer in length, feeding on vegetation as they go. Migratory flights of adult locusts occur while the ovaries of the females are still immature (Figs. 9 and 10).

Control

In general, satisfactory control of acridids has been obtained by applications of dieldrin, aldrin, BHC or malathion. Diazinon has given good results on the experimental scale.

As the use of insecticides such as dieldrin and aldrin entails a certain danger for man and domestic animals, and as acridid infestations are liable to occur in remote areas and on a large scale, particular care is necessary to ensure proper supervision in the conduct of the control campaigns. However, the availability of chlorinated hydrocarbon insecticides and the development of effective techniques for their application by aircraft have made antiacridid operations much easier, quicker and more effective than the measures previously employed, such as the distribution of poisoned bait transported in bulk by trucks and the digging of trenches and erection of barriers to stop the advance of the bands of hoppers.

In Thailand, in 1961, maize, rice, sugarcane and banana cultivations suffered serious damage caused by an outbreak of *Patanga succincta* Linnaeus (Fig. 14) (Bhenchitra, 1964). The insect was combated by aerial spraying of 2.5 percent dieldrin in oil at about 140 grams dieldrin per hectare. Although coconut palms were not attacked on this occasion, it is worth noting that at this relatively low dosage the same treatment would be appropriate in the eventuality of an attack by *Patanga* on coconut estates.

In India, the application of 100-200 grams of 10 percent BHC per palm is recommended for control of acridids (Kurian, 1963).

The natural enemies of acridids (*Diptera*, *Hymenoptera*, *Coleoptera*, birds, bacteria and fungi) have been considerably investigated and the conclusions have been reached that, while they sometimes destroy a high percentage of an acridid population locally, and in particular circumstances, on the whole they are ineffective as controlling agents.

Locusta migratoria manilensis Meyen

Economic aspect

Outbreaks of this locust in Borneo are associated with extensive clearing of forest (Uvarov, 1928).

Several instances of damage to fruits and leaves of the coconut palm through breakage by the weight of locusts settled on them have been recorded in the Philippines (Fig. 13). Since 1919, it has been noticed that all the swarms of this locust have originated in the rice- and maize-growing areas of Cotabato or in the Masbate grasslands, in which areas efforts are made to prevent their migration to the fertile zones of Luzon and Visayas (Otanes, 1956). In 1940, by utilizing the knowledge gained from studies of the intermediate (*transiens*) phase, it was possible to predict an outbreak which occurred in 1941-44 (Otanes, 1941). Sometimes, locusts which have originated in the Philippines have migrated in the gregarious phase to the Malay Peninsula, 1,600 km away, but outbreaks also arise there by local gregarization from the solitary phase (Corbett, 1932).

In addition to coconut, rice and maize, plants attacked are sugarcane, pineapple, bamboo, and various other gramineous species, both wild and cultivated.

Geographic distribution

The Philippines, Borneo, the Malay Peninsula, Indonesia, southern China and Taiwan.

Description/Biology

In the gregarious phase, the hoppers are blackish and the adults are grayish green and constricted in the thorax; the body of the male is 40-50 mm long, that of the female 42-55 mm. In the solitary phase, the hoppers are greenish and the adults green to blackish, without constriction in the thorax; the body length is 29-35 mm in the male and 37-60 mm in the female (Corbett, 1932).

In the Malay Peninsula, the egg stage lasts about 2 weeks. The hopper stage, comprising five or six instars, covers 37-51 days.

Control

In aerial spraying, DDT, which was formerly employed, has been replaced by dieldrin and aldrin. Outbreaks, which have lasted 7-11 years in the past and have caused serious damage to coconut palms, should in the future be brought under control much more rapidly (Otanes, 1956).

Locusta migratoria migratorioides Reiche and Fairmaire

Economic aspect

Damage to coconut palms by the African migratory locust, *L. m. migratorioides*, was reported in Dahomey and Ghana during 1930-34 (Bullen, 1964), the swarms concerned having originated in the permanent breeding grounds of this locust in the floodplains of the Niger in Mali. *Elaeis* and rice also are attacked.

Geographic distribution

This locust is found in the solitary phase in the Near East and many African countries. During the last plague period (1928-41), serious infestations of the gregarious phase occurred in nearly all the countries of Africa south of the Sahara.

Schistocerca gregaria Forskål

Economic aspect

This is the well-known desert locust (Figs. 8 to 12). It has damaged date palms more often than coconuts, but the latter have been seriously defoliated by it in coastal Kenya, in Tanzania, and in parts of India (Bullen, 1964). It eats a great range of plants and does enormous damage to many different food and cash crops.

Geographic distribution

Northern, western and eastern Africa, the Near East, Pakistan and India.

Biology

The number of generations per year varies from 2 to 4, which may occur in different areas connected by migrations. The female lays 3 egg pods on average, each pod containing about 70 eggs.

Tropidacris cristata Linnaeus

Economic aspect

This large grasshopper is one of many species that occasionally cause damage to coconut palms in South America; it was particularly severe in Brazil in 1914/15.

Biology

The egg pods, which are relatively large, are deposited at a depth of about 5 cm in the soil. The egg stage lasts 47 days, the hopper stage 166 days, and the adult stage 240 days (Azevedo, 1922).

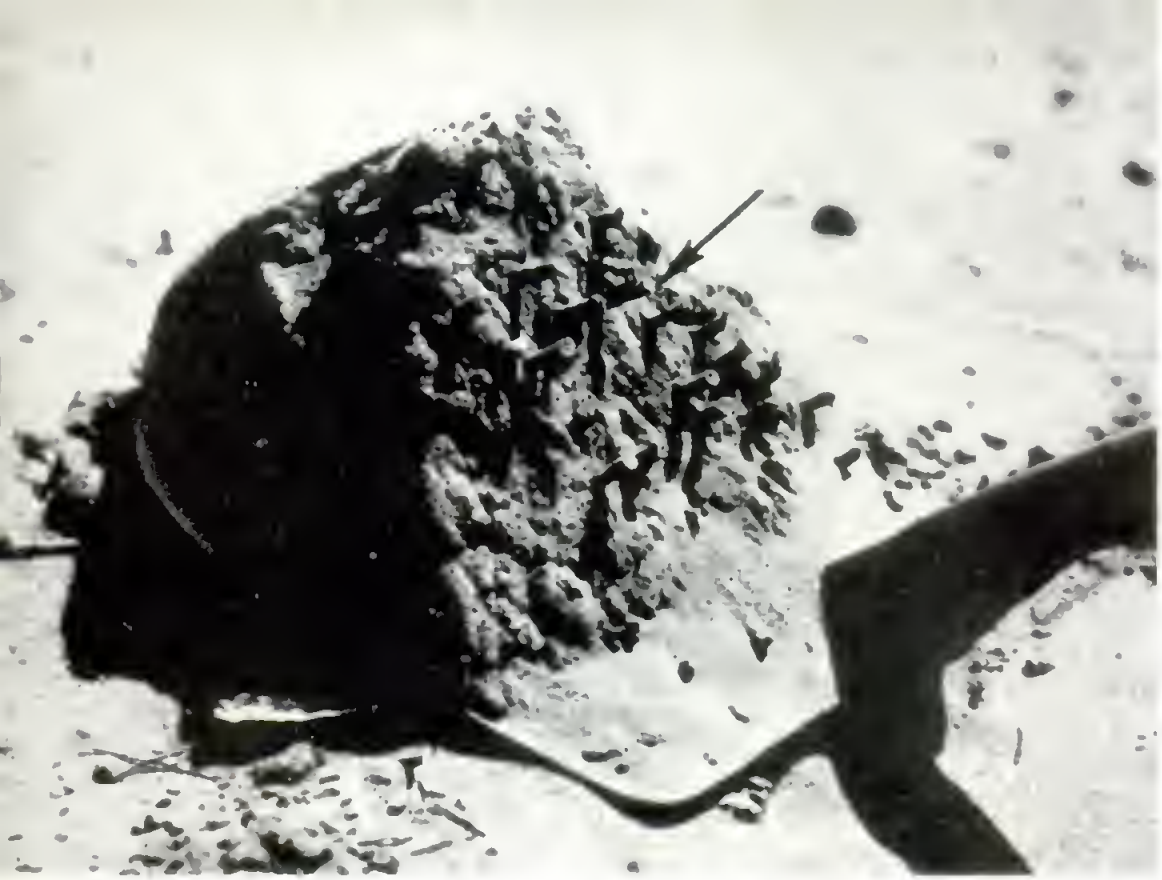
Control

The egg pods can be exposed by plowing or digging; this results in the death of the embryos. Arsenical insecticides were formerly used against the active stages but presumably dieldrin sprays would be effective if applied suitably in relation to the biology of the insect.

Tropidacris dux Drury

Economic aspect

This species occurs in Trinidad and Venezuela. In 1954, 400 hectares of coconut plantations were damaged in Trinidad. *Quassia*, *Meliocea*, *Erythrina* and banana are also attacked, and are preferred to coconut.



FIGURES 8-9. - *Schistocerca gregaria* Forskål. Shovel sample from an egg site (8, above) and a marching band of first-instar hoppers early in the morning (9, below).

FIGURES 10-11. - *Schistocerca gregaria* Forskål. Thinly populated marching band of fourth-instar hoppers (10, above) and migrating adults (11, below).

FIGURE 12. - *Schistocerca gregaria* Forskål. Adult.

Control

In 1955, spraying with BHC in Venezuela failed to give satisfactory control (Hall, 1955), but in 1957 low-dosage application of dieldrin over some 35 hectares was effective (Hall, 1958).

Tropidacris latreillei Perty

Economic aspect

This grasshopper attained pest status in Guyana in 1957 and damaged coconuts; it had not previously been a serious pest for 40 years. Its main host plant is *Quassia*.

Control

Spraying with 0.5 percent dieldrin at about 200 liters per hectare is claimed to be effective; aldrin and BHC are less so.

Aularches miliaris Linnaeus

Economic aspect

This is an Asiatic species which appears to be confined to coastal areas. It attacks coconut, coffee, *Areca*, *Erythrina*, *Casuarina* and banana.

Geographic distribution

India, Ceylon, the Malay Peninsula, Thailand, Java.

Description/Biology

A rather large and conspicuously colored insect, with black head, yellow tuberculate thorax, greenish elytra (forewings) with yellow spots and black abdomen. The incubation period is long, about 5 months, and the hopper period is of similar duration. Each egg pod contains 45-115 eggs, and the pods are deposited in a range of soil types, including loose sand, stiff clay and loam (Uvarov, 1928).

Control

Poisoned bait can be used, but spraying with parathion is recommended against the young hoppers, as is scorching with flame guns when they are on low weeds. In Thailand, destruction of the eggs is achieved by plowing to a depth of 10-12 cm (Meksongsee, 1963).

Nomadacris septemfasciata Serville

Economic aspect

Damage to young coconut palms by this locust, which is known as the red locust, has occurred in Tanzania and in Kenya. In 1934/35, when severe infestation by swarms and hopper bands occurred, 40 hectares of young palms were defoliated by large hoppers. This species mainly frequents grasses and is therefore more frequently a pest of gramineous crops, notably sugarcane, than of coconuts.

Geographic distribution

The red locust has recognized outbreak areas, mainly in southern Tanzania and Zambia, from which swarms would escape if swarming were not controlled as it is. During the last severe plague period (1930-44) almost all countries of Africa south of the equator were invaded. The solitary phase occurs in several African countries, and also in Madagascar and Mauritius.

Valanga nigricornis Burmeister

Economic aspect

The damage done by this acridid may be severe but is very localized and is normally confined to the tops of trees. It has been recorded as a pest of coconuts in the Malay Peninsula and Java, and is said to be most

FIGURE 13 (above). - Defoliation of palms by adults of *Locusta migratoria manilensis* Meyen. Arrows indicate densest groups of locusts causing sagging of leaves. The Philippines.

(*Courtesy Philippine Bureau of Plant Industry*)

FIGURE 14. - Individuals of *Patanga succincta* Linnaeus.

harmful when there is an undergrowth of *Mimosa* (Corbett, 1932). It occasionally occurs in very large numbers over small areas. It has a wide range of food plants, including *Areca*, *Elaeis*, tea, coffee, rubber, *Ficus*, *Citrus*, *Castiloa* and *Artocarpus*; wild sugarcane and *Imperata* grass are said to be immune from attack.

Geographic distribution

V. nigricornis extends from India through Southeast Asia to Australia.

Description/Biology

The adult insect is greenish yellow or brown, with two black bands or patches on the femur of the hind leg. The number of eggs per egg pod is 55-115.

Oxya chinensis Thunberg

Economic aspect

This insect, known as the rice grasshopper, since it is common in areas of wet soil, particularly rice fields, occasionally attacks coconut palms. When the level of the water is high, it lays its eggs in the clumps of rice instead of in the soil. In addition to rice and coconuts, it attacks sugarcane, cotton, coffee and kapok.

Geographic distribution

Southeast Asia and Melanesia.

Other species of Acrididae

The following species have occasionally damaged coconut palms in Asia: *Patanga succincta* Linnaeus (the Bombay locust), *Catantops splendens* Thunberg, *C. humilis* Serville and *Atractomorpha psittacina* Serville.

Tettigoniidae

This family comprises the long-horned grasshoppers. Only a few of them attack coconut palms, but these include species of the genus *Sexava* which are very harmful:

***Sexava nubila* Stål**

***S. coriacea* Linnaeus**

***S. novae-guineae* Brancsik**

***S. karnyi* Leefmans**

Economic aspect

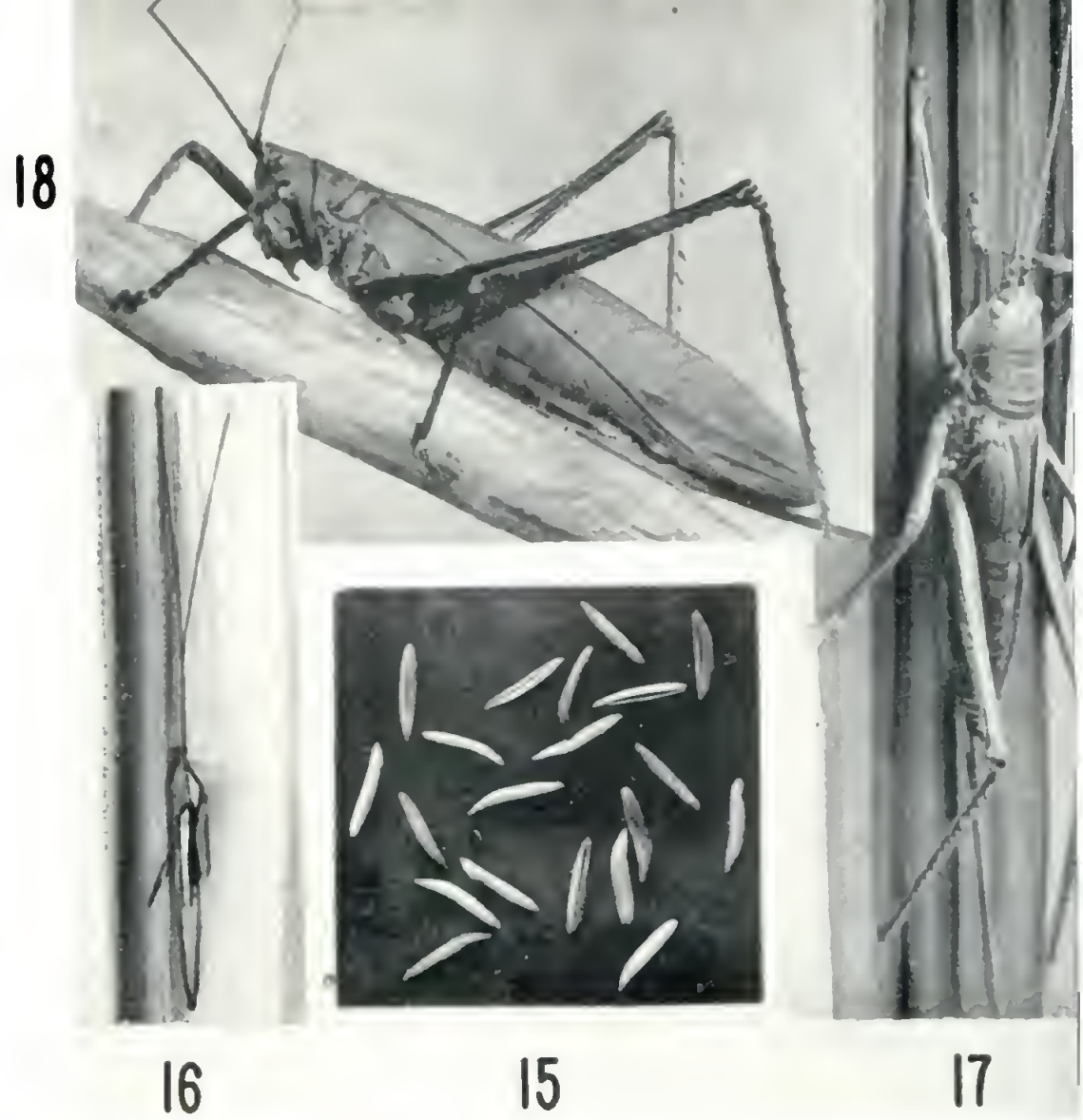
The early stages and the adults damage coconut palms and sometimes cause serious defoliation. When the leaves are reduced to the midribs the insects attack the inflorescences and the young fruits (Fig. 22). The destruction of the leaves results in immature nutfall, the tree being no longer able to nourish the normal crop (Dwyer, 1937). Other plants attacked are *Areca*, *Metroxylon*, *Nypa*, banana, sugarcane, *Ravenala*, *Heliconia* and *Pandanus*.

Geographic distribution

S. nubila occurs in Ceram, Kei, Aru and New Guinea; *S. coriacea* (Figs. 15 to 18, and 22) in the islands east of Celebes as far as Ceram and New Guinea; *S. novae-guineae* in New Guinea and the Bismarck Archipelago; and *S. karnyi* in Poat (in the Gulf of Celebes).

Description/Biology

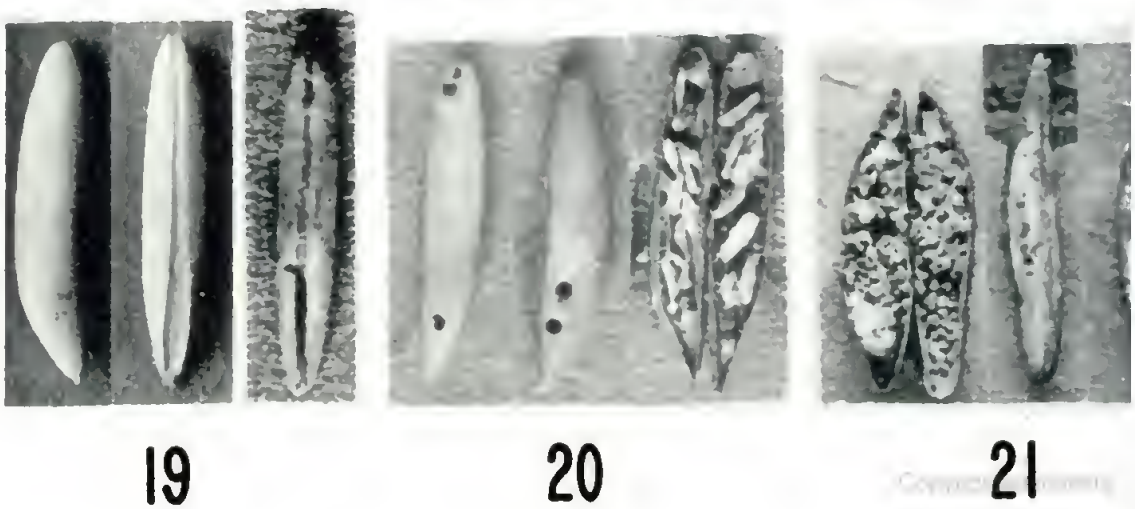
The filiform antennae, being much longer than the body, distinguish these insects from the *Acrididae* (short-horned grasshoppers and locusts). In the females, the ovipositor is relatively large and scimitar-like. The males are 48-57 mm long and the females 57-63 mm, excluding the antennae which themselves measure up to 200 mm. The eggs are slender, slightly curved and 9-13 mm long. Each female produces 20-40 eggs, which are usually deposited in the soil at a depth of 10-15 mm but may also be laid in the epiphytic plants of the crown of the palm. The incubation period varies from 6 to 14 weeks, averaging 8½. The nymphs (nonadult stages) molt six times in the course of their development and become adult in 20-22 weeks in the male and a slightly longer period in the female. Thus, the developmental cycle from oviposition to the attainment of the adult stage covers 30-40 weeks (Froggatt, 1935). The rate of development is similar among the four species considered here. The insects descend to the ground at night and climb again to the crowns of the palms in the morning. They are said to be particularly harmful during or after periods of heavy rainfall.



FIGURES 15-18. - *Sexava* species. Eggs (15); first-instar (16) and last-instar (17) nymphs; and adult (18) of *S. coriacea* Linnaeus.

FIGURES 19-21. - Eggs of *Sexava* species before and after hatching of nymphs (19, left), parasitized by *Leefmansia bicolor* Waterston (20, center), and by *Doirania leefmansi* Waterston (21, right), with typical emergence hole of the parasites. Photos 15-21 S. Leefmans, *in* L.G.E. Kalshoven, 1950-51.

(*Courtesy N.V. Uitgeverij W. van Hoeve, The Hague*)



Control

BHC is recommended, either as a dust or as an oil emulsion, for application to the soil as an ovicide or to the crowns of the trees as a residual insecticide (Dun, 1955). Dieldrin, as a wettable powder, has also given satisfactory results.

As regards biological control, two parasites of the eggs, *Leefmansia bicolor* Waterston (*Hym., Chalcidoidea, Encyrtidae*) and *Doirania leefmansi* Waterston (*Hym., Chalcidoidea, Trichogrammatidae*), introduced into the Talaud Islands (north of Celebes) and New Guinea from Amboina (Moluccas), have proved effective (Figs. 20 and 21). A considerable increase in the degree of parasitization in Talaud resulted from the replacement of wild host plants of *Sexava* in the coconut plantations by cocoa, cloves and *Centrosema pubescens* (grown as a green manure), the latter forming a mat about 40 cm thick. The *Sexava* females laid their eggs in these plants, and the percentage parasitization by *Leefmansia* reached 85-95 percent (Franssen, 1954). In New Guinea, another parasitic insect, *Stictotrema dallatorreana* Hoffer, of the order Strepsiptera, having a very high reproductive rate, has given good control (O'Connor, 1959b). Lizards and birds contribute to the destruction of *Sexava* in the crowns of the trees.

Other tettigoniids

Certain species of the genera *Eumossula, Segestidea* and *Pseudoniscara*, attributed in the past to the genus *Sexava*, are pests of the coconut palm in New Guinea and neighboring islands (Szent-Ivany, 1956). Also in this region, *Segestes decoratus* Redtenbacher damages the fronds, and in the Palau Islands (Micronesia) *S. unicolor* Redtenbacher is similarly harmful.

All these tettigoniids, including *Sexava*, do much less damage on palms growing in the jungle than in coconut plantations (Leefmans, 1927). Like *Sexava*, they can be controlled by suitable application of BHC and dieldrin.

GRYLLIDAE

Cardiodactylus novae-guineae Haan is the only member of this family recorded as harmful to the coconut palm. Damage by it is most severe on seedling palms; it attacks *Pandanus* and *Codiaeum* also. It occurs in New Guinea and in the Solomon Islands. The adults are recognizable by the coloration of their wings, which are smoky black with white spots; the legs are reddish brown.

FIGURE 22. - *Sexava coriacea* Linnaeus. Feeding traces on coconuts. Photo S. Leefmans, *in* L.G.E. Kalshoven, 1950-51. Amboina, Indonesia.
(Courtesy N.V. Uitgeverij W. van Hoeve, The Hague)

Phasmida

PHASMIDAE

Graeffea crouani Le Guillou (formerly known as *G. cocophaga* Newport)

Economic aspect

This stick insect is a serious pest of coconut palms in Polynesia and a large part of Melanesia, where it is responsible for defoliation and sometimes even death of the trees. In Fiji, the outbreaks are limited in extent to about 20 hectares. The damage by both young and adult insects takes the form of gaps cut out of the edges of the leaflets as if by scissors. In addition to coconut, *Pandanus tectorius*, *Miscanthus japonicus* and *Hibiscus tiliaceus* are attacked; this last is said to be preferred to coconut in the New Hebrides (Risbec, 1937).

Geographic distribution

This species is common in the New Hebrides, New Caledonia, Fiji, Samoa, Tonga, Wallis and Futuna. A much wider distribution, including Australia and the Society, Marquesas and Gambier Islands in eastern Polynesia, has recently been recorded for it (Nakata, 1962). It has been suggested that the eggs may be carried by masses of vegetation which float on the sea.

Description/Biology

The male is 65-70 mm long, the female 105-116 mm. The wings are vestigial in both sexes but are particularly reduced in the female; the hindwing is slightly less reduced than the forewing, and is rose-pink posteriorly. The nymphs measure 20 mm at hatching, and are very fragile. The egg resembles a small grain and has a nipple-like projection. About 120 eggs are laid per female. The incubation period lasts about 100 days. The nymph molts five times if male, and six if female, in the course of its development, which occupies 92 days in the former case and 111 in the latter (O'Connor, 1954b). The total cycle therefore covers 6-7 months. The eggs are laid separately and unattached; most of them drop to the ground but some lodge in the axils of the leaves. The nymphs that hatch on the ground climb up to the crowns of the palms, where they live. Feeding occurs at night; the insects rest by day beneath the leaves, the female often carrying the male on its back. When disturbed, they eject an acrid white fluid from thoracic pores. A normal population is about 150 individuals per palm. Heavy infestations are often associated with the presence of *Buchloë dactyloides* (buffalo grass) under the trees (Simmonds, H.W., 1938); their direct cause is probably ineffectiveness of their natural parasitic enemies due to temporarily adverse conditions.

Control

Control is difficult, since the insect lives in the crown of the tree. Recently, however, satisfactory results have been obtained in Fiji by application from the air of a spray of 0.5 percent gamma BHC in oil at about 28 liters per hectare; alternatively, a 50 percent BHC dispersible powder can be applied at about 11 kg per hectare. Treatment should be repeated every four months (O'Connor, 1959a). Putting sticky bands round the trunks to prevent the insects from ascending also gives some control; the sticky material contains 2-3 parts resin mixed with 1 part oil (linseed, coconut or castor) in which is incorporated DDT at 60 grams per kilogram of the mixture. About 50 kg of this mixture suffice for applying bands 7-8 cm wide to

300 palms; the rate of treatment is about 27 palms per man-hour (O'Connor, 1954a).

The old method of causing the insects to drop to the ground by lighting fires is liable to injure the trees.

In addition to two indigenous parasites of the eggs, both belonging to the genus *Paranastatus* (*Hym.*, *Chalcidoidea*, *Eupelmidae*), the ant *Tapinoma melanocephalum* Fabricius contributes to the destruction of the eggs. An attempt to establish in Fiji an egg parasite, *Myrmecomimesis rubrifemur* Mickel, (*Hym.*, *Cleptidae*), was unsuccessful.

Graeffea seychellensis Ferrari *and G. lifuensis* Sharp

These species damage the coconut palm in the same way as *G. crouani*, the first in the Seychelles and the second in the Loyalty Islands, near New Caledonia. Outbreaks of them are often recorded in the smaller islands, where indigenous parasites may become scarce from time to time.

Ophicrania leveri Günther

Economic aspect

This insect (Figs. 23 and 24) causes damage intermittently in Savo, an island of the Solomons, where it defoliates coconut palms in coastal plantations, but not inland (Pagden and Lever, 1935). *Areca*, *Calamus* and *Metroxylon* are also attacked.

Geographic distribution

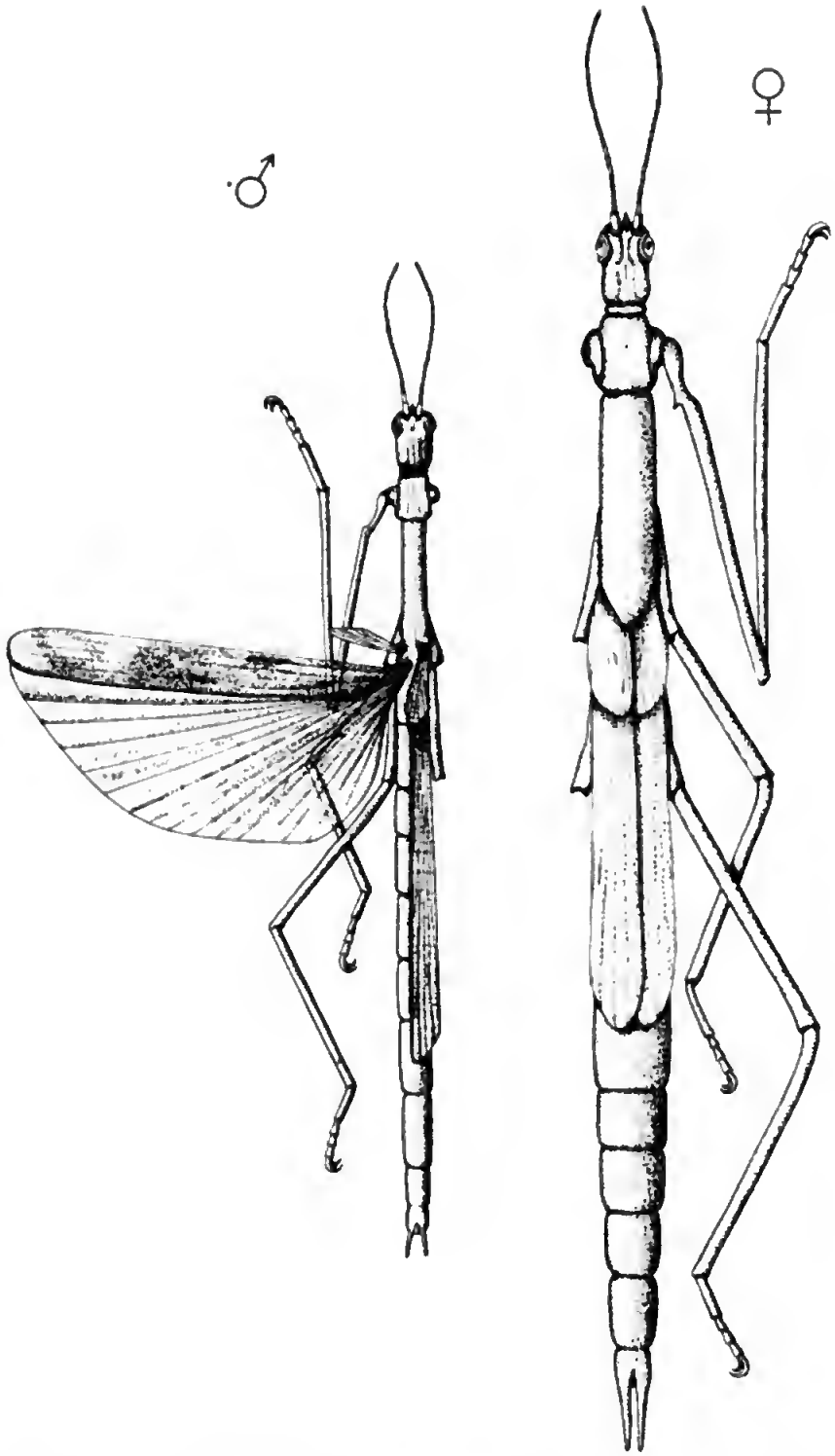
O. leveri is present in all the more important of the Solomon Islands, including the isolated Santa Cruz group, but it has never been recorded as a serious pest except in Savo.

Description/Biology

The adults are rather larger than those of the preceding species, the males measuring 72-90 mm and the females 102-120 mm. The body is green and brown, and the hindwings are pale pink. Outbreaks, like those of *Graeffea*, seem to be particularly associated with a dense ground cover of grasses and weeds under the palms.

Control

In Guadalcanal and New Georgia, this insect is parasitized by a tachinid fly (*Dipt.*), which has also been recorded in Kolombangara Island and is attaining 35 percent parasitization. The parasite seems to be absent from Savo (Paine, R.W.).



FIGURES 23-24. - *Ophicrania leveri* Günther. Male (23, left) and female (24, right).

Megacrania phelaus Westwood

This is another large phasmatid found in the Solomon Islands. It damages coconut palms on the Island of Ugi only; elsewhere it attacks *Pandanus* only. It would be interesting to ascertain why this and some other phasmatids attain relatively much larger numbers in small islands than in large ones, this phenomenon having been recorded for many years. According to recent investigations of R.W. Paine on this species and *O. leveri* in the Solomons, it seems that the inter-island variation noted in the intensity of infestation is related to the degree of parasitization by tachinid flies.

Isoptera

Rhinotermitidae

The species of termites belonging to this family live in subterranean nests. The individuals of the "soldier" caste have an enormous gland which opens by a pore at the front of the head and secretes a sticky fluid.

Coptotermes curvignathus Holmgren

Economic aspect

The coconut palm is liable to be attacked by this termite at any stage of its growth, but damage by it is most severe in trees 2-4 years old. Seedling palms are attacked through the nut or at the base of the young shoot, older palms through the crown or trunk (Corbett, 1932). Other plants attacked include mango, rubber, *Elaeis* and *Oncosperma*.

Geographic distribution

New Guinea, Borneo, the Malay Peninsula, Indonesia.

Description/Biology

The soldiers (Fig. 25) are 6-8 mm long and have a large, brown, pear-shaped head. The workers are smaller and have a pale yellow head. The nest is composed of horizontal plates of hardened evacuated food material and is normally situated in hardwood logs or stumps or in hollowed-out boles of living trees; this species is not a mound builder. From the nest the termites tunnel through the soil searching for food, and their galleries may extend for several hundred meters at a depth in the ground varying from only a few centimeters to more than half a meter. An enormous

quantity of wood is required to feed the colony. It is not possible to control this pest simply by removing the current queen because the workers can, by special feeding, create fertile queens from certain individuals called supplementary queens (Corbett, 1932).

Other species of Coptotermes

Another species of the same genus, *C. ceylonicus* Holmgren, which occurs in Ceylon, causes similar damage to palms by hollowing out the trunks. A third species, *C. truncatus* Wasmann, in the Seychelles, increases the damage done by the beetle *Melittomma* by driving tunnels further in the sound wood of the trunk.

Schedorhinotermes marjoriae Snyder

Economic aspect

This termite excavates large compact nests among the roots of the coconut palm and also in accumulated dead vegetation. Occasionally it is found nesting in epiphytic plants on the trees.

Geographic distribution

Solomon Islands.

Description/Biology

There are two kinds of soldiers (Fig. 26) in this species, one larger than the other. The larger has a median groove at the front of the head which canalizes the viscous liquid to the mandibles. The soldiers have a characteristic yellow color.

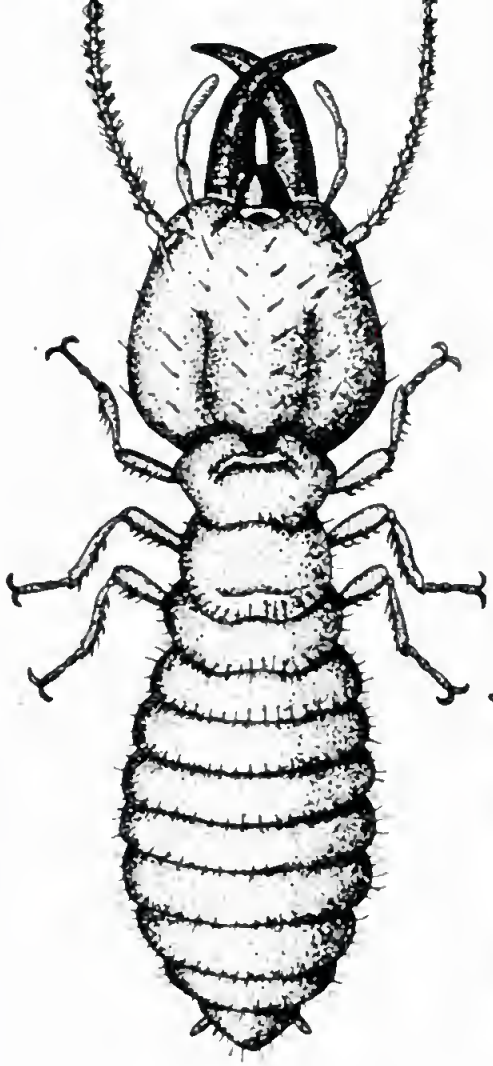
Termitidae

Most of the species of termites belong to this family, which includes species that are entirely subterranean and others that build mounds. There is great variation both in types of the soldier caste and in form of nest.

Microcerotermes biroi Desneux (formerly referred to as *M. piliceps* Snyder)

Economic aspect

M. biroi is the commonest species of termite in the Solomon Islands. It constructs carton nests on the trunks of coconut trees about a meter above the ground, and also nests among the aerial roots at the base of the trunk and in fallen nuts (Fig. 29). It is not very harmful, although its nests are a



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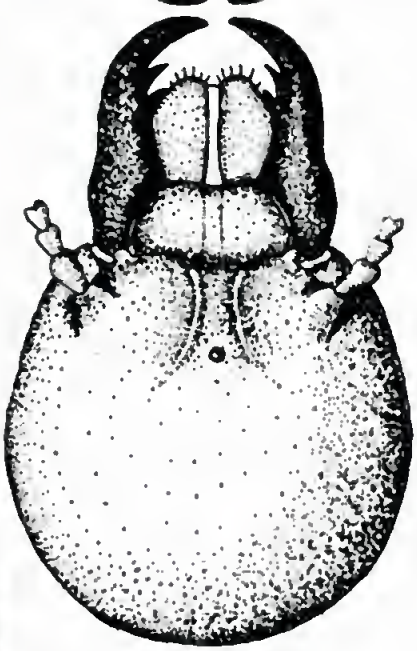

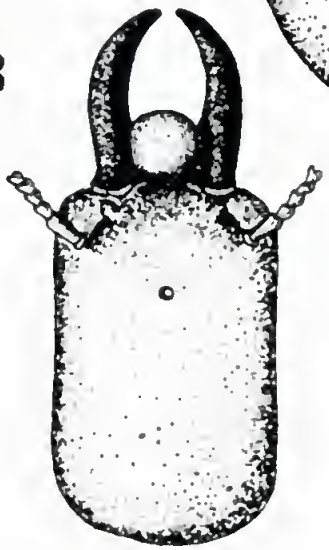

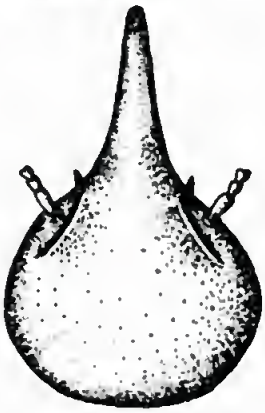

25 27 28

FIGURES 25-28. - Termites. Heads of soldiers of different species, i.e., *Coptotermes curvignatus* Holmgren (25, according to Corbett, 1932), *Schedorhniotermes marjoriae* Snyder (26), *Microcerotermes biroi* Desneux (27), and *Nasutitermes novarumhebridarum* Holmgren (28, according to Harris, 1961).

FIGURE 29. - Termitarium of *Microcerotermes biroi* Desneux on a jungle tree trunk. Solomon Islands.

(*Photo R.J.A.W. Lever*)

characteristic feature of coconut plantations in the islands. Its workers have been found in the leaf stalks of young palms.

Geographic distribution

Solomon Islands and New Guinea.

Description/Biology

The winged adults probably occur throughout the year. They are small, with blackish wings. The inner edge of the mandibles of the soldiers is finely serrated (Fig. 27). The queen is only 18 mm long. Nests on the ground are smoother than those on the trunk, the latter nests usually being covered with protuberances (Harris, 1958). Strong carton runways radiate out from the nest, both upward and downward; they are constructed at the rate of about 3 cm per day.

Control

Because of the very wide range of nesting places of this termite, the practice of proper estate hygiene is particularly important in its control.

Other species of Microcerotermes

M. bugnioni Holmgren and *M. peraffinis* Silvestri also occur in coconut plantations, in Ceylon and Samoa, respectively, the former nesting deep down among the roots (Harris, 1961) and the latter on the trunks about 2 meters above the ground; abandoned galleries of *M. peraffinis* allow rain to enter the trunk, which rots in consequence (Hopkins, 1927).

Nasutitermes ceylonicus Holmgren

N. ephrates Holmgren

N. laticeps Wasmann

N. novarum-hebridarum Holmgren

These four species have all been recorded as pests of the coconut palm. Their soldiers have a pointed snout and minute mandibles; these features are common to all species of the genus *Nasutitermes* (Fig. 28).

N. ceylonicus, in Ceylon, nests in the roots and constructs long runways on the trunks; *N. ephrates*, in Panama, lives between the leaf sheath and the petiole and damages the living tissues; *N. laticeps*, in Madagascar, is considered to be harmful mainly because it exposes the tissues of the palm to subsequent attack by boring insects of other kinds (Harris, 1961); and *N. novarum-*

hebridarum (Fig. 28) (formerly known as *Eutermes yandiniensis* Hill), in the Bismarck Archipelago, New Guinea, the Solomons and the New Hebrides, attacks palms which have been struck by lightning or otherwise grossly damaged (Szent-Ivany, 1956).

Other species of Termitidae

The following species damage seedling coconut palms, particularly in nurseries:

Allodontotermes morogoroensis Harris, in eastern Africa.

Odontotermes obesus Rambur and *O. redemanni* Wasmann, in India and Ceylon. These termites are more severe (causing up to 20 percent loss of seedlings) on lateritic than on sandy soils (Nirula *et al.*, 1953); the wilting of the central shoot is the first sign of their attack, which usually occurs at the base of the collar.

Macrotermes nigeriensis Sjöstedt, in western Africa; *M. bellicosus* Smeath in Zanzibar, where 50 percent losses have occurred; and *M. gilvus* Hagen in New Guinea and the Malay Peninsula.

Kalotermitidae

The species of this family, collectively known as dry wood termites, are mainly pests of seasoned timber and woodwork rather than living trees; nevertheless, living coconut palms have been severely attacked on occasion.

Neotermes rainbowi Hill

Economic aspect

This is a serious pest in the northern Cook Islands. The infestation starts at or near ground level and may extend up the trunk as far as the crown, even on tall palms. According to Hopkins (1927) the damage so weakened the trees that the trunks broke in hurricanes. Given (1964) records that young palms may have their fruiting capacity seriously restricted by infestations extending only 1.5 meters on the trunk. The potential danger from this termite is locally considered to be at least as great as that from *Oryctes rhinoceros*. *Pandanus* is frequently attacked, as are all other woody plants, except *Cordia subcordata*.

Geographic distribution

Cook Islands and Ellice Islands.

The control of termites

A high standard of plantation management and hygiene is the basis of all preventive action against termites. Fallen leaves, useless nuts and felled or broken palms must be collected and burned.

For the chemical control of termites, a wide range of insecticides is now available, and considerable success has been achieved. Harris (1961) recommends the use of BHC, dieldrin, aldrin or chlordane, and Child (1964) advises application of 10 percent BHC dust or 2 percent dieldrin dust at about 56 kg and 112 kg powder, respectively, per hectare. Nursery beds and young palms, being particularly susceptible, can be sprayed with water-miscible oil emulsions, and it is specially recommended that insecticidal dust should be incorporated in the potting soil. Other chemicals used to combat termites are pentachlorphenol, sodium pentachlorphenate, parathion and heptachlor. Covering the germinating nuts with a layer of sand has sometimes proved useful.

Since the most serious damage occurs in the nursery and during the first four years of growth, it is particularly important that treatment should be applied whenever necessary during these years, in order to ensure that the palms have a good start. Young palms when first planted out are highly susceptible to damage, and this operation should therefore not be undertaken too early in areas where termites are prevalent.

On older palms termite injury appears to encourage injury by borers, and to aggravate existing damage due to them and to man-made or other wounds on the trunks. The practice of cutting steps in the trunks to facilitate the tapping of toddy or the collecting of nuts for drinking should be made an offense in plantations and villages. Child has pointed out that termite attacks on established palms are largely confined to weak, moribund and even dead palms.

Rhynchota or Hemiptera (Heteroptera)

Coreidae

Amblypelta cocophaga China

Economic aspect

A single feeding puncture of this insect in the inflorescence of the coconut palm can cause a deep fissure to develop in the tissues because the salivary glands produce a highly toxic secretion. The wound provokes a gummy exudation, and if it is on or associated with the young nuts it causes them to fall off prematurely (Figs. 30 and 31). For many years *Amblypelta* was not incriminated as a causative factor in nutfall because it is usually very

scarce in the trees, but its guilt was eventually established by Lever (1935, 1937) and was confirmed and amplified by Phillips (1940, 1956), O'Connor (1950) and Brown (1956, 1959). Since each feeding puncture destroys a relatively large amount of tissue, a single insect (young or adult) can do great damage in the course of its life to the inflorescences that it visits. In areas where premature nutfall was regarded as only moderate, the loss of crop due to *Amblypelta* was about 10 percent (Brown, 1959).

A. cocophaga also attacks cocoa, mango, kapok, cassava, sugarcane, papaya and many other tropical plants.

Geographic distribution

Solomon Islands; *A. cocophaga* extends from Bougainville through most of the islands of the southern chain; in the northern chain of islands it is present on Malaita.

Description/Biology

The adult male is 13-14 mm long, the female 14.5-16 mm. The antennae are four-segmented, and as long as the body. The thorax is green in front, brown behind and furnished with two small basal spines; the forewing is reddish brown but transparent distally, revealing the brown abdomen. The legs and the ventral surface of the abdomen are yellow-brown (Fig. 32).

The eggs are 2 mm long and change from golden green to wine red as they develop; they are laid on the underside of the bases of the older leaves (Brown, 1959). The egg stage lasts 6-8 days and is followed by five nymphal instars which together cover 4½-5 weeks, the complete development thus requiring 5½-6 weeks (Lever, 1933c; Phillips, 1940). The adults take flight readily. The mean density of populations is very low, on the order of one adult only per tree, and the nymphal stage is elusive and rarely seen.

Control

The best results have been obtained with dieldrin, though endrin in the same conditions had the most rapid initial action. Emulsions of BHC and chlordane were unsatisfactory. Aerial spraying was considered uneconomic (Fenemore, 1958) and the use of ground-operated equipment is not economic or practical since the height of the trees on long-established plantations is 20-25 meters and the manipulation of the necessary high-power mist blowers on rough ground is difficult.

With regard to control by natural enemies, neither an indigenous parasite of the eggs, *Anastatus axiagasti* Ferrière (*Hym., Chalcidoidea, Eupelmidae*), nor indigenous predatory reduviid bugs exert sufficient pressure on this sparsely distributed insect (Lever, 1935). Two egg parasites, *Ooencyrtus*

malayensis Ferrière (*Hym., Chalcidoidea, Encyrtidae*) and *Hadronotus homoeoceri* Nixon (*Hym., Proctotrupoidea, Scelionidae*), were introduced into the Solomons from Indonesia but failed to become established (Phillips, 1941). Similarly, two tachinid parasites, *Pentatomophaga bicincta* de Meijere from Queensland and *Trichopoda pennipes* Fabricius from Florida, were introduced, but neither was ever recovered in the Solomons (Phillips, 1956).

A fauna rather rich in ants in the coconut plantations of the Solomons has been found to be closely related to the degree of abundance of *Amblypelta* and therefore to the amount of damage done by it. The predatory ant *Oecophylla smaragdina* Fabricius, which nests on the palms, is a very effective natural limiting factor when undisturbed, but in many localities it is itself attacked and rendered ineffective by two other species of ants, notably *Pheidole megacephala* Fabricius, which thus allow *Amblypelta* to maintain itself in such numbers that much damage is done to the young nuts (O'Connor, 1950; Phillips, 1956; Brown, 1959; Lever, 1961; Greenslade, 1964). This complex of insect species, in which several other ant species in addition to those mentioned are involved, has been the subject of several intensive investigations, as a result of which attempts have been made to control *Amblypelta* by adjusting the conditions in the plantations so as to favor *Oecophylla* at the expense of *Pheidole* and other ant species.

Amblypelta lutescens Distant

This species, of which two forms are recognized, occurs in New Guinea and Queensland (Australia). It resembles *A. cocophaga* but has a much wider body. It has been known in the past as a pest of banana and beans but has recently been found to attack coconut and also rubber, cassava and *Ipomaea carna* (Szent-Ivany and Catley, 1960). The eggs are parasitized by *Anastatus* and *Ooencyrtus* (*Hym., Chalcidoidea*) which, however, are negligible as limiting agents.

Other species of *Amblypelta* occur in the Solomons on coconut but they are not yet of any economic importance (Brown, 1959).

Pseudotheraptus wayi Brown (formerly placed in the genus *Theraptus*)

Economic aspect

This insect (Fig. 36) causes the same damage to coconut palms in eastern Africa and Zanzibar as *Amblypelta* in Melanesia. A single puncture by it, resulting in necrotic lesion and gummosis, can cause the shedding of nuts even in the third month of their development (Figs. 33 to 35), but from the

FIGURE 30. - *Amblypelta cocophaga* China. Injury to young nut (with perianth removed) . . .

FIGURE 31. - . . . and to older nut by feeding. According to R. Leach, *in* B.A. O'Connor, 1950.

FIGURE 32. - Adult.

(*Photo E.S. Brown*)

age of 4 months onward nuts are able to continue their development even if severely punctured by the bugs. The annual crop loss in Zanzibar due to *Pseudotheraptus* has been valued at the equivalent of U.S. $1,400,000-$5,600,000 (Vanderplank, 1960b). The first investigations of this insect were conducted by Way (1951, 1953b), who incriminated it as the cause of gummosis; previous investigators of nutfall had attributed it to unfavorable soil conditions.

Other plants attacked are: cocoa, guava, mango and cinnamon (Tait, 1954).

Geographic distribution

Coastal zones of Tanzania and Kenya, and the islands of Zanzibar, Pemba and Mafia.

Description/Biology

The adult is reddish brown above; beneath it is paler, with pink spots. The male is 12-14 mm long, the female 13-15.5 mm. The period of development (egg plus nymphal instars) is 26-40 days, of which 6-9 days is the incubation period. The adult life of the male is 84 days, and that of the female 73. The female lays, on average, 74 eggs. The first-instar nymphs have not been found on the coconut palm; the damage done to the tissues begins to be serious when the nymphs are about half-grown. Adults of both sexes take wing readily when disturbed. Each individual makes about 200 punctures in the course of its existence. The insect lives in the crown of the palm throughout its life and the nymphs are found only on or near the spadix. Few can be caught by day because they shun direct sunshine and heavy rain. Feeding takes place in late afternoon and early morning, and the insects are most active on cloudy but not heavily overcast days (Vanderplank, 1958b). The density of population varies greatly from tree to tree, but it is always low and the average per tree is only about one individual (as in the case of *Amblypelta* in the Solomons) (Vanderplank, 1960a,b; 1961).

Control

Dusting with 0.4 percent gamma-BHC at about 22.5 kg per hectare gave good results (Way, 1953b), but it destroyed the beneficial predatory ant *Oecophylla longinoda* Latreille and should therefore never be used where this ant occurs. If additional control is needed in such areas, a selective insecticide, composed of 120 kg of 80 percent p,p′-DDT and 12 kg of coumarin resin in a mixture of 500 liters of kerosine and 500 liters of dieselene, can be applied round the trunks; the "bloom" of crystals which forms subsequently does not harm the relatively large *Oecophylla* but destroys the small ants

(mentioned below) which prey upon it. The resinous mixture should be applied on paper bands to avoid scorching the trunks. These bands can prevent the passage of the small, harmful ants for 6-9 months (Vanderplank, 1958a). The effectiveness of this insecticide, which is called 10 DRDK, was not improved by the addition of pyrethrum, dieldrin, endrin or rotenone.

It was later calculated that, to cover the cost of this treatment (of which 80 percent is the cost of the insecticide), an increase in yield of nuts of 45 percent was necessary. Unfortunately, the increase was only 40 percent in Tanzania and 20 percent in Zanzibar, and in the following year treated palms yielded less than others. It was therefore concluded that, despite the promising results obtained experimentally for a limited period, it would be more economical to resort to clean cultivation (Hyde-Wyatt and McKinley, 1959), together with spraying where and when necessary. The best single residual insecticide was found to be dieldrin (Wheatley, 1961).

The problem of the natural control of *Amblypelta* in the Solomons is remarkably closely paralleled by that of *Pseudotheraptus* in eastern Africa and Zanzibar. In both cases, a complex of ant species is a dominant factor, involving not only a species which is highly beneficial because it destroys the bug but also other species which prey on the beneficial one and are therefore harmful; moreover, in both cases the beneficial ant belongs to the genus *Oecophylla* and the undesirable ones include a species of the genus *Pheidole*. A further similarity lies in the fact that careful ecological studies of the two complexes of insects have revealed that it is extremely difficult so to arrange the ecological conditions that the potentially highly beneficial *Oecophylla* is enabled permanently to achieve an adequate degree of control of the bug.

Workers of the ant *Pheidole punctulata* Mayr, which is one of those that attack *Oecophylla*, destroy eggs of *Pseudotheraptus*. The later stages of the latter are parasitized by *Halictophagus zanzibarae* Bohart of the order Strepsiptera. An unidentified lizard devours *Pseudotheraptus* in palms that do not contain *Oecophylla* (Vanderplank, 1958b).

It has been observed that cashew, mango and citrus trees growing among the coconut palms on plantations favor *Oecophylla* and so check *Pseudotheraptus*. Interplanting with such trees is therefore a standard recommendation in Kenya.[1]

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[1] In the publication *Host list of fungi and insects recorded on coconut in South East Asia and the Pacific* (Anon., 1962) the bug *Physomerus grossipes* Fabricius is mentioned as a pest of coconut palms, apparently in error; it is, in fact, a pest of beans and sweet potatoes.

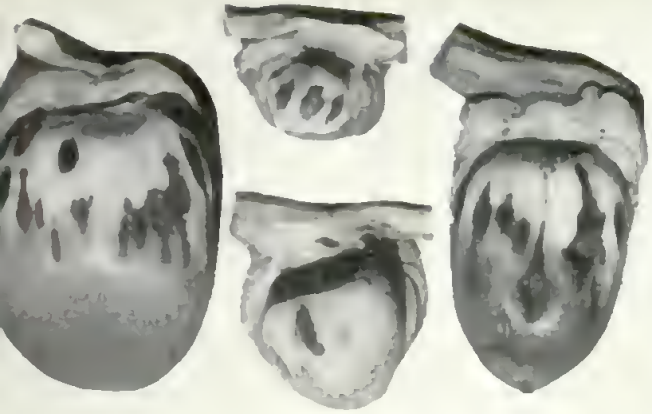


FIGURE 33. - *Pseudotheraptus wayi* Brown. Female flowers and 6 to 10-week-old nuts showing feeding punctures. Zanzibar.

FIGURE 34. - 5 to 6-month-old nut damaged by feeding (right), compared with an undamaged nut of same age (left).

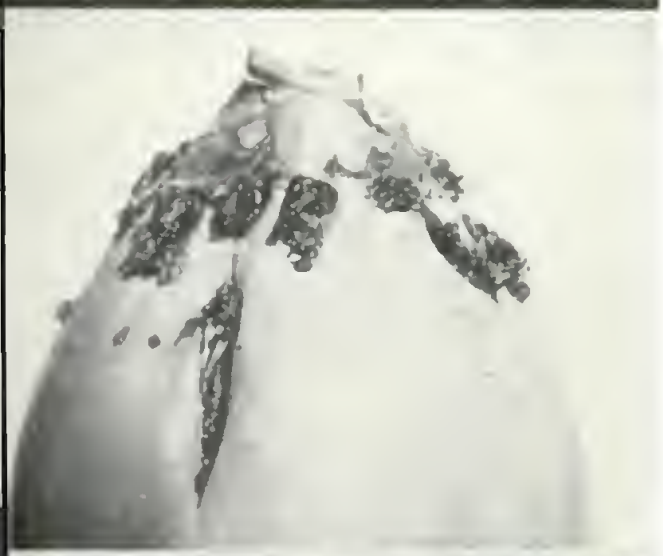


FIGURE 35. - 6-month-old nut, showing gum oozing from base two weeks after puncturing.

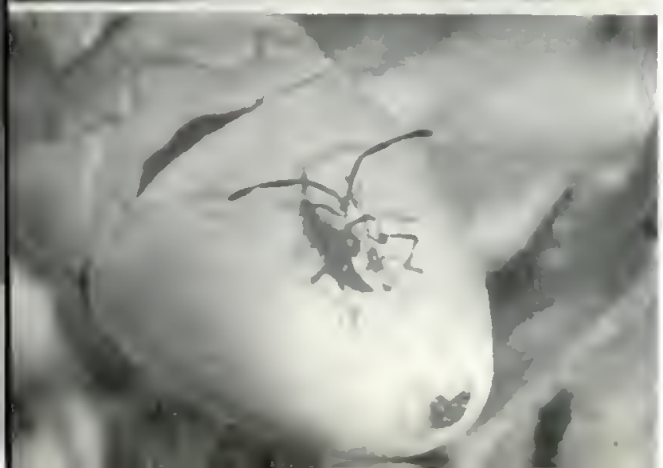


FIGURE 36. - Nymph on young nut.
(*Figures 33-36 M.J. Way*)

PENTATOMIDAE

Axiagastus cambelli Distant

Economic aspect

This bug often occurs in abundance on the newly opened spadices, feeding on both male and female flowers. It can cause some fall of immature nuts, but its economic status is difficult to assess, since the damage done by it appears to be much less than the number of insects present would suggest (Fig. 37). The nutfall is probably due to loss of sap, not to injection of toxic fluid (*cf. Amblypelta* and *Pseudotheraptus*). *A. cambelli* is reported as causing severe nutfall in parts of the Bismarck Archipelago (Dwyer, 1937) but is rarely a serious pest in the Solomons. It attacks *Areca* as well as coconut.

Geographic distribution

Solomon Islands, New Hebrides, New Guinea, Bismarck Archipelago.

Description/Biology

The head, thorax and abdomen of the adult are dark brown with yellow marks, and its length is 14-15 mm. The eggs are barrel-shaped and pearly; they are laid in clusters of about 14 on the fibrous sheath which envelops the leaf base and on the spadix, and only rarely on the leaves (*cf.* Tothill, 1929). The nymphs are whitish at first, then yellow, and finally orange with black markings. The incubation period is 7 days and the five nymphal instars together last about 45 days, so that the total developmental period is about 7½ weeks.

Control

Spraying with DDT or with a wettable powder of 50 percent dieldrin is recommended.

Two parasites of the eggs are known: *Anastatus axiagasti* Ferrière (*Hym., Chalcidoidea, Eupelmidae*) and *Microphanurus painei* Ferrière (*Hym., Proctotrupoidea, Scelionidae*). The species of parasite which has attacked an egg can be recognized after the adult parasite has emerged from it, because each species leaves a characteristic pattern on the egg shell.

Agapophyta bipunctata Boisduval

This bug damages the leaves of young coconut palms and of *Metroxylon* in New Guinea (Szent-Ivany and Catley, 1960). Its biology has not yet been studied.

FIGURE 37. - *Axiagastus cambelli* Distant. Typical deformation of young nuts damaged by feeding. New Hebrides.
(*Photo V.L. Delucchi*)

TINGIDAE

Stephanitis typicus Distant

Economic aspect

Until recently this bug was regarded mainly as a pest of banana which did only slight damage to coconut, but investigations which are still in progress suggest that it may be important as a vector of virus root wilt and other diseases, including kadang-kadang in the Philippines (Mathen, 1960) and bronze leaf wilt. In addition to coconut and banana, its host plants include Manila hemp, camphor, cardamom, *Alpinia*, *Hedychium*, *Anona* and *Artocarpus*. Lepesme (1947) cites pineapple also as a host plant. In the laboratory, a wilt has been transmitted by this insect to cowpea (*Vigna sinensis*) (Shanta and Menon, 1960).

Geographic distribution

Southern China, Taiwan, Korea, the Philippines, south India, Pakistan, Ceylon, the Malay Peninsula, Indonesia, New Guinea.

Description/Biology

The body is black and 2.4 mm long. The wings are hyaline, and the forewings are ornamented with a raised brown network characteristic of Tingidae.

Control

Application of malathion at 0.1 percent in an emulsifiable solution, or of diazinon or parathion at the same concentration, is recommended.

(Homoptera)

APHIDIDAE

***Astegopteryx nipae* van der Goot** (formerly placed in the genus *Oregma*)

Economic aspect

This parthenogenetic aphid causes yellow spotting on the lower surface of the coconut leaves; it is usually of little importance but occasionally multiplies sufficiently to be harmful. It also attacks *Nypa*, *Elaeis*, *Zalacca* and *Languas*.

Geographic distribution

The Malay Peninsula, China (Taiwan), New Hebrides, New Guinea.

Description

The margin of the body produces numerous white waxy filaments which mask its shape.

Control

Treatment with malathion at about 0.1 percent is recommended. The ant *Oecophylla smaragdina* protects the nymphs.

***Cerataphis lataniae* Boisduval**

Economic aspect

The damage done by this aphid is seldom severe. It feeds on the leaves and sometimes on the nuts. On the rare occasions when dense infestations

occur, its presence results in the development of sooty mold (*Capnodium*) on the leaflets. Other host plants are *Areca*, *Calamus*, *Elaeis*, *Kentia*, *Roystonea* and orchids.

Geographic distribution

C. lataniae originated in tropical America but now occurs in eastern Africa and in some islands of the Pacific; it is especially serious in the Hawaiian Islands.

Description

The young individuals are green. The adults are black with a conspicuous, uniform, white waxy fringe round the margin, which gives them the appearance of scale insects.

Control

Except when beneficial coccinellid beetles are present, malathion, diazinon or parathion should be applied as a spray.

COCCIDAE

***Aspidiotus destructor* Signoret**

Economic aspect

This scale insect is one of the most serious pests of the coconut palm. It is commonly known as the Bourbon scale, the transparent scale, or the coconut scale. In severe outbreaks, it forms a continuous crust (Fig. 40) over the lower surface of all the leaves, which first become yellow owing to heavy loss of sap and blocking of the stomata, and finally die. The leaf petioles, flower spikes and young nuts are also liable to be infested.

The range of host plants is very wide, including, in addition to coconut: *Elaeis*, *Phoenix*, avocado, banana, cocoa, citrus, ginger, guava, *Artocarpus*, *Pandanus*, papaya, rubber, sugarcane, yam and many wild plants.

Geographic distribution

A. destructor is almost tropicopolitan, and is or has been a pest of coconut palms almost wherever they are grown. Recent instances of its spread are from French Polynesia to New Caledonia shortly before 1961 (Cohic, 1961) and to the New Hebrides in 1962.

Description/Biology

The body of the female is bright yellow and nearly circular in outline, and is covered with a flimsy semitransparent, only slightly convex scale, of which the diameter is 1.5-2 mm. The male scale is much smaller and oval in outline, and the insect beneath it is reddish. The adult male, unlike the female, has a pair of wings and leaves the scale when it is fully developed.

The eggs, which are yellow, are laid under the scale around the body of the female. On hatching, the minute active larvae leave the maternal scale and each takes up a position on the leaf suitable for its feeding needs; it remains in this position throughout its development and, if it is a female, throughout its adult life also. The male sheds its skin three times in the course of its growth and the female twice. The incubation period is 7-8 days in both sexes, and the subsequent development to the adult stage occupies 24 days in the male and a little longer in the female, the total period of development being 31-35 days. These data on the duration of the cycle were derived from investigations in Fiji (Taylor and Paine, 1935) and Mauritius (Moutia and Mamet, 1946); in Java, the duration is about three days shorter, corresponding to a higher mean temperature. There are about ten generations per year.

Infestation is most severe in areas where the rainfall is high and the palms are close together; neglected plantations and palms growing in dense semi-wild vegetation are particularly susceptible. In general, palms growing in well-managed plantations exposed to the prevailing winds are not severely infested.

In Indonesia, a form of *A. destructor*, called *A. destructor rigidus* Reyne, occurs on several of the islands and often predominates over the typical form, from which it differs in several biological respects (Reyne, 1948). Very severe outbreaks of this form of *A. destructor* came to an end through natural causes, which were apparently reduction of fecundity of the females and heavy mortality in the young insects. In the Philippines also the form *rigidus* occurs and is often more harmful than the typical form.

Control

The waxy scale which covers the insect makes control by insecticides difficult. However, good results have been obtained in Fiji on young palms sprayed with malathion at 0.1 percent or diazinon at 0.25 percent (Hinckley, 1961). DDT is not recommended. In Trinidad, similarly satisfactory results were obtained with parathion, malathion and dieldrin.

In at least five groups of islands, successful biological control of *A. destructor* has been achieved by the introduction of predacious ladybird beetles (Coccinellidae). Since several parasitic enemies of the scale insect (mainly chalcids) which were brought to Fiji from Java in 1926 made no impression on the infestations and probably failed to become established, it was decided in 1928 to introduce certain species of coccinellid beetles from Trinidad.

These included *Cryptognatha nodiceps* Marshall, which was immediately highly successful, consuming all stages of the pest so voraciously and multiplying and spreading so rapidly that within nine months control was achieved and after a further nine months *A. destructor* was virtually eradicated (Taylor and Paine, 1935).

Similarly successful results were obtained in Mauritius in 1937 by the introduction of two other species of ladybird beetles, *Chilocorus nigritus* Fabricius from Ceylon and *Chilocorus politus* Mulsant from Java. Ten years earlier, 50 percent of the palms in Mauritius were dying in consequence of severe infestation (Moutia and Mamet, 1946). In the Chagos Archipelago, however, *C. nigritus* has been less effective than in Mauritius (Orian, 1959). *Cryptognatha nodiceps* gave successful control within two years in Principe Island, in the Gulf of Guinea, where it was released in 1955, and after a further year copra production, which had been seriously affected, was back to normal (Simmonds, F.J., 1960). In Efate Island, in the New Hebrides, where *A. destructor* became established in 1962 and subsequently became very injurious to the coconut palms, *C. nodiceps* and two other coccinellid beetles which were introduced failed to check it sufficiently, probably because relatively low night temperatures in the cool season adversely affected oviposition. Fortunately, another species of coccinellid beetle, *Lindorus lophanthae* Blaisdell was already known to be present elsewhere in the New Hebrides (and also in New Caledonia) and this was collected in large numbers (80,000 adults) and released in the outbreak area of *A. destructor* in Efate with immediate success; the outbreak was brought to an end within five months, and there is good reason to believe that a lasting biological equilibrium has been established there such that the scale insect is no longer of economic importance (Cochereau, 1965).

There are many other predatory and parasitic insects that attack *A. destructor*, often attaining a high degree of destruction but failing to suppress it satisfactorily. These include predacious beetles of the family *Nitidulidae* in the Malay Peninsula (Lever, 1964b) and in Mauritius (Moutia and Mamet, 1946), and minute parasitic " wasps " of the superfamily Chalcidoidea, notably the aphelinids *Aspidiotiphagus citrinus* Crawford and *Aphytis chrysomphali* Mercet, both of which are very widely distributed, and the encyrtid *Comperiella unifasciata* Ishii in Indonesia, which has sometimes destroyed no less than 90 percent of the scale insects without, however, bringing the outbreaks under control (Reyne, 1948).

Aonidiella aurantii Maskell

This species, commonly known as the citrus red scale, is very widely distributed in the tropics and subtropics. Particularly serious damage to

coconut palms has occurred in the New Hebrides. *Metroxylon*, *Nypa* and *Phoenix* are also attacked. The adult female, with its covering scale, is circular, and is yellow-orange; the kidney shape of this and related species is characteristic. Control of *A. aurantii* is usually maintained by chalcid parasites, of which 20 species are recorded (Lepesme, 1947).

Chrysomphalus ficus Ashmead

This is often called the Florida red scale. In addition to coconut, many other species of palms are attacked, including *Areca*, *Howea*, *Kentia*, *Latania*, *Livistona*, *Phoenix*, *Ptychosperma* and *Roystonea;* among other plants on which it feeds are cinnamon, citrus and mango. In the Seychelles, damage to coconut palms was reported to be particularly severe on palms growing in good soil (Vesey-Fitzgerald, 1941a).

C. ficus is of Central American origin, but is now very widely distributed through the tropics and subtropics.

The female scale is circular and brownish violet; it has a reddish brown " boss " near the center.

Chalcid parasites, of which some 15 species have been recorded, usually check this scale insect (Lepesme, 1947). In the Seychelles, where further control was needed, coccinellid beetles of the genera *Chilocorus* and *Exochomus*, which were introduced from eastern Africa, gave good results.

Ischnaspis longirostris Signoret

This is commonly known as the black thread scale.

Economic aspect

On coconut, this species is found mainly on the leaves, where it forms dense colonies, but it occurs on the leaf stalk and nuts also. In severe cases, the vigor of the tree and the yield of nuts are reduced. In the Seychelles, it is more harmful on palms growing in alluvial soils than in coral sand or on eroded ridges. Other plants commonly attacked are *Strychnos cinnabarina*, *Annona*, *Areca*, *Elaeis*, *Rafia*, *Roystonea*, *Pritchardia*, *Sabal*, *Washingtonia*, *Zalacca*, bamboo, banana, coffee, citrus, cinnamon, litchi and mango.

Geographic distribution

Tropicopolitan.

Description

The female scale is long and slender, black and shiny, and wider posteriorly; the shed skin of the first instar remains attached to the scale conspicuously at the anterior end. The eggs are orange.

Control

Coccinellid beetles of the genera *Chilocborus* and *Exochomus*, introduced into the Seychelles from eastern Africa to control this and other scale insects, have greatly reduced the damage done by it.

Pinnaspis buxi Bouché

This species is sometimes called the coconut scale, but this name is applied to *Aspidiotus destructor* also.

Economic aspect

Outbreaks of *P. buxi* are sometimes so severe that the yellow-brown spots made on the coconut leaflets coalesce (as in the case of *A. destructor*) and the whole leaf becomes yellow. In extreme cases, the yield of the palms is reduced to nil. The insect lives also on *Acrocomia*, *Areca*, *Calamus*, *Dictyosperma*, *Elaeis*, *Kentia* and *Trachycarpus*, as well as on *Pandanus*, which was its first recorded host plant in the Seychelles.

Geographic distribution

Tropical America, Puerto Rico, Ghana, Sierra Leone, Seychelles, Hawaii, Fiji.

Description

The scale is brown, thin, translucent and mussel-shaped, and the shed skin of the first instar is conspicuous at the narrow (anterior) end, as in *Ischnaspis longirostris*. Males are unknown, reproduction being parthenogenetic.

Control

In Hawaii, where coconut leaves are used for the manufacture of baskets and mats, the palms were formerly subject to serious damage by *P. buxi*, but a coccinellid beetle, *Telsimia nitida* Chapin, which was introduced from Guam in 1936, has exercised satisfactory control since then. In the Seychelles, severe outbreaks of *P. buxi* caused the leaflets to curl up in such a

way as to provide shelter for an ant, *Technomyrmex albipes* Smith, which prevented the coccinellids of the genera *Chilocorus* and *Exochomus* (already introduced for the control of scale insects) from attaining the desired degree of control in the trees in which it was present. Investigations conducted some 14 years later showed that *P. buxi* was still causing damage despite the destruction of a considerable proportion of the scale insects by the coccinellids (Vesey-Fitzgerald, 1953).

Eucalymnatus tessellatus Signoret

Economic aspect

This species is usually found on the lower surface of the leaves but it also feeds on the immature nuts. Its secretion of honeydew results in the development of sooty mold (*Capnodium*) on the leaves, which may inhibit photosynthesis. It attacks mainly the distal leaflets of each leaf and chiefly the distal part of each leaflet, and only the newly opened leaflets of the youngest leaf are free from attack.

Geographic distribution

Generally distributed in the tropics and subtropics.

Description

The scale of this species is characterized by its tessellated appearance, its surface being divided by slender furrows into a pattern of polygons.

Control

As in the case of *Pinnaspis*, the effectiveness of predatory coccinellids is limited in the presence of the ant *Technomyrmex*, though this effect of the latter has been somewhat offset, particularly in the Seychelles, by a fungus disease, *Cephalosporium lecanii*, which kills the scale insects; in 1953 it was observed in the Seychelles that there was much less *E. tessellatus* and correspondingly less sooty mold than there had been in 1939 (Vesey-Fitzgerald, 1953).

Vinsonia stellifera Westwood

Economic aspect

This is yet another scale insect which adversely affects the vigor of the palm by mass-feeding on the leaves. Other host plants are *Elaeis*, *Phoenix*, mango and orchids.

Geographic distribution

Tropical America, eastern Africa, Seychelles, Ceylon, Fiji.

Description

V. stellifera is characteristically shaped like a seven- or eight-rayed star.

Control

Where no effective parasites or predators are present, treatment with parathion, malathion, Rogor or white oil is recommended (Wyniger, 1962). These insecticides are suitable for use against all the species of scale insects which are serious pests of the coconut palm.

ALEURODIDAE (ALEYRODIDAE)

Aleurodicus destructor Mackie

Economic aspect

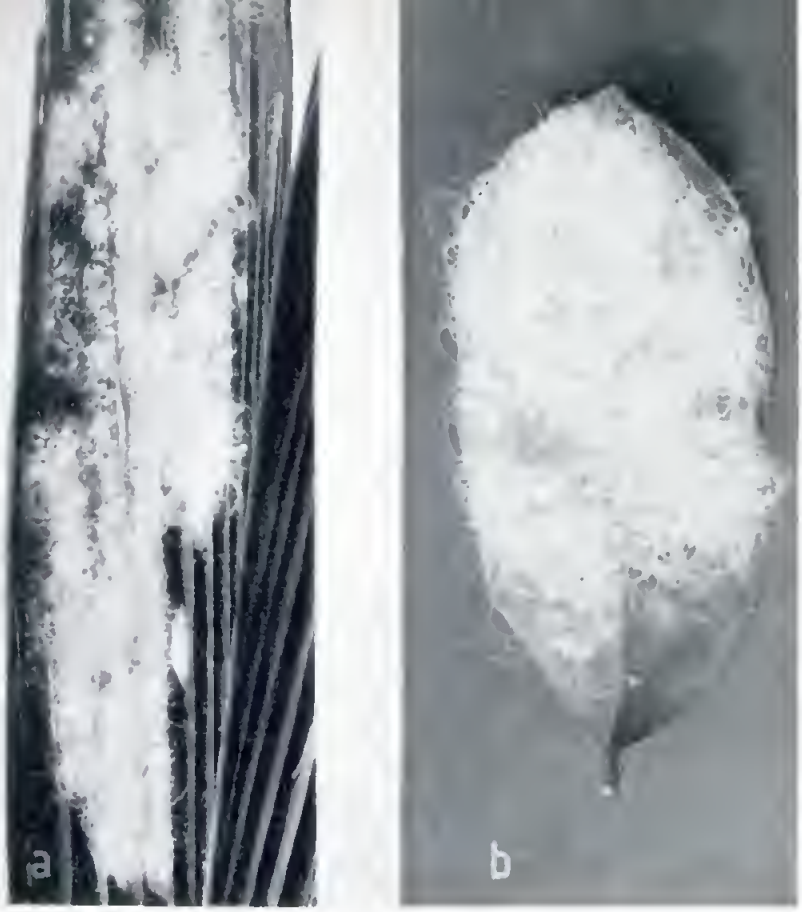
This insect (like all aleurodids, which are collectively known as whiteflies because the wings of the adults are dusted with white powdery wax) lives in the same way as scale insects, feeding by sucking leaf or other tissues, and tending to form colonies which cause the leaves to become yellow in the areas attacked and later to shrivel. The colonies of this whitefly sometimes become very dense and cover the lower surface of the leaf with a thick white layer of tangled waxen threads (Figs. 38 and 39). The immature stages produce honeydew in abundance, which encourages development of sooty mold, particularly in the dry season and on palms about 6-8 years old. Damage to coconuts has been recorded as slight in the Malay Peninsula but severe in the Philippines (Dammerman, 1929). Other plants attacked are *Annona* and *Washingtonia*.

Geographic distribution

Southeast Asia, the Philippines, Melanesia.

Description/Control

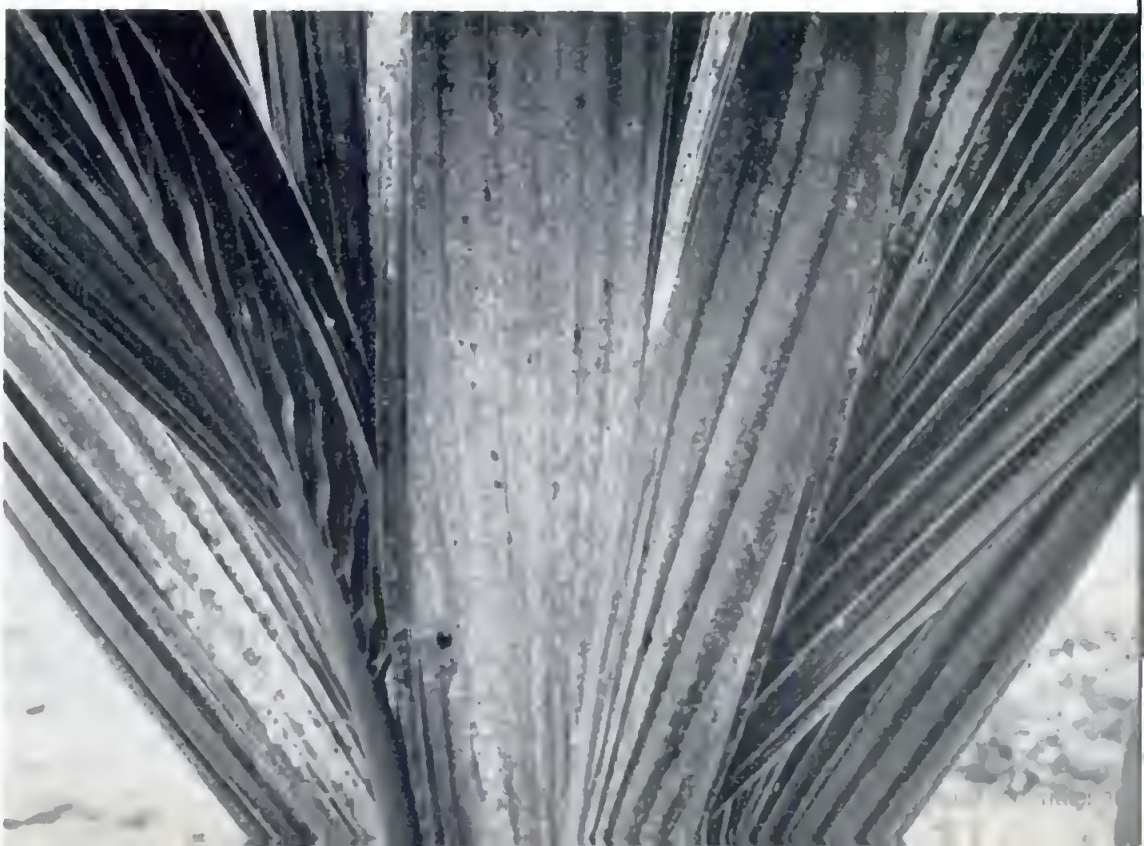
The waxy threads produced by the penultimate instar (usually referred to as the pupa) may be ten times as long as its body. Except in localities where parasites and predators normally exercise sufficient control, the insecticides recommended for spraying scale insects can be used to control whiteflies also.



FIGURES 38-39. - *Aleurodicus destructor* Mackie on coconut palm(a) and on *Annona* leaf (b). *In* L.G.E. Kalshoven, 1950-51.

(*Courtesy N.V. Uitgeverij W. van Hoeve, The Hague*)

FIGURE 40. - *Aspidiotus destructor* Signoret on coconut seedlings. Photo D. Mariau. (*Courtesy Institut de recherches pour les huiles et les oléagineux, Paris, France*)



Dialeurodes elongatus Dumbleton

This whitefly is a pest in New Caledonia. Control measures recommended for young palms are spraying with parathion or with nicotine sulfate in oil emulsion; old palms badly infested should be felled and burned (Cohic, 1959).

Lepidoptera

(Rhopalocera)

AMATHUSIIDAE

Amathusia phidippus Linnaeus

Economic aspect

The caterpillars of this large butterfly, which eat the leaves of palms, are less harmful to coconut palms than to oil palms (*Elaeis*). *Areca*, *Roystonea* and *Cyrtostachys* are also attacked, and caterpillars are occasionally found on banana.

Geographic distribution

Malaysia.

Description/Biology

The distinctive hairy caterpillar (Figs. 42 and 43) is greenish gray and has a pair of spiny horns on the head, a pair of " tails " on the posterior segment and a tuft of longer hair on the second and third segments. It attains a length of 90 mm. The light green chrysalis hangs from a leaf by its posterior extremity; the duration of this stage is 10-12 days. The adult, which has a wing span of 85-105 mm, is mainly brown with various pale and dark streaks on the wings, and the hindwing bears on its underside two large eye-like spots and a pair of smaller dark spots on its blunt tail; the latter spots are on the upper side also (Fig. 41). The butterfly is crepuscular in habit, resting by day under the leaves (Corbett, 1932). Development from egg to adult occupies about 2 months (Kalshoven, 1950-51).

Control

Two species of tachinid flies belonging to the genera *Tricholyga* and *Sturmia*, parasitize the caterpillars. Being more susceptible to the action of

FIGURE 41. - *Amathusia phidippus* Linnaeus. Imago just after emergence. Photo S. Leefmans, *in* L.G.E. Kalshoven, 1950-51.

FIGURE 42 (left). - Young, and last-instar (Figure 43, right) caterpillars. Photos S. Leefmans, *in* L.G.E. Kalshoven, 1950-51.

(*Figures 41-43 courtesy N.V. Uitgeverij W. van Hoeve, The Hague*)

insecticides than their hosts, they would be destroyed by chemical treatments directed against the caterpillars, but when the parasites are not effective DDT, as a wettable powder, should be applied.

BRASSOLIDAE

Brassolis sophorae Linnaeus

Economic aspect

The caterpillars of this butterfly are gregarious. The extensive defoliation which they cause on coconut palms during the wet season can result in the premature shedding of nuts and a reduction of yield for 12-18 months and, in extreme cases, even the death of the trees. They feed also on *Archontophoenix*, *Attalea*, *Bactris*, *Copernicia*, *Desmoncus*, *Euterpe*, *Livistona*, *Orbigyna* and *Roystonea*, and occasionally on banana (Lepesme, 1947).

Geographic distribution

Tropical South America, Trinidad.

Description/Biology

The adult butterfly is large and brown, and has a diagonal orange band on the forewing. Its wing span is 70-105 mm. The eggs are laid in masses of 100 or more on the trunks of the trees and hatch after an incubation period of 20-25 days. The caterpillars are brownish red, with longitudinal yellow stripes. They live by day in a large silken nest which they construct on the palms by spinning leaflets together, and come out to feed at night; the nest is the size of a football. The pupal stage lasts 10-14 days.

Control

The eggs of *B. sophorae* are parasitized by species of *Telenomus* (*Hym.*, *Proctotrupoidea*, *Scelionidae*) and *Anastatus* (*Hym.*, *Chalcidoidea*, *Eupelmidae*); the caterpillars by *Winthemia pinguis* Fabricius (*Dipt.*, *Tachinidae*); and the pupae by two species of *Brachymeria* and by *Spilochalcis morleyi* Ashmead (*Hym.*, *Chalcidoidea*, *Chalcididae*). The combined effect of these parasites is usually not great, and the entomopathogenous fungus *Metarrhizium anisopliae* is also ineffective as a rule.

In Guyana, good results have been obtained by spraying with 0.5 percent dieldrin, and in Brazil the application of 2 percent BHC dust every 20-25 days in tall trees is recommended (Marconi, 1952). Treatment with DDT as either dust or spray proved satisfactory in Surinam (Dinther, 1955).

The nests of caterpillars should be cut down and burned whenever this is practicable. Hand-collection of insects as a method of controlling them is seldom practiced nowadays, but in the case of this insect it can be done effectively.

Brassolis astyra Godart

This is another large butterfly whose caterpillars live in nests and feed on the leaves of coconut palms. They also attack *Arecastrum*, date palm, banana and sugarcane. Unlike *B. sophorae*, it is restricted to the mainland of South America. *Xanthozona melanopyga* Wiedemann (*Dipt.*, *Tachinidae*) parasitizes the caterpillars. The control measures used against *B. sophorae* apply equally to this species.

SATYRIDAE

Elymnias hypermnestra Linnaeus

Economic aspect

This is one of several species of the genus *Elymnias* whose caterpillars feed on palm leaves and occasionally cause damage. In addition to coconut, *Areca* and *Cyrtostachys* are attacked.

Geographic distribution

Malaysia.

Description

The caterpillar is green with longitudinal yellow stripes, and has a pair of horns on the head and a pair of "tails" on the posterior segment. It is about 40 mm long when fully grown. The chrysalis is green, and is suspended from a leaf by its hind end. The colors of the wings differ between the sexes; the male is dark brown with metallic blue markings along the outer margin, while the female is lighter in color, orange-brown, and with ill-defined, pure white spots along the margin. The wing expanse is 55-75 mm, the male being smaller than the female.

Control

DDT at 50 percent in the form of a wettable powder is used for control.

HESPERIIDAE

Hidari irava Moore and Horsfield

Economic aspect

Severe damage by this insect is not frequent, but occasionally the tissue of leaflets is entirely eaten away by the caterpillars so that only the midribs remain and groups of trees are almost completely defoliated (Fig. 46). The leaves of old palms are said to be attacked more severely than those of young ones. *Arenga*, *Elaeis*, *Areca*, *Metroxylon*, *Livistona* and bamboo are also attacked.

Geographic distribution

The Malay Peninsula, Indonesia.

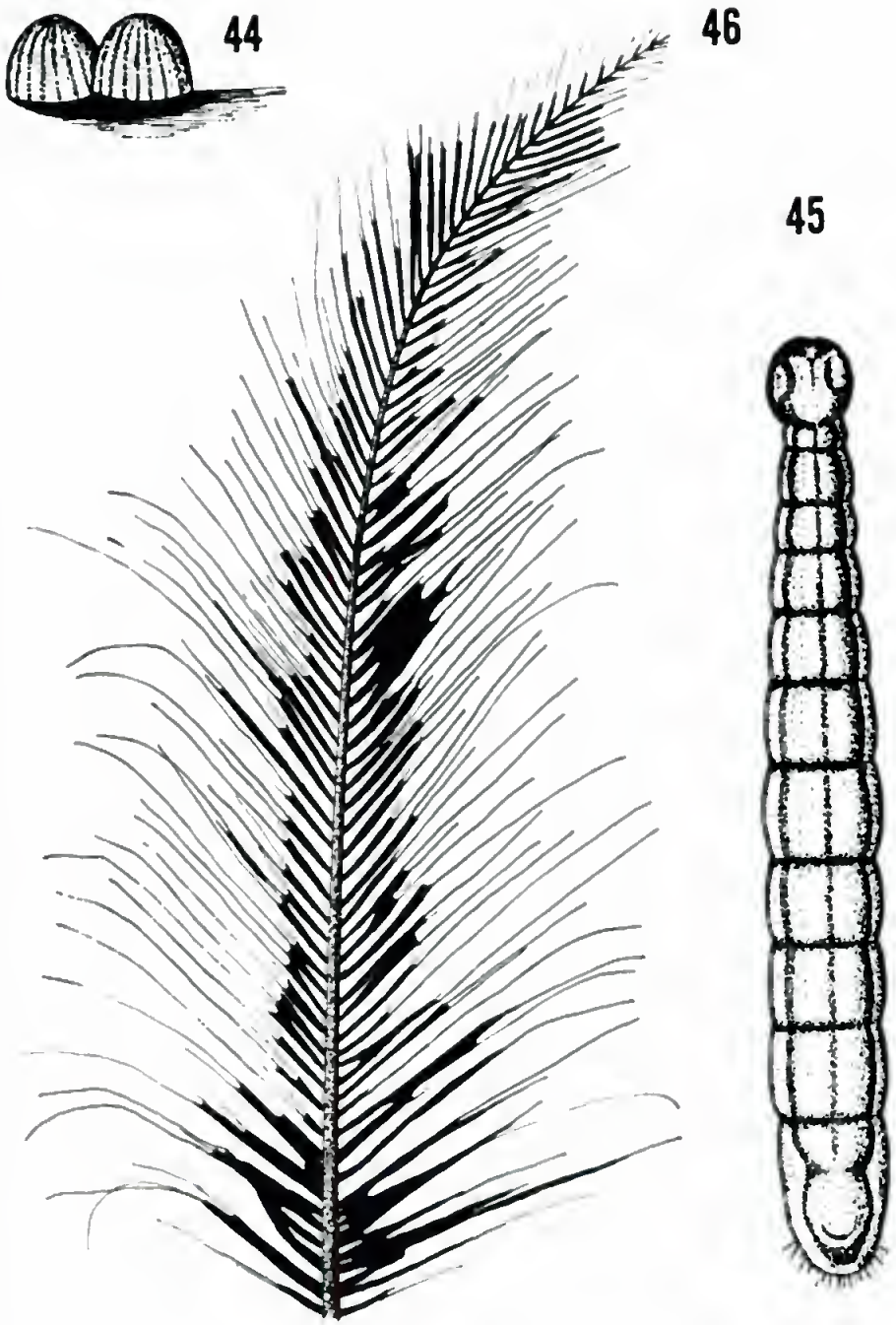
Description/Biology

The butterfly measures 50 mm in wing expanse, and is brown with four prominent golden spots and one to three small translucent spots on each forewing. The eggs (Fig. 44) are laid in chains or masses covered with the scales of the female; the incubation period is 7 days. The greenish yellow caterpillar, which is 45-50 mm long when fully grown, has a large, dark brown head and a violet stripe along each side, and its body widens posteriorly (Fig. 45). The caterpillar stage, which comprises five instars, lasts about 5 weeks. The chrysalis is attached to a leaf at its hind end and is supported by a silken girdle round the middle; it is pinkish brown and covered with a bloom of powdery waxy material. The chrysalis period lasts 10 days, so that the whole life cycle, to the emergence of the adult from the chrysalis, occupies about 52 days.

The caterpillars are more or less gregarious. They spin the two edges of leaflets together to form tubes, in which they live and in which the chrysalis is formed.

Control

Hand-collecting and destruction by burning of the rolled-up leaflets, which are conspicuous, should be undertaken. On tall trees, heavily infested leaves should be cut off at the base. Dipterous and hymenopterous parasites of the caterpillar or chrysalis, as the case may be, are known to exert some controlling influence on this pest locally. Where they are absent or obviously ineffective, a DDT spray can be used.



FIGURES 44-46. - *Hidari irava* Moore and Horsfield. Eggs (44), caterpillar (45), and damage to coconut palm (46). According to P. Lepesme, 1947, redrawn.

(Courtesy P. Lechevalier, Paris, France)

Telicota palmarum Moore (formerly placed in the genus *Corone*)

Economic aspect

The damage done by this insect is similar to that already described for *Hidari irava*. The royal palm (*Roystonea*) seems to be preferred, but coconut palms are commonly attacked and young wild palms aged 2-4 years are particularly susceptible. *Areca*, *Calamus*, *Elaeis* and *Phoenix* are also damaged.

Geographic distribution

India, Southeast Asia, the Philippines.

Description/Biology

The butterfly is brown and yellow, the male with much more extensive and brighter yellow areas than the female. The female, which is much larger than the male, has a wing expanse of 40 mm. The caterpillar, 40 mm long when fully grown, is dull green without a lateral stripe. The chrysalis is light green, with a dusting of white wax. The caterpillar and chrysalis stages are passed within rolled leaflets, of which the edges are spun together with silk by the caterpillars, as in the case of *Hidari irava*.

Control

Numerous parasitic insects destroy *T. palmarum*. Wherever further control is required, the measures advocated for *H. irava* should be applied.[2]

Gangara thyrsis Fabricius

Economic aspect

This is another species whose caterpillars feed on a wide range of palms including, in addition to coconut, *Livistona*, *Roystonea*, *Nypa*, *Arenga* and *Metroxylon*; they have also been recorded on banana. Damage to coconut palms is said to be more severe in India than elsewhere.

Geographic distribution

India, Thailand, Malaysia, the Philippines.

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[2] A very closely related species, *Telicota bambusae* Moore, in New Guinea, the Solomons and Queensland (Australia), damages coconut palms in exactly the same manner.

Description/Biology

The butterfly is chocolate brown with, on the forewing, two large, quadrangular, hyaline golden spots in the center and four smaller golden spots nearer the apex. The wing expanse of the female is about 80 mm. The caterpillar is covered with dense rows of long, white, waxy filaments which hide the body. The incubation period is 7 days, and the caterpillar and chrysalis stages last about 35 and 10 days, respectively, so that the total cycle to emergence of the adult covers 7-8 weeks. Both the caterpillar and the chrysalis stages are spent inside tubes made by spinning together the edges of leaflets, and the chrysalis makes an audible noise by vibrating inside the tube.

Control

Measures recommended in India are application of DDT or BHC, supplemented by hand-picking and burning of the rolled leaflets with the caterpillars inside them, or of whole infested leaves.

Other species

Three other species of *Hesperiidae* occasionally become numerous enough locally to cause damage on coconut palms. These are: *Erionota thrax* Linnaeus (which is mainly a pest of banana) in Southeast Asia; *Suastus gremius* Fabricius, mainly in India; and *Zophopetes dysmephila* Trimen in Senegal and South Africa. The caterpillars of all these species live in rolled leaves and can therefore be destroyed in the manner already indicated for other species of this family.

Heterocera

COSSIDAE

Acritocera negligens Butler

Economic aspect

The caterpillar of this moth, which is commonly known as the spathe borer, bores into the unopened flower spike and tunnels through the developing male flowers inside, feeding and growing as it goes. In this behavior, the species differs from *Tirathaba*, of which the caterpillars attack the inflorescence after the spathes have split. The coconut palm is the only known food plant of *A. negligens*. Although in some plantations 50 percent

of the trees may be attacked, the damage done in terms of crop loss is usually not very serious, but on rare occasions inflorescences are almost wholly destroyed (Simmonds, H.W., 1951).

Geographic distribution

Fiji only. (This species has been recorded in error from the Malay Peninsula [Nirula *et al.*, 1955b]).

Description/Biology

The relatively large, flat, oval eggs are laid in the fibrous sheaths which invest the bases of the leaves and spathes. The newly hatched caterpillar wanders in search of an unopened flower spike and, on finding a suitable spike, usually the oldest one, bores into it near the apical extremity. The point of penetration is marked by a gummy exudation, and there are often more than a dozen of such holes in a single spathe. The caterpillar then burrows through the tightly apposed immature male flowers, leaving moist brown excrement behind it which, after the spathe has burst open, dries to form a sawdust-like mass. It has been observed that the young caterpillars are capable of boring into the leaf stalk. After feeding for about four weeks inside the unopened spadix, the caterpillar is fully grown. It then bores through the spathes, leaving a neat round hole which is very characteristic, resembling a bullet hole, and proceeds to drop from the crown of the tree to the ground. The caterpillar then burrows into the soil, sometimes to a depth of about 30 cm, and there surrounds itself with a tough ovoid cocoon, in which it becomes a chrysalis. This stage lasts about 6½ weeks, and when the adult (moth) is ready to emerge, the chrysalis thrusts its way upward through the cocoon and through the soil so as to project from the surface. The moth then emerges; pairing occurs within a few hours and the female moth lives only about 3 days. The incubation period is not definitely known but the complete cycle of development probably covers 3 months (Taylor, 1930).

Because the emergence holes of the caterpillars in the spathes are large and conspicuous and the damage done to the spadices is often seen when the spathes open to be extensive, there is a tendency to assume that this insect must cause considerable reduction of yield. The reason why the effect on the yield is not commensurate with the scale of the visible injury is that the caterpillar, feeding almost entirely in the distal two thirds of the flower spike, rarely encounters the female flower buds.

Control

Wyniger (1962) suggests that dieldrin at 50 percent in the form of a wettable powder, at 2-3 grams per liter of water, should be used to control this pest if chemical measures are ever considered necessary. Simmonds, H.W. (1951) suggests that cultivation beneath the palms might kill the insects, since the chrysalis period is spent in the ground.

No parasites of *A. negligens* are known.

COSMOPTERYGIDAE

Batrachedra arenosella Walker

Economic aspect

This small moth (Fig. 47) has been studied in several tropical countries; its caterpillar attacks the young flowers of the coconut palm (Fig. 48), but its economic importance is still in doubt. The consensus of opinion has been that the net damage done is very slight, even where the insect is abundant; this applies in the Solomons (Pagden and Lever, 1935), New Hebrides (Risbec, 1935, 1937) and Fiji. However, although Corbett and Gater considered the injury in the Malay Peninsula to be negligible in 1924, Corbett (1932), while indicating that there was still no definite evidence to the contrary, expressed the view that when the factors concerned in premature nutfall were understood, *B. arenosella* might well prove to be of considerable importance. Similarly, Simmonds, H.W. (1938) thought there was need in Fiji for investigation of the extent to which the loss of male flowers reduces pollination and whether any damage that may be done to the female flowers affects the yield of nuts.

Other plant species attacked are *Elaeis* and *Arecastrum*; the caterpillars have also been found in fallen oranges, grains of *Juncus* and the fungus *Protubera*.

Geographic distribution

The Guianas, Congo, India, the Malay Peninsula, Indonesia, New Guinea, Melanesia, Australia, Tasmania. Nirula *et al.*, (1955b), however, record it as occurring in India only.

Description/Biology

The moth measures only 13-14 mm in wing expanse. The forewing is straw-colored, speckled with dark gray, and has two relatively conspicuous black spots; the hindwing is fawn. Both wings are narrow and have long fringes of hair-like scales. The egg is flat and translucent, its surface

hexagonally reticulate. The caterpillar is brownish yellow, with a dark brown head, and has a brown plate divided by a pale median line on the first segment; it is 8.5 mm long when fully grown. The chrysalis is enclosed in an oval white cocoon which is about 9 mm long (Taylor, 1930).

The eggs are laid singly, in the grooves of the unopened spathes, shortly before they are due to split. The newly hatched caterpillars, according to Corbett and Gater (1924), working in the Malay Peninsula, immediately bore through the spathe and begin feeding on the developing male and female flowers, injuring up to 65 percent of the latter but without seriously affecting the crop. On the other hand, Taylor, working in Fiji, described how the young caterpillars remain in the grooves on the spathe for several days if necessary, under flimsy webs which they spin across the grooves, and wait thus without feeding until the spathe bursts open; he stresses that they do not bore through the spathe and also that they do not attack female flowers. The cocoon constructed by the fully fed caterpillar is situated on the branches of the spadix or among the dead flowers that accumulate at the bases of the leaves (Fig. 48).

With regard to the duration of the life cycle, Corbett (1932) records, for the Malay Peninsula, a period of 2-3 days for incubation, 5-8 days for the caterpillar stage, and 6-8 days for the chrysalis, giving a total of 13-19 days. The corresponding periods in Fiji, according to Taylor, are 4, 10-14, and 9-11 days, with a total varying from 24 to 28 days. These differences are probably due to differences in temperature.

Control

Efficient protection can be obtained, if needed, by spraying with DDT wettable powder, either alone or mixed with wettable diazinon.

Various parasites are known in Melanesia but they seem to be of little economic importance. The eggs are parasitized by a species of *Trichogramma* (*Hym.*, *Chalcidoidea*, *Trichogrammatidae*) and the caterpillars by species of *Meteorus* and *Apanteles* (*Hym.*, *Braconidae*).

Batrachedra peroptusa Meyrick

The caterpillars of this species of *Batrachedra* devour the pollen of coconut palms and therefore may reduce pollination. Other palms attacked are *Syagrus* and *Attalea* (Bondar, 1940a). This insect occurs in Brazil and the Guianas. The duration of its cycle of development is 15-18 days.[3]

[3] There are numerous other microlepidopterous insects which feed on the male flowers of coconut palms, but there is no reason to suspect that they adversely affect the crop.

FIGURE 47. - *Batrachedra arenosella* Walker. Adult. After P. Lepesme, 1947, redrawn.
(*Courtesy P. Lechevalier, Paris, France*)

FIGURE 48. - Caterpillars feeding in the inflorescence of coconut palm. According to L.G.E. Kalshoven, 1950, redrawn.
(*Courtesy N. V. Uitgeverij W. van Hoeve, The Hague*)

CRYPTOPHASIIDAE

Nephantis serinopa Meyrick

Economic aspect

This insect is considered to be the most important lepidopterous pest on coconut palms in Ceylon, where its caterpillars feed on the lower surface of the older leaves (Figs. 49 and 50). Its importance was recognized before 1905, but particularly serious infestations developed in 1919 (Child, 1964) and have occurred since then at intervals of about four years. In severe outbreaks, thousands of palms have all the older leaves reduced to dead brown tissue and only the three or four youngest leaves at the center of the crown remain green (Jayaratnam, 1941b). In the year following a severe outbreak the crop may be reduced to half, or even more where the palms are overcrowded or growing in poor soil. In India, where the insect was comparatively rare prior to 1920, damage is most severe during the hot months (March-May); indigenous parasites are very active, but the degree of parasitization varies greatly in the course of the year and is not economically satisfactory. During the season of the southwest monsoon, the galleries (described below) in which the caterpillars live become flooded, and this favors the development of fungi (Nirula, 1956a,b). The severe damage done to the leaves results in a reduction in the rate of production of flower spikes, an increase in the premature nutfall, constriction of the trunk and retardation of growth.

Other palms attacked are *Borassus*, *Corypha*, *Hyphaene*, *Phoenix* and *Roystonea*.

Geographic distribution

Ceylon, southern India, Burma.

Description/Biology

The eggs are laid distally on the lower surface of the older leaves. The female lays on average 140 eggs, and the egg stage lasts 3-5 days. The caterpillar is pink, with a black head and dark thoracic plates. The galleries or runways in which the caterpillars live are constructed of silk, in which excrement is incorporated, on the underside of the leaflets. The caterpillar stage, which comprises five instars, lasts 5-8 weeks, and the chrysalis stage 9-14 days. The male moth lives about 7 days, the female 5 only. Thus, the duration of the whole cycle is 2-2½ months. The wings are gray, the forewing pale with dark specks; the wing expanse is 20-25 mm.

FIGURE 49. - Damage by *Nephantis serinopa* Meyrick. Close-up of attacked leaflets. (*Photo C. Kurian*)

Control

Sprays of DDT at 0.2 percent gave a reduction of caterpillars of 80 percent in two weeks (Nirula *et al.*, 1951b), but the persistence of the insecticide, of about two weeks, was prejudicial to the beneficial parasite *Trichospilus pupivora* Ferrière (*Hym., Chalcidoidea, Eulophidae*) which attacks the chrysalis stage. BHC at 0.2 percent, on the other hand, lost its toxicity in 6-10 days. Experimental treatments with dieldrin at 0.05 percent destroyed 77 percent of the caterpillars; increasing the dieldrin concentration to 0.2 percent gave only 5 percent increase in the kill (Pillai and Kurian, 1960).

FIGURE 50. - Damage by *Nephantis serinopa* Meyrick. Infested tree. (*Photo C. Kurian*)

In India and Ceylon, a rich insect fauna provides a wide range of natural enemies of *Nephantis*. Hymenopterous and dipterous enemies are:

Parasitizing the egg:

Trichogramma sp. (*Hym., Chalcidoidea, Trichogrammatidae*)

Parasitizing the caterpillar:

Apanteles taragnae Viereck (*Hym., Ichneumonoidea, Braconidae*)
Microbracon brevicornis Wesmael (*Hym., Ichneumonoidea, Braconidae*)

Perisierola nephantidis Muesebeck (*Hym., Bethyloidea, Bethylidae*)
Elasmus nephantidis Rohwer (*Hym., Chalcidoidea, Elasmidae*)
Winthemia sp. (*Dipt., Tachinidae*)
Stomatomyia bezziana Baranov (*Dipt., Tachinidae*)

Parasitizing the chrysalis:

Trichospilus pupivora Ferrière (*Hym., Chalcidoidea, Eulophidae*)
Goryphus nursei Cameron (*Hym., Ichneumonoidea, Ichneumonidae*)
Xanthopimpla punctata Fabricius (*Hym., Ichneumonoidea, Ichneumonidae*)
Brachymeria nephantidis Gahan (*Hym., Chalcidoidea, Chalcididae*)
Stomatoceras sulcatiscutellum Girault (*Hym., Chalcidoidea, Chalcididae*)

The efficacy of most of these parasites is reduced by secondary parasites. Predators that attack *Nephantis* include: carabid beetles of the genera *Parena* and *Phlaedromius*, which devour the caterpillars in their galleries; an anthocorid bug of the genus *Triphleps* and a reduviid bug of the genus *Sphedanolestes*, which feed on both eggs and caterpillars; and the mite *Pyemotes ventricosus* Newport which attacks the caterpillars in southern India but without much effect on the *Nephantis* infestations.

In the course of chemical control operations, efforts have been made to avoid neutralizing the beneficial effect of this complex of natural enemies. Persistent insecticides should be either not used, or applied with careful timing in relation to the stage of the outbreak and the biology of the insects concerned. The adult parasites are highly susceptible to toxic residues on the trees.

The parasite *Trichospilus pupivora* has been reared en masse in the laboratory and released in *Nephantis*-infested plantations at the rate of more than a million per month (Jayaratnam, 1941b). The parasite *Perisierola nephantidis* has also been mass-reared for this purpose. These experimental operations did not give satisfactory control.

Attempts have also been made recently to control this pest by means of the bacterium *Serratia marcescens*, which causes a septicemia in the caterpillars.

AGONOXENIDAE

Agonoxena argaula Meyrick

Economic aspect

The caterpillars of this small moth scarify the lower surface of the leaflets and can cause serious damage, especially on young palms. This is the most common pest of coconut palms in Fiji (Hinckley, 1963). It also attacks *Metroxylon* and *Clinostigma*.

Geographic distribution

New Hebrides, Fiji, Tonga, Samoa, Wallis and Futuna, Ellice Islands, Guam, Hawaii, Palmyra.

Description/Biology

The egg is usually laid near an old feeding scar, under the web made by a larva. Incubation occupies 7-8 days. The caterpillar, which is at first yellow and later becomes green, feeds entirely on the underside of a leaflet, removing all the leaf tissue except the upper epidermis between adjacent parallel veins and thus forming a short, mainly parallel-sided scar. There are usually three or four such scars in a group. In severe cases, the scars are so numerous that they reduce the functioning leaf area of the trees by 8-20 percent (Hinckley, 1961) and the leaflets are so weakened that they bend and break in the wind, allowing the entry of fungi. The caterpillars live under a protective web which they spin over the leaf surface. The chrysalis is formed in a whitish cocoon which is formed on the leaflet or, if the caterpillar drops from the tree, on the undergrowth (Simmonds, H.W., 1938). The caterpillar stage lasts 16-22 days and the period spent in the cocoon is 9-10 days, making a total period of development to the emergence of the moth of about 5 weeks (Singh, 1951).

Control

The young palms should be treated with an aqueous preparation of malathion at about 0.3-0.4 percent. Fertilizers, drainage and control of weeds all help to reduce the harm done to the trees.

There are several indigenous insect parasites of *Agonoxena* in Fiji; those attacking the caterpillar belong to the genera *Apanteles*, *Bracon* and *Agathis* (*Hym.*, *Braconidae*) and *Tongamyia* (*Dipt.*, *Tachinidae*), and a parasite attacking the chrysalis belongs to *Brachymeria* (*Hym.*, *Chalcidoidea*). These have been reinforced by the introduction into Fiji of *Elachertus agonoxenae* Kerrich (*Hym.*, *Chalcidoidea*, *Eulophidae*) from New Guinea and a tachinid, *Actia painei* Crosskey, from New Britain, both of which parasitize another species of *Agonoxena*, *A. pyrogramma* Meyrick, in their own countries, and also by a braconid, *Macrocentrus*, from Java. All these introduced parasites attack the caterpillars, and the average total level of parasitization by them and the indigenous species is 71 percent, of which about half is due to *Apanteles*. *Brachymeria* destroys 35 percent of the chrysalides, the total mortality of which is 51 percent.

GALLERIIDAE

Tirathaba complexa **Butler** (formerly known as *T. trichogramma* Meyrick)

Economic aspect

The caterpillars of this moth feed on the flowers of recently opened inflorescences of the coconut palm. They usually inflict serious damage on the female flowers as well as on the male, and cause much shedding of young nuts. The loss of crop due to this insect is very difficult to estimate; many of the potential nuts attacked by it would be shed by the tree in any case, since the number of female flowers produced greatly exceeds the number of nuts which the tree can nourish and for which there is room. An estimate made in Fiji indicated that, if *Tirathaba* could be eliminated or thoroughly suppressed, the premature shedding of nuts would be reduced by 9 percent and the yield increased by 32 percent (Taylor, 1930). The damage to the male flowers, although very great, is of no consequence (Hinckley, 1964). An unusual type of damage was reported in the New Hebrides by Risbec (1935); the caterpillars fed at the heart of the crown of palms which were 20 years old, but the trees were growing in a swampy area and were already in poor health.

Other palms attacked are *Roystonea* and *Pritchardia.*

Geographic distribution

New Hebrides, Fiji, Tonga, Samoa, Wallis, Ellice Islands.[4]

Description/Biology

The eggs are laid singly or in small irregular batches in the fibrous sheaths at the bases of the leaves and flower spikes, and also among the male flowers and buds, particularly on inflorescences that have failed to open fully because the spathes did not split normally. The female deposits at least 250 eggs over a period of adult life of about 8 days. The incubation period is 5.5-6 days. The young caterpillars feed on the male flowers, in and among which they spin silken galleries; the female flowers or the young nuts are seldom attacked until the caterpillars are about half-grown. As the caterpillars grow they construct larger and longer runways which are conspicuous among the flowers and which, since excrement is incorporated in the silk, give affected inflorescences a dirty appearance. The caterpillar stage lasts about 20 days, when the food consists of fresh flowers, but sometimes this stage is spent in the mass of dead, rotting flowers which accumulate at the

[4] Records of it elsewhere than in the Pacific Islands are incorrect.

leaf bases and, in such circumstances, development is much slower. The full-grown caterpillar is 30 mm long, almost hairless, smooth, shiny and slate gray and it has a dark brown head. It constructs a tough silken cocoon, reddish brown in color, with a pointed anterior end, and the period spent therein, mainly as a chrysalis, is about 14 days. The total cycle thus covers about 40 days on average. The moth is uniformly grayish brown, with a wing span of 28-35 mm, which is greater than that of the male. The sexes are very different, the female being readily distinguishable by its snout-like palps projecting forward from the head and its long abdomen tapering to a point; there is also much difference in the shape of the forewing, and the color of the male is paler, less gray and less uniform (Taylor, 1930).

Control

Wyniger (1962) suggests treatment with a dieldrin wettable powder as soon as the first damage appears on the spadix.

In Fiji, indigenous parasites are: a trichogrammatid (*Hym., Chalcidoidea*) attacking the egg, a species of *Meteorus* (*Hym., Braconidae*) and one of *Echthromorpha* (*Hym., Ichneumonidae*) the caterpillar, and *Antrocephalus renalis* Waterston (*Hym., Chalcidoidea*) the chrysalis. Since these were economically ineffective, four more species were introduced in 1930-34 from Java, where they parasitized other, closely related species of *Tirathaba* (Paine, 1935). These additional parasites were: *Argyrophylax* (*Erycia*) *basifulva* Bezzi (*Dipt., Tachinidae*), *Devorgilla* (*Nemeritis*) *palmaris* Wilkinson (*Hym., Ichneumonidae*), *Apanteles tirathabae* Wilkinson (*Hym., Braconidae*) and *Telenomus tirathabae* Wilkinson (*Hym., Proctotrupoidea, Scelionidae*). All these introduced parasites became established in Fiji and have jointly increased to a valuable extent the natural control of *Tirathaba*.

Tirathaba rufivena Walker

Economic aspect

The caterpillars of this species cause the same damage to the inflorescences as *T. complexa*, but they are particularly destructive to those that are unusually small and those that do not open properly. Male flowers are preferred but female flowers are also attacked; one caterpillar usually destroys only one female flower. A detailed study of the part played by this insect in premature nutfall was made in the Malay Peninsula by Corbett (1932). This author concluded that the palm sheds those female flowers (and very young nuts) damaged by *Tirathaba* rather than healthy ones and that, since a great excess of female flowers is normally produced and must be eliminated, the insect is harmful only if it causes 58 percent or more of shedding. Other plants attacked are *Nypa*, *Elaeis*, *Areca*, *Roystonea*, *Musa*, *Phaseolus* and *Coix* (Lepesme, 1947).

Geographic distribution

Ceylon, the Malay Peninsula, Borneo, Indonesia, New Guinea, Queensland, Solomon Islands, New Hebrides, New Caledonia.

Description/Biology

The forewing of the female has a green reflection and bright red veins. The wing span of the female is 25-30 mm (or rather more, according to Lepesme, 1947) and that of the male 22-26 mm. The egg and the caterpillar are very similar to those of *T. complexa*. In the Solomons, the caterpillar is a pale plum color when feeding on healthy flowers on the spadix but darker when its food is fallen flowers at the base of the spathe (Lever, 1933b).

The duration of the egg stage is 4-5 days, the caterpillar stage lasts 14-15 days, and the period spent in the cocoon 11-12 days, so that the whole cycle covers about 4½ weeks. These data apply to individuals reared on healthy flowers; when they are fed on old fallen male flowers, the duration of the cycle is greatly extended, to about 7 weeks (Paine, R.W.).

Control

Since the newly split spathe shelters the partially released inflorescence, and in so doing provides feeding sites particularly favorable for the caterpillar, Corbett (1932) suggested that spathes that are about to burst open should be removed so that the flowering branches are fully exposed; this operation is practicable on young palms but would be difficult on tall ones.

Wyniger (1962) suggests the same insecticidal treatment as for *T. complexa*.

The most important parasites of *T. rufivena* in Malaysia are *Devorgilla palmaris* and *Apanteles tirathabae*, both of which have been introduced into Fiji to combat *T. complexa*. *A. tirathabae* has also been found in the Solomons, where it parasitizes *Tirathaba* on *Nypa* palms as well as coconut (Lever, 1933b). Two other parasites of *T. rufivena* in Malaysia are *Trichospilus pupivora* (which also attacks *Nephantis* in Ceylon) and *Argyrophylax basifulva*, which is another of the parasites introduced into Fiji.[5]

Tirathaba mundella Walker

This is yet another species of *Tirathaba*, which occurs in coconut palms. Its distribution extends from Thailand and Indonesia to the Solomon Islands.

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[5] *T. ignevena* Hampson of New Guinea is now regarded as synonymous with *T. rufivena* Walker, and the latter name has priority.

Its habits and the damage caused by it closely resemble those of the species already described.

PYRAUSTIDAE

Hedylepta blackburni **Butler** (formerly assigned to the genera *Phostria* and *Omiodes*)

Economic aspect

The caterpillar of this moth eats the leaves of the coconut palm, giving them a very ragged appearance and considerably reducing the effective leaf surface when the attack is continuous (Fullaway and Krauss, 1945; Zimmerman, 1958). The damage is often especially severe in exposed situations, probably because the activities of the natural enemies are hindered by the strong winds. Other plants attacked are *Pritchardia* palms (*P. pacifica* was the endemic host plant) and banana.

Geographic distribution

Hawaiian Islands only.

Description/Biology

The eggs are laid in rows of about 40 along the midribs of the leaflets, overlapping like tiles. They are flattened, and broadly oval in outline. On hatching, the young caterpillars feed gregariously on the underside of the leaflet, protected by a flimsy web of silk. At first they do not eat right through the leaflet but leave the upper epidermis intact. Soon they scatter and make tubes, in which they shelter, by spinning the edges of each leaflet together. From this stage onward they feed at the edge of the leaflet and eat the tissues away completely; when only a small part of their shelter remains on the midrib, they move to another leaflet and repeat the process. They become full-grown in about 4 weeks, and are then dull greenish, with two dorsal whitish lines and a whitish line along each side, and are 32-35 mm long. The chrysalis is formed in a slight cocoon constructed in the rolled leaflet; this stage lasts 11-13 days (Zimmerman, 1958). The adult measures 30 mm in wing span; the forewing is brownish ocher with two cream-colored crosslines sharply angled outward and the veins conspicuously pale, and the paler hindwing has a single, similarly angled crossline.

Control

Apparently no chemical control measures are applied.

H. blackburni is attacked by a wide range of hymenopterous and dipterous parasites, some native and some introduced. The most important is *Zalepto-pygus flavo-orbitalis* Cameron (*Hym., Ichneumonidae*), which sometimes attains 90 percent parasitization, without, however, preventing outbreaks. The others include species of *Chelonus, Microbracon* and *Bracon* (*Hym., Braconidae*), *Ech-thromorpha* and *Nesopimpla* (*Hym., Ichneumonidae*), *Brachymeria* and *Tricho-gramma* (*Hym., Chalcidoidea*) and *Frontina* and *Chaetogidia* (*Dipt., Tachinidae*). The two tachinids were introduced into Hawaii from America and the *Bra-chymeria* and the *Bracon* from Japan, all for biological control purposes. The caterpillars and the eggs are destroyed by the predatory ant *Pheidole megacephala* Fabricius and the caterpillars are intermittently stricken with disease.

This complex of natural enemies undoubtedly exerts a considerable degree of control on *Hedylepta.*

Pimelephila ghesquierei Tams

Economic aspect

The caterpillars damage the spike of young unexpanded leaves at the center of the crown of the coconut palm by burrowing into it. Coconut, though sometimes severely damaged, is not a preferred host plant; *Elaeis* is the principal host plant. *Ancistrophyllum* is also attacked.

Geographic distribution

Throughout the forest zone of central and western Africa, wherever the oil palm (*Elaeis*) is native.

Description/Biology

The adult insect is a small moth, 25-34 mm in wing expanse. The fore-wing is olive-green, with dark brown mottling and diffuse cinnamon spots; the hindwing is olive-gray, and paler. The eggs are characteristic, being much flattened and reminiscent of minute fatty droplets or tiny lenses. At first milky yellow, they become bloodred as development of the embryo proceeds, this being the color of the newly hatched caterpillar. Later, the color of the caterpillar becomes lighter and changes to a yellowish pink, except the head which is light chestnut brown and the first segment which is yellowish. The body is slightly hairy. When fully grown, the cater-pillar is about 35 mm long. The mahogany brown chrysalis is enclosed in a cocoon composed of fibrous debris spun together with fine silk, and generally situated on the inward face of the stalk of an old leaf.

Control

The following procedures are recommended as preventive measures: maintaining the young palms in good condition in the nursery beds, with suitable manuring as required; ensuring, when the young palms are planted out, that the spacing adopted suffices to allow maximum light and aeration; avoiding planting in poorly drained soil; removing neglected palms, young or old, from the proximity of nurseries, since they constitute potential sources of infestation. Hand-collection of the caterpillars and cocoons on young trees is recommended, subject to supervision to ensure that the trees are not damaged. Where chemical treatment is necessary, spraying with DDT at 1 percent, parathion at 0.02 percent, or endrin at 0.1 percent can be expected to give good results, especially if the spray reaches the bases of the central leaves.

PHYCITIDAE

Hyalospila ptychis Dyar

Economic aspect

Insufficient attention has been paid to this insect, which may be the most important pest of the coconut palm in Bahia State of Brazil. The caterpillar feeds on the female flowers and bores into the young nuts which, in consequence, are either deformed or caused to fall off prematurely. Gum issues from the tunnels made in the nuts. This is one of the very few lepidopterous insects which bore into nuts when they are at a rather advanced stage of development. Other plants attacked are *Attalea* and *Syagrus*.

Geographic distribution

Brazil.

Description/Biology

The caterpillar is white with a brown head, and is 15-16 mm long when fully grown. The adult measures 14 mm in wing span; the forewing is brown at the base and whitish distally, with reddish violet marks and black spots, and the hindwing is transparent except for a brown border (Lepesme, 1947). The development cycle lasts 25-30 days (Bondar, 1940a).

Cadra cautella Walker (formerly assigned to the genus *Ephestia*)

This is a very well-known pest of certain stored products, including copra, and is therefore dealt with in Chapter 3 of this study. The caterpillars

have, however, been recorded in Brazil as attacking coconut flowers, both male and female, and also ripe nuts on the trees. The duration of the cycle of development in this role is one month (Bondar, 1940b).

PSYCHIDAE

Mahasena corbetti Tams

Economic aspect

The caterpillar of this moth is easily recognized among coconut pests because it constructs and lives in a conical silken case in which fragments of leaf are incorporated (Figs. 51 and 52). It is typical, in this respect, of the family *Psychidae* to which the name " bagworms " is commonly and collectively applied. The caterpillar of *M. corbetti* feeds on the leaflets, first scarifying the tissues on the lower surface, then eating holes right through the leaflets and finally feeding at the edges. The damage done to the trees, though sometimes severe, is usually localized. Numerous other plant species are attacked, including *Areca*, *Arenga*, *Elaeis*, *Aleurites*, *Cupressus*, citrus, kapok, derris and species which yield gutta-percha.

Geographic distribution

From Malaysia and Thailand to New Guinea.

Description/Biology

The male adult is a normally winged moth, brown in color and 25-30 mm in wing expanse. The female is wingless, yellowish brown and 17 mm long; its life is passed entirely within the case which it constructed around itself as a caterpillar. In fact, the female is a very degenerate insect, little more than a bag of eggs. The caterpillar secretes a long thread of silk with which it is transported by the wind, particularly from tall trees to shorter ones. Movement to trees in new areas, however, is more often effected by crawling along the ground and up the trunks. The case constructed by the caterpillar is about 30 mm long when full growth is attained. The duration of the life cycle is probably about 3 months (Corbett, 1932).

Control

Sticky bands of resin and castor oil are applied to the trunks to prevent the caterpillars from climbing to the crowns of the trees. Dusts or sprays of DDT sufficiently protect attacked leaves.

In the Malay Peninsula, this pest is parasitized by a chalcid and a tachinid; the latter is *Tricholyga aberrans* Strobl, 41 individuals of which emerged from a single caterpillar. In Thailand, this bagworm is attacked by the tachinid *Exorista quadrimaculata* Baranov (Meksongsee, 1963).

Acanthopsyche hypoleuca Hampson and *A. cana* Hampson

While *Mahasena corbetti*, with its wide geographical range, is the most likely psychid to be encountered on coconut palms, there are, in Ceylon, two species of *Acanthopsyche* which are similar in appearance and life history to it and which are liable to occur on them.[6]

LIMACODIDAE

Setora nitens Walker

Economic aspect

There are several species of this family which attack and damage coconut palms, and *Setora nitens* is probably the most harmful of them. The caterpillars eat the leaves and in severe outbreaks they are so abundant that the leaves become brown and the crowns of the trees appear scorched. Young trees suffer more severely than older ones. The body of the caterpillar is armed with urticating spines which can cause great discomfort to laborers employed on the plantations. Other plants attacked are *Elaeis*, *Nypa*, banana, cocoa, coffee, tea, citrus and tobacco.

Geographic distribution

Malaysia, Viet-Nam, Laos and through Indonesia to New Guinea.

Description/Biology

The egg is somewhat flattened and is 3 mm long and broadly oval in outline; it is semitransparent and for this reason is difficult to detect on the underside of the leaflet where it is deposited. The period of incubation is 6-7 days. The caterpillar moves in a smooth gliding manner reminiscent of slugs (hence the popular name of "slug caterpillars" which is applied to the family, though many of the species have no other similarity to slugs),

[6] Other species which occur in South Viet-Nam on *Nypa* should be regarded as potential coconut pests.

FIGURES 51-52. - *Mahasena corbetti* Tams. Caterpillar (51, above) and chrysalis (52, below) in their typical case. According to P. Lepesme, 1947, redrawn.

(Courtesy P. Lechevalier, Paris, France)

and is fully grown in 18-32 days. The color of the caterpillar varies from green to orange-red, with a median purple band ornamented with spots. At each end there are two pairs of prominent spine-bearing processes, of which the first and the last pairs are largest. The length of the caterpillar varies greatly, up to 35 mm, mainly according to its sex. It constructs, usually near the ground, to which it drops from the tree, a smooth, spherical, parchment-like cocoon, which somewhat resembles an "oak apple" gall, and transforms to a chrysalis therein; the cocoon varies in diameter up to 15 mm (Kalshoven, 1950-51). The period spent in the cocoon, like the previous stage, varies greatly in duration, 17-31 days. The whole cycle covers 6 to 10 weeks, and exceptionally much longer, and the variation in rate of development results in marked overlapping of generations. The moth is brown, with darker reddish brown bands across the wings; the female measures 30-35 mm in wing expanse but the male is much smaller.

Control

Spraying infested trees with DDT at 0.1-0.2 percent is recommended as a general measure (Kurian, 1963), but in Sabah good results have been obtained by spraying the undergrowth with BHC at times of large-scale movement of the caterpillars to the ground; this reduces the risk of destroy-

ing the useful parasitic insects, which mainly frequent the crowns of the trees.

The tachinid fly, *Chaetoxorista javana* Brauer and Bergenstamm, is the most effective controlling agent of the parasite complex; the duration of its life cycle is only 2-3 weeks, less than half that of *S. nitens*. Hymenopterous parasites include species of *Brachymeria*, *Eurytoma* (*Chalcidoidea*), *Spinaria* (*Braconidae*) and *Xanthopimpla* (*Ichneumonidae*).

Macroplectra nararia **Moore** (often assigned to the genera *Natada* and *Parasa*)

Economic aspect

In India, this species, in the caterpillar stage, damages the leaves of the coconut palm, particularly during the dry season. In Ceylon, it is injurious to coffee, tea, *Zizyphus* and *Pithecolobium*, in addition to coconut.

Geographic distribution

Eastern India and Ceylon.

Description/Biology

The eggs are laid on both the upper and lower surfaces of leaves. Their period of incubation is 4-5 days. The caterpillar is yellow-green above, pink below, is 8-11 mm long at the completion of its growth, and bears tubercles with short spines. It is fully fed after 31 days, and then proceeds to construct a spherical, brown cocoon, 6 mm in diameter. The moth emerges from the cocoon 16 days later (Menon and Pandalai, 1958). The cycle from egg to moth covers 7 weeks. The moth is brownish ocher; the basal two thirds of the forewing is red, bordered with brown.

Control

Among the numerous chalcids and braconids which parasitize *M. nararia*, the eulophid *Neoplectrus maculatus* Ferrière (*Hym., Chalcidoidea*) is the most effective. The natural enemies also include a wasp of the family *Chrysididae*. During the rainy season in India, entomogenous fungi of the genus *Aspergillus* contribute to the natural control (Kurian, 1963), and in Ceylon a suspension of a granulosis virus has been applied in an attempt to suppress this pest.

Parasa lepida Cramer

Economic aspect

The caterpillars of this species are injurious to the leaves of coconut palms, and are sometimes so abundant that large trees are completely defoliated by them. Other plants attacked are: *Borassus*, *Nypa*, banana, *Aleurites*, *Artocarpus*, *Ricinus*, tea, coffee, *Canavalia*, mango, *Fagraea*, cocoa, pepper, pomegranate and cauliflower (Corbett, 1932).

Geographic distribution

Western Africa, Mozambique, India, and eastward through South Viet-Nam and Malaysia to New Guinea.

Description/Biology

The eggs are laid in masses on the underside of the leaflets; the incubation period is 7 days. The caterpillars are gregarious. When fully grown, they are green with a greenish blue dorsal stripe bordered with yellow, and they are armed with spine-bearing tubercles but not with longer processes like those of *Setora nitens;* the length of the larger (female) caterpillars is about 25 mm, and the period from hatching to construction of the cocoon is about 6 weeks. The nearly spherical cocoons are often formed on the trunks of trees, massed together in large numbers (Kalshoven, 1950-51); the moths emerge 3-5 weeks later, the total cycle covering some 10-12 weeks. The adult is mainly green but the outer margin of the forewing is reddish brown. The wing expanse of the male is 30 mm, of the female 45 mm.

Control

Against this pest, an aqueous preparation of DDT at 0.2 percent can be applied as a spray; alternatively, BHC is effective.

Many parasitic enemies of *Parasa lepida* are known. Among these are: *Eurytoma monemae* Ruschka, *Eupelmus catoxanthae* Ferrière, a species of *Pediobius* (*Hym.*, *Chalcidoidea*), *Apanteles parasae* Rohwer (*Hym.*, *Braconidae*), *Goryphus oxymorus* Tosquinet (*Hym.*, *Ichneumonidae*), *Stilbum splendidum* Fabricius and *Chrysis shanghaiensis* Smith (*Hym.*, *Chrysididae*), *Chaetexorista javana* Brauer and Bergenstamm (*Dipt.*, *Tachinidae*) and *Sarcophaga antilope* Bottcher (*Dipt.*, *Calliphoridae*). The caterpillar of the moth *Phycita dentilinella* is predacious on the chrysalis of *P. lepida* in its cocoon, and the chrysalis is also susceptible to attack by an entomogenous fungus of the genus *Cordyceps* (Lepesme, 1947).

Contheyla rotunda Hampson

Economic aspect

This species, like some other members of the family *Limacodidae* (*cf. Macroplectra nararia*), is liable to occur in great numbers locally during the dry season. When the caterpillars have virtually defoliated the coconut palms, they turn their attention to the flower spikes and the developing nuts. Tall trees are most severely attacked, but when there is little foliage left on them the pest attacks even seedlings. Banana and tea are also damaged.

Geographic distribution

India, principally the western coastal zone.

Description/Biology

The eggs are deposited in groups of 4-15 on the lower surface of the leaves; the number produced per female averages 215. Incubation requires 3-6 days, development of the caterpillar about 5 weeks, and the subsequent development in the cocoon 10-14 days, so that the cycle covers about 52 days (Nirula, 1954). The moths are grayish brown, with a wing span of 16 mm in the male and 20 mm in the female.

Control

Spraying with DDT at 0.1 percent is recommended. The known parasites of *C. rotunda* are all hymenopterous: a species of *Chrysis* (*Chrysididae*) which may attain 20 percent parasitization, one of *Rogas* (*Braconidae*), one of *Goryphus* (*Ichneumonidae*) and one of *Antrocephalus* (*Chalcididae*). During the monsoon season the caterpillars and chrysalides succumb to bacterial and fungous disease.

Chalcocelis albiguttata Snellen (formerly assigned to the genus *Altha*)

Economic aspect

The caterpillar feeds on the lower surface of the coconut leaflet and, in doing so, facilitates the entry of spores of the leaf-spot fungus *Pestaloptiopsis palmarum*, which is more harmful to the leaves than the feeding of the insect itself. Other plants attacked are *Acacia*, *Aleurites*, coffee, tea, *Erythrina*, *Eugenia*, *Gardenia* and *Hydnocarpus*.

Geographic distribution

From Malaysia eastward to New Guinea.

Description|Biology

The flattened eggs are laid on the coconut leaflets, singly or in small groups of not more than four (Kalshoven, 1950-51). They develop rapidly and hatch in only 2-3 days. The further development is relatively slow, the caterpillar stage lasting 60-70 days and the chrysalis 21-28 days, making a total period of development of 12-14 weeks. The smooth, translucent, ovoid caterpillar has the appearance of a gelatinous mass. The cocoon is nearly spherical, about 10 mm in greatest diameter, and whitish, as if whitewashed (Dammerman, 1929). The adult is grayish brown, with a reddish spot on the forewing; the male is darker and smaller than the female, which has a wing span of about 32 mm.

Control

The treatment recommended against other limacodids is applicable in this case also but a fungicide should be added. The parasite complex of *C. albiguttata* includes *Brachymeria euploeae* Westwood (*Hym., Chalcidoidea*), *Fornicia chalcoscelidis* Wilkinson (*Hym., Braconidae*), a species of *Goryphus* (*Hym., Ichneumonidae*) and *Exorista cervinodes* van der Wulp (*Dipt., Tachinidae*).

Orthocraspeda catenatus **Snellen** (assigned by some authors to the genus *Darna*)

Economic aspect

This species is most harmful in relatively dry areas and seasons. In 1950, no less than 100,000 coconut palms were seriously damaged by it in northwest Celebes; the defoliation reduced the yield of copra over a period of 18-24 months (Ponto and Mo, T.T., 1950). *Metroxylon*, *Elaeis* and other palms are also attacked.

Geographic distribution

Celebes (and adjacent small islands) and New Guinea.

Description|Biology

Incubation of the egg requires 4 days. The caterpillar is brown above and green beneath, and is armed with two rows of spiny tubercles on each side. It attains full growth in about 24 days and then constructs a brown, nearly spherical cocoon which is about 7.5 mm in greatest diameter; the

moth emerges from the cocoon 10-14 days later, and the whole cycle from egg to adult covers about 6 weeks. The forewing is grayish ocher and has a black central lunule, and the head, thorax and hindwing are gray. The wing expanse is 15-19 mm in the male, 19-23 mm in the female. The female lays about 300 eggs (Lepesme, 1947; Kalshoven, 1950-51).

Control

When the number of caterpillars per leaflet reaches three on most of the leaves, all the leaves except the three or four youngest should be cut off and burned. It is important to initiate control measures while the areas of severe infestation are still small and well separated.

O. catenatus is parasitized by species of *Euplectrus* and *Syntomosphyrum* (*Eulophidae*), as well as by other hymenopterous insects of the genera *Apanteles* (*Braconidae*) and *Chrysis* (*Chrysididae*), and by species of the dipterous genera *Chaetexorista* and *Bessa* (*Tachinidae*). Bacterial disease sometimes destroys up to 80 percent of the pest.

Trogocrada deleter Tams

A severe outbreak of this limacodid on coconut palms occurred in Mozambique in 1952 (Child, 1964). It is mentioned here mainly as an example of the sudden appearance in great numbers of an insect previously unknown as a pest or (as in this case) previously not believed to exist. The cause of the outbreak in Mozambique is not known, but it was suggested that exceptional flooding which preceded the outbreak may have eliminated, at least temporarily, the normal host plants of the insect and so caused it to attack the palms.

Castniidae

Castnia daedalus Cramer

Economic aspect

The large caterpillars of this moth burrow between the leaf bases and the trunk of the palm, causing the older leaves to hang down the trunk and the nuts to fall off through lack of adequate support. The continuous feeding of the caterpillars causes longitudinal furrows on the trunk which sometimes attain a length of a meter or more (Figs. 55 and 56) (Bodkin, 1913). The most serious damage occurs in plantations on clay soils. *Roystonea*, *Mauritia* and banana are also liable to be attacked.

Geographic distribution

The Guianas and the Amazon basin.

Description/Biology

The caterpillars are whitish, and 100 mm long when fully grown. The elongate cocoon is made of coarse fibers from the leaf bases. The moth is dark brown, with a whitish bar; it is crescent on the forewing and has two rows of spots on the hindwing. Its wing span is 140-180 mm (Figs. 53 and 54).

Control

Spraying with a 5 percent solution of dieldrin at 4-5 liters per tree is advocated. Kennard (1960) used dieldrin at only 1 percent, however, applying it directly to the center of the crown of the tree by means of stirrup pumps and long hoses, the latter attached to bamboo poles.

Castnia licus Drury

Economic aspect

This is a somewhat smaller species of *Castnia* but it does the same type of damage to the palms as *C. daedalus*. Young palms are the worst affected; their leaves become yellow (Wolcott, 1933). Banana and sugarcane are also attacked.

Geographic distribution

Central and South America, and Trinidad.

Description

The adult is similar to *C. daedalus*, but the whitish markings on the forewing are relatively larger and wide bands replace the spots on the hindwing. The wing expanse is 90-110 mm.

Control

For this species, dieldrin at 1 percent in solution applied at 2.5 liters per tree is claimed to suffice.

ZYGAENIDAE

***Brachartona catoxantha* Hampson** (often referred to as *Artona catoxantha*)

Economic aspect

The destruction of leaf tissue of the coconut palm by the caterpillars of this small moth can be so severe as to result in the complete loss of a crop for about 18 months (van der Vecht, 1947). Between outbreaks this insect becomes extremely rare or nonexistent in the coconut plantations, and it is assumed to be confined at such times to localized areas in the jungle from which it is intermittently transported by the wind. All investigators agree that severe infestations usually become obvious in dry weather and end soon after the onset of the monsoon season with its strong winds and torrential rains; this applies in the Philippines (Merino, 1938), Indonesia (van der Vecht, 1950) and the Malay Peninsula (Gater, 1925; Lever, 1953), and the outbreaks develop and terminate relatively suddenly. In an examination of the dates of 48 Malayan outbreaks (Lever, 1953) it was shown that 36 occurred in the drier half of the year (January-June) and only 12 in the wetter half. Figures 57 and 58 illustrate typical damage due to this insect.

B. catoxantha attacks other palms besides coconut: *Nypa*, *Elaeis*, *Areca*, *Arenga*, *Metroxylon*, *Oncosperma*, *Zalacca*, *Calamus*. It also feeds on banana. It should be noted, however, that whereas *Metroxylon*, like coconut, appears to be a normal food plant and outbreaks sometimes originate on it, other plants are, in general, not attacked unless the normal food (*Metroxylon* and coconut) becomes scarce through heavy infestation (van der Vecht, 1950).

Geographic distribution

Malaysia, the Philippines, New Guinea.[7]

Description/Biology

The eggs are yellow, somewhat flattened and broadly oval in outline. They are laid singly or, more frequently, in irregular groups of 3 to 12, on the underside of the leaflets, and the usual number produced per female is 40-50. They hatch after 3-5 days. The caterpillar is pale in color with a conspicuous, dark purplish, middorsal line and less dark sidelines. There are three rows of tubercles along each side, each row being represented by one tubercle on each segment; each tubercle bears numerous short bris-

[7] A report of the occurrence of this species in Fiji (Anon., 1962) is erroneous.

FIGURE 53. - *Castnia daedalus* Cramer. Female with some eggs. Surinam.

FIGURE 54. - Caterpillar, chrysalis (right), empty chrysalis and empty cocoon (left).
(Courtesy Royal Tropical Institute, Amsterdam)

FIGURES 55-56. - *Castnia daedalus* Cramer. Trunk of coconut tree damaged by caterpillars (55, left) and halved trunk, showing rotting process at top (56, right). Surinam.
(*Courtesy Royal Tropical Institute, Amsterdam*)

►

FIGURES 57-58. - *Brachartona catoxantha* Hampson. Injury to coconut palms by larval feeding (57, above) and detail of damage to leaves (58, below). Malaysia.
(*Photos R.J.A.W. Lever*)

tles. The first segment, into which the head is retracted and which hides it completely during feeding and resting, is large and dorsally brown. About 3 weeks after hatching the caterpillar is fully grown and about 10 mm long. The feeding scars on the underside of the leaflets are very characteristic, being short, parallel-sided furrows bounded by principal veins of the leaflet; the upper epidermis and the larger crossveins are not eaten at this stage, and the scars resemble ladders, with the crossveins as rungs. When the caterpillar reaches the last of its five instars, however, it feeds at the edge of the leaflet and eats right through it. The chrysalis is formed in an oval, somewhat flattened whitish cocoon, 12-14 mm long and of a papery texture. The cocoons — often many clustered together — are formed mainly at the bases of the leaflets but also at the bases of the leaves, or, in the case of caterpillars which fall or make their way to the ground, on undergrowth or debris. The period spent in the cocoon is 9 days, and the complete cycle from egg to emergence of the moth is about 5½ weeks, from which it follows that there can be about 9 generations a year in suitable conditions. The moths, which are 13-16 mm in wing expanse, have dark brown wings and body; the wings are narrowly yellow-bordered but without markings, and are yellow on the underside. When the moth is at rest, the front of the body is held away from the surface on which it is resting at an angle of about 60°. Both sexes are active in the early morning and the afternoon, and in outbreaks can be seen in great numbers in and around the crowns of the trees and feeding on the coconut flowers (Kalshoven, 1950-51).

Control

Insecticidal treatment against *Brachartona* was first undertaken in Java, with pyrethrum and later derris as the basis of the formulations used. Experience resulted in the recommendation of a derris-talc suspension containing 10 percent of derris (which gave 0.005 percent rotenone in the suspension) (Leefmans and Awibowo, 1935). Treatments recommended in the Malay Peninsula much later included spraying with lead arsenate at 0.4 percent, gamma-BHC at 0.025 percent, or DDT at 0.1 percent, and the application of DDT at 12.5 percent as a fog at about 17 liters per hectare. Emphasis was always laid in the Malay Peninsula, however, on the necessity to refrain from insecticidal treatment unless the outbreak was still confined to a small area and the degree of parasitization by the tachinid fly *Bessa remota* was below 70 percent in caterpillars of the relevant age.

Early action, before the infestation becomes unmanageable, is important, and this depends on proper inspection of the trees, by means of field glasses where the trees are tall. The use of an insecticide less persistent than BHC, such as malathion, has the advantage of having a correspondingly less adverse effect on the parasites.

The parasite complex of *Brachartona* has been intensively studied, partly in connection with a need for biological control of other harmful species of the family *Zygaenidae* and of *B. catoxantha* itself when it becomes established in islands or areas from which it has previously been absent, and also to gain an understanding of the factors concerned in the causation of outbreaks and the population dynamics of the pest. In this last respect, particularly noteworthy investigations were carried out in Java (van der Vecht, 1947 and subsequent papers).

The principal parasites of the complex are the following:

Bessa remota Aldrich (formerly *Ptychomyia remota*). This is a tachinid which lays one or several eggs on the thoracic segments of the half-grown caterpillar. Its developmental cycle lasts about 25 days and is shorter by 12-15 days than that of its host. In areas of the Malay Peninsula, where parasitization by *B. remota* reaches its maximum, virtually all *Brachartona* caterpillars of suitable age are eliminated by it at approximately the same time, with the result that an interval is established between generations, whereas otherwise there would be complete overlapping. This tachinid is more effective in the Malay Peninsula than in Indonesia. It was introduced into Fiji to control *Levuana iridescens*. A secondary parasite, *Pediobius parvulus* Ferrière (*Hym., Chalcidoidea*) often attacks it.

Cadurcia leefmansi Baranov (formerly *Degeeria albiceps* Macquart). This is another tachinid. It is particularly effective in Java toward the end of outbreaks and is almost absent from the coconut plantations when *Brachartona* is scarce.

Apanteles artonae Wilkinson. This braconid plays an important part in the natural limitation of populations of *Brachartona* in Java. By parasitizing almost all the caterpillars at approximately the same time (just as *Bessa* does in the Malay Peninsula) it creates conditions unfavorable for its own survival because complete overlapping of generations no longer occurs. It is often heavily attacked by a secondary parasite of the genus *Ceraphron* (*Hym., Proctotrupoidea*).

Other parasites that attack the caterpillars commonly are species of *Euplectromorpha* and *Euplectrus* (*Hym., Chalcidoidea*), while the chrysalides are destroyed by two species of *Goryphus* (*Hym., Ichneumonidae*). *Euplectromorpha* attains about 40 percent parasitization when *Brachartona* is rare but (unlike *Cadurcia*) almost disappears when it is common (van der Vecht, 1950).

A beetle, *Callimerus arcufer* Chapin (*Cleridae*), is a predatory enemy of *Brachartona*, which certainly contributes to its control. It too was introduced into Fiji for the control of *Levuana*.

A fungus, *Beauveria bassiana* (formerly called *Botyris necans*), infects and kills the caterpillars. An outbreak in Singapore was brought to an end by it, but the combination of weather conditions that favor it seems to be unusual. Attempts to utilize it for control purposes have not been successful.

Levuana iridescens Bethune-Baker

Economic aspect

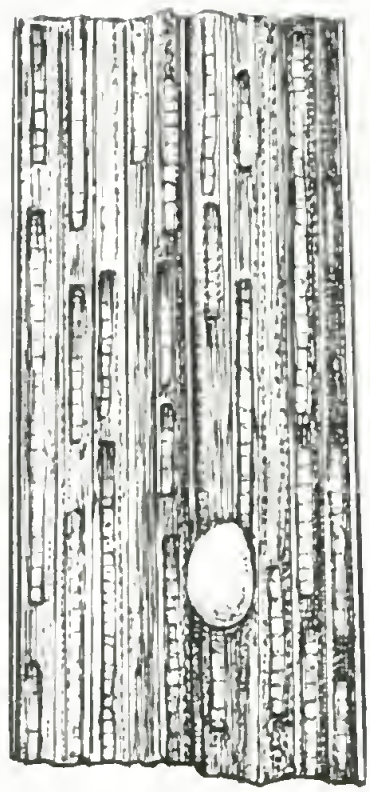
The caterpillars of this species do the same type of damage to the coconut palm as those of *Brachartona*, which they resemble in appearance as well as behavior. This insect was formerly a very severe pest in Fiji, to which it was confined, and did in fact constitute a serious threat to the coconut industry as a whole. It is, however, no longer a pest, having been brought under permanent control in 1925 by the introduction of a parasitic fly from the Malay Peninsula. Small local outbreaks still occur occasionally but they are quickly suppressed and are almost negligible. Nevertheless, there is always the risk of unintentional transportation of the insect to other countries; a possibility that the control achieved in Fiji may yet have to be applied elsewhere must therefore be recognized. Figures 63 and 64 illustrate typical damage done by *Levuana* on coconut. Other palms attacked by it are *Metroxylon vitiensis* and *Veitchia joannis*, which are indigenous to Fiji, and various introduced species of the genera *Roystonea*, *Elaeis*, *Livistona*, *Areca* and others. In severe outbreaks, caterpillars were found feeding on banana and sugarcane, but these plants are not to be regarded as true host plants.

Geographic distribution

Fiji Islands only. Originally confined to the largest island, Viti Levu, it had spread to certain other islands before it was brought under control.

Description/Biology

The eggs (Fig. 59) are opalescent and whitish when first laid, and are variable in shape but in general barrel-shaped. They are deposited on the lower surface of the leaflets in clusters of 10 to 40, and hatch in 7-8 days. The caterpillar (Fig. 60) is whitish with two dark purplish, longitudinal bands on the back, one on either side of the middle line. The first segment is large and covers the head, as in *Brachartona*, and has a blackish area dorsally divided by a pale median line. The body is armed with three rows of tubercles, each bearing numerous short bristles along each side; every row is represented on each segment by a single tubercle. The length of the fully grown caterpillar is 13 mm, and the duration of the caterpillar stage is 26-30 days. A noteworthy difference between this caterpillar and *Brachartona* is that whereas the latter, when nearly full-grown, feeds at the edge of the leaflet and eats right through it, *Levuana* feeds throughout the caterpillar stage by making parallel-sided furrows in the leaflet from below in the manner already described for all but the last instar of *Bra-*



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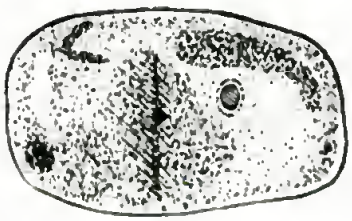

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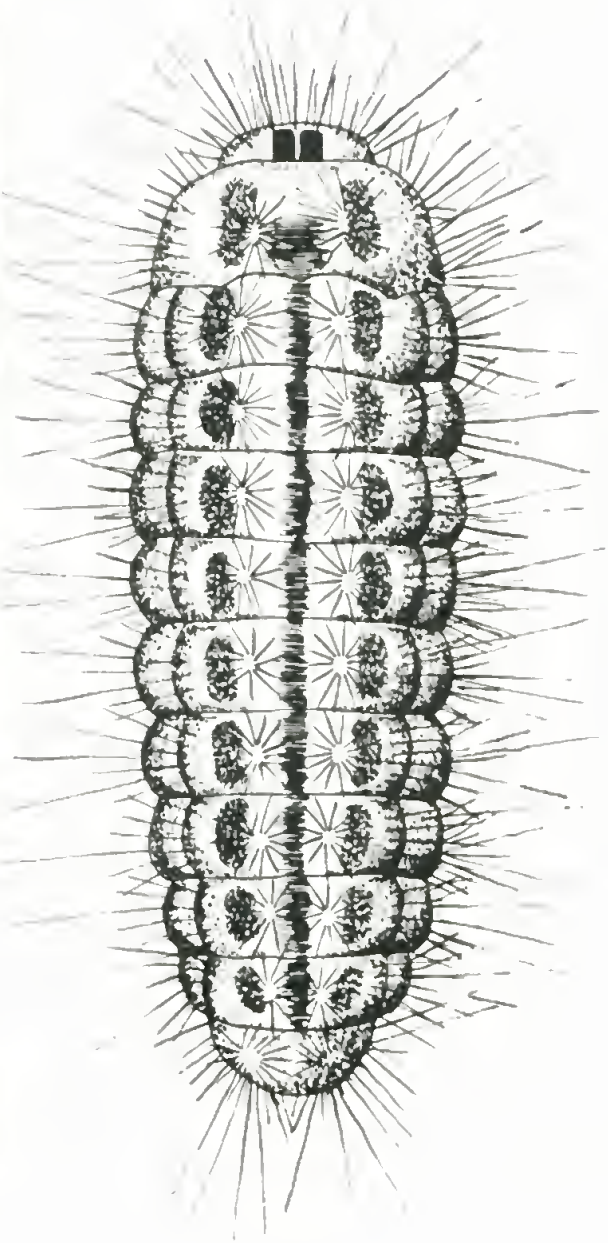

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FIGURES 59-61. - *Levuana iridescens* Bethune-Baker. Egg (59); adult caterpillar (60); larval damage and a cocoon on leaf (61). According to Tothill, Taylor and Paine, 1930, redrawn.

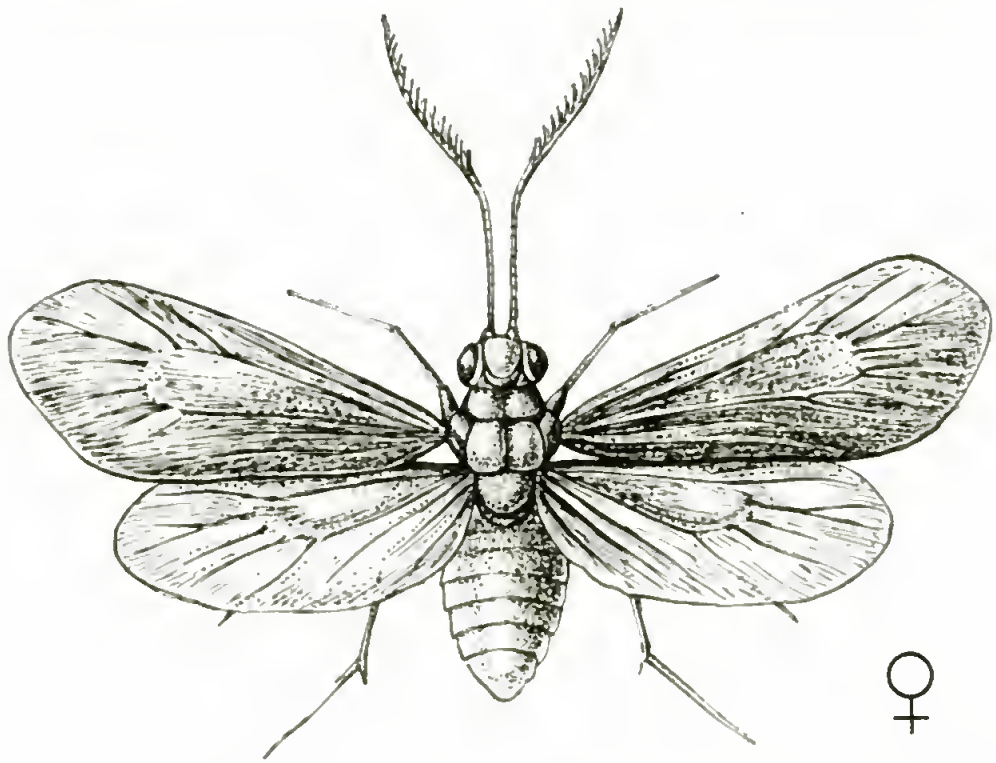


FIGURE 62. - *Levuana iridescens* Bethune-Baker. Female moth. According to Tothill, Taylor and Paine, 1930, redrawn.

chartona. When feeding is completed, a whitish cocoon is formed, just as in *Brachartona*, and it is similar in shape and texture to that of the latter, but whereas in *Brachartona* the majority of cocoons are constructed at the bases of the leaflets, in *Levuana* the majority of them are situated in the crevice between the base of the petiole of the leaf and the fibrous sheath of the succeeding leaf (Fig. 61). The duration of the cocoon stage is 10-13 days. The whole developmental cycle from egg to moth occupies about 43 and 51 days in the hot season and cool season, respectively. The moth is a dark metallic purple color, without markings; the metallic sheen is particularly noticeable on the head and thorax. The male measures 13-15 mm in wing expanse, the female 15-17 mm (Fig. 62) (Tothill, Taylor and Paine, 1930).

Control

In 1925, the tachinid fly *Bessa remota* Aldrich was introduced into Fiji from the Malay Peninsula and within only six months it had multiplied

FIGURES 63-64. - Fiji. *Levuana iridescens* Bethune-Baker. General view of a coconut palm tree, showing larval damage (63, above), and detail of damage to fronds (64, below).

(*Photos R.J.A.W. Lever*)

to so great an extent that the *Levuana* populations had been reduced to negligible dimensions. This is regarded as one of the classic examples of successful biological control. It resulted from the breeding in captivity and subsequent liberation of 32,600 flies in 38 localities over a period of four months. Proof was obtained that the fly could traverse a distance of 12 miles (19 kilometers) over open sea, and there seems little doubt that it could go much further. A predacious beetle, *Callimerus arcufer* Chapin (*Cleridae*), which attacks *Brachartona*, was introduced into Fiji from the Malay Peninsula with *Bessa remota* but failed to become established.

Chalconycles catori **Jordan** (sometimes assigned to the genus *Homophylotis*)

Economic aspect

This West African species is injurious to coconut palms less than 15 years of age, especially near the sea. However, *Elaeis* is preferred.

Geographic distribution

Ivory Coast and Ghana.

Biology/Control

Incubation occupies 6-13 days, the caterpillar period 22-33 days, the chrysalis 10-14; the mean total period from egg to adult is about 7 weeks. For control, aerial spraying of DDT at 0.037 percent is recommended. This should be done after rains, at which time the caterpillar population increases (Cachan, 1959).

NOCTUIDAE

Cyclodes omma **van der Hoeven**

The caterpillars bore deeply into the young nuts and cause them to fall off. The species is not very common and has never been studied adequately, but it is clearly potentially dangerous. It attacks other species of palms also (Lepesme, 1947), and has been recorded from India, Ceylon, Indonesia, Cambodia, Laos and Viet-Nam. Spraying with dieldrin is recommended as a control measure.

Coleoptera

LYMEXYLONIDAE

Melittomma insulare Fairmaire

Economic aspect

This wood-boring beetle, belonging to a little-known family, is the principal limiting factor in coconut growing in the Seychelles (Vesey-Fitzgerald, 1941b). The larvae excavate tunnels in the central portion of the trunk near the ground, and the trunks of attacked trees may be so weakened that they fall down. Wild palms of the genera *Stevensonia* and *Nephrosperma*, and more rarely *Deckenia* and *Roscheria*, are also attacked; they were the host plants of *M. insulare* before the coconut palm was introduced into the islands. In this connection it is interesting to note that two other local palms, *Lodoicea* and *Verschaffeltia*, are not attacked (Brown, 1954). Vigorous, well-manured trees are said to be more liable to attack than less healthy ones (Nye, 1961), and trees 7 to 20 years old are the most severely infested.

Geographic distribution

Seychelles and Madagascar.

Description/Biology

The white eggs are deposited in masses of 100 or more in crevices in the trunk. They hatch in 11 days. The larva is white and, when fully grown, 20 mm long; the first segment is large and strongly chitinized and the last segment has a hoof-shaped chitinized plate in which there are 18 or more small pits (Figs. 65 and 66). The young larvae enter the bole at the points where roots arise, and many larvae (up to about 200) may be found together in the same trunk. The soft wood at the heart of the trunk is preferred to the hard outer layers, and the larvae tunnel upward in it. A severely attacked bole is reduced to a black pulpy mass. The wood itself is not eaten; the juice is extracted from it and characteristic yellowish brown pellets issue from the boreholes. The pupal stage is passed in a cell excavated in the wood. The pupa is white, 17 mm long, and provided with thorny spines. The adult (Fig. 67), which is cinnamon brown in color, varies greatly in size, from 6 to 13 mm long in the male and 9 to 18 mm in the female.[8]

The adults do not feed; the males, which are more active, live 6 days and the females only 3 or 4 days.

This insect occurs on islands of granitic origin, not on those composed

[8] The beetle illustrated by Lepesme (1947) as *M. insulare* is actually another species of the same family.

of coral, and the most severe infestations are in localities where the trunks of the trees have a high water content (Brown, 1954). Palm trunks lying on the ground, having been caused to fall by the ravages of *Melittomma*, provide scope for the breeding of other pests, including *Oryctes*, termites and a weevil, and should therefore be destroyed by burning.

Control

Fumigation of the infested boles by inserting paradichlorobenzene into the cavities and covering their entrances gave fairly good results (Brown, 1954), but it was eventually decided that the resultant mortality of the larvae was not high enough. The best method is to excise the necrotic wood and expose the entrances of the tunnels, care being taken not to remove more of the hard outer wood than is necessary, and then to apply a mixture of tar creosote (60 percent), coke residue (9 percent), water (3 percent) and an inert, nonsoluble material. If excrement of the larvae is still appearing after a week, a second application is necessary. By this method, the loss of trees has been reduced to 1 percent and infestation of trees from 80 to 18 percent (Nye, 1961).

Much consideration has been given to the possibility of biological control, but the conclusion has been reached that this method is unlikely to succeed in this case. A predatory beetle of the family *Nitidulidae* was introduced but has not given satisfactory results (Simmonds, F.J., 1956).

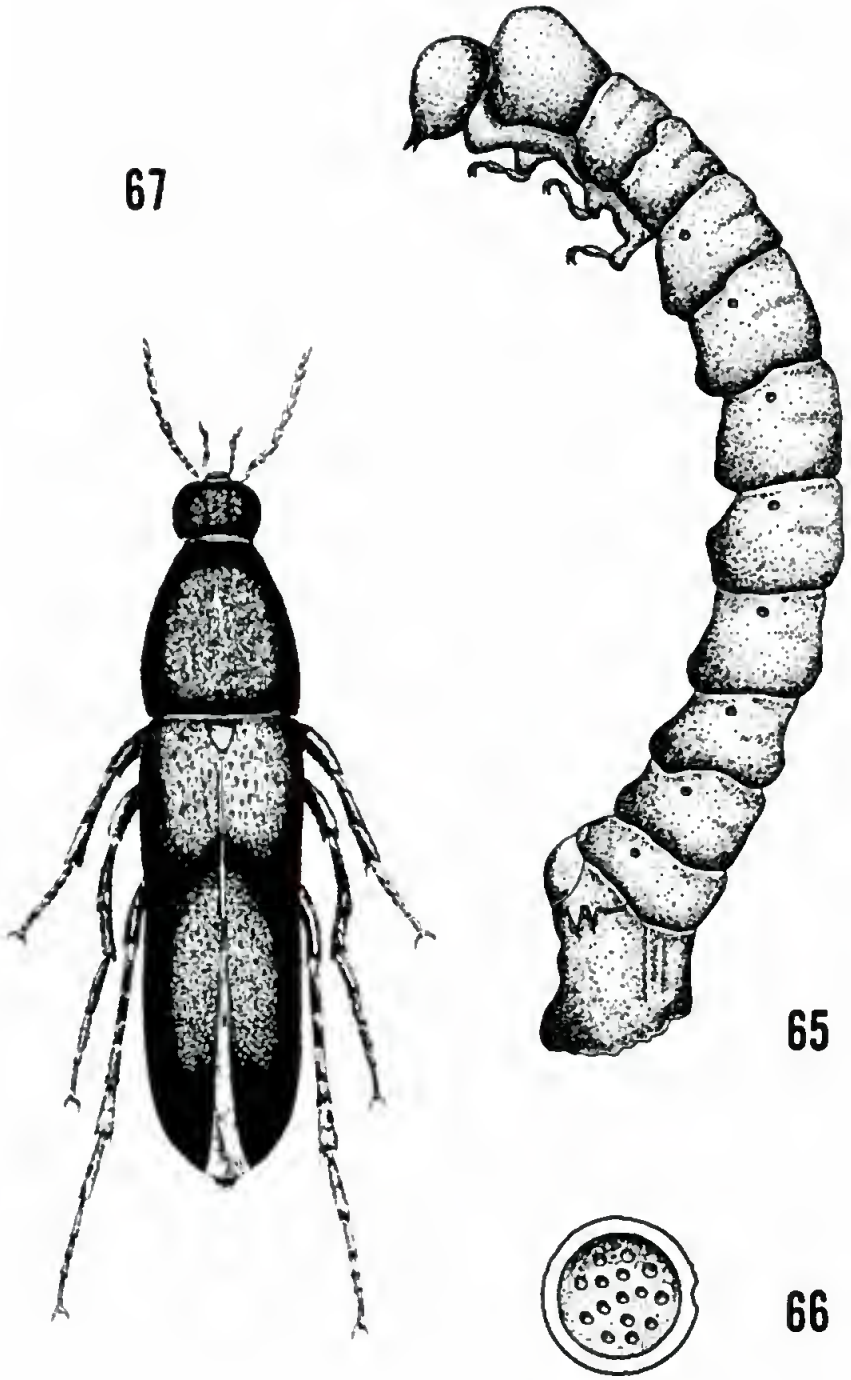
HISPIDAE

In an important analysis of the damage done by beetles of this family, Kalshoven (1957) has shown that they have an association with monocotyledonous plants, particularly palms, zingiberaceous plants, bamboos and orchids. These produce an almost continuous succession of terminal shoots which provide the various hispid species with the leaves, stalks or unopened "hearts" that they need.

***Promecotheca coeruleipennis* Blanchard** (This insect, as a coconut pest, has long been referred to as *P. reichei* Baly).

Economic aspect

The species of the genus *Promecotheca*, the adults of most of which are brightly colored, cause very serious damage of two quite distinct kinds to the leaves of coconut palms: the larvae feed by mining the tissues of the basal half of the leaflets (Figs. 68 and 69), whereas the adults feed by making narrow grooves in the lower surface of the distal half of the leaflets. Thus, in severe infestations, the larvae and adults jointly make the greater part of each leaflet and therefore of each leaf nonfunctional, and



FIGURES 65-67. - *Melittomma insulare* Fairmaire. Larva (65) with anal plate (66), and adult (67). (*Courtesy Institut de recherches pour les huiles et les oléagineux, Paris, France*)

since all the leaves are damaged in the same way, affected trees are greatly weakened and the crop is drastically reduced. The damaged leaflets shrivel and readily tear and break in the wind, and the trees acquire a brownish gray color which makes severe outbreaks recognizable at a considerable distance. Alternative food plants are palms of the genera *Pritchardia*, *Livistona* and *Metroxylon*.

Geographic distribution

Fiji, Tonga, Samoa, Futuna and Wallis (Taylor, 1937).[9]

Description/Biology

The eggs are laid singly on the lower surface of the leaflet. Each is covered by a close-fitting brown capsule composed of semidigested leaf fragments cemented together. The number of eggs laid per female is, on average, only 20. Incubation occupies 15-19 days, according to season. The newly hatched larva penetrates directly into the leaf tissues beneath the egg capsule and proceeds to excavate a mine toward the apex of the leaflet, between the upper and lower epidermes (Fig. 68). In the course of its development, the larva molts three times, and it widens the mine as it grows in the first two instars, but not in the third. The typical mine is straight, about 150 mm long and about 10 mm wide over the greater part of its length; thus each larva destroys about 12 cm^2 of leaf. The fully grown larva is 9.5 mm long, yellow, markedly flattened and legless, and the first segment is very large and bears a shiny, brown, strongly chitinized triangular plate, both above and below. The mean duration of the larval stage is 43 days in the hot season and 52 in the cool season. The pupa is formed in the mine and the pupal stage lasts about 12 and 18 days in the two seasons, respectively. On emergence from the pupa, the adult beetle rests for about 3 days inside the mine and then escapes by biting a conspicuous oval hole in the upper wall of the mine. The total duration of the developmental period, from egg to emergence of the adult from the mine, is about 10 and 13 weeks in the hot and cool seasons, respectively. A further period of about 13-16 days elapses before the female begins egg laying, and the total duration of adult life in both sexes is about a month. The adult is 8 mm long; its anterior half is orange-yellow and its posterior half metallic blue. The beetles fly by day and when abundant they can be seen on sunny days flying slowly around the crowns of the palms. The population of adults per tree in outbreak conditions is approximately 4,000 (Taylor, 1937).

[9] Reports of the occurrence of this insect in Tahiti and Hawaii (Wyniger, 1962) and in the Solomons and the Philippines (Kalshoven, 1957) are erroneous.

Control

Chemical control of this insect has never been attempted, biological control having been successfully achieved in 1933.

Taylor (1937) studied the natural enemies already present in Fiji prior to 1933. The more important species were: a parasite of the egg, *Oligosita utilis* Kowalski (*Hym., Chalcidoidea, Trichogrammatidae*); a parasite of the larva, *Elasmus hispidarum* Ferrière (*Hym., Chalcidoidea, Elasmidae*); and a predacious mite, *Pyemotes ventricosus* Newport [10] (*Acarina, Pyemotidae*), which attacks larvae of all ages and pupae. The first two of these, which are undoubtedly indigenous to Fiji, seem to have kept. *P. coeruleipennis* well under control until the unintentional butin evitable introduction into Fiji of the mite *P. ventricosus*, which is well known as a nearly cosmopolitan predator of many different kinds of soft-bodied insects that live in sheltered situations, especially insects that are pests of stored products. This mite multiplies extremely rapidly in favorable circumstances, which evidently include those prevailing in the mines of *Promecotheca* during the dry season, and it was found to be destroying virtually all the larvae and pupae in their mines during that season, leaving only the adult beetles and eggs. This established a " one-stage condition " in the population of *Promecotheca*, such that the indigenous parasites were unable to find larvae and pupae on which to breed, and consequently almost died out. When the next wet season began, the mite was no longer able to multiply, since the wet leaves, often-flooded mines and high humidity were highly unfavorable to it; thus, the beetle bred virtually without any natural controlling agencies throughout the wet season and attained once more a very high and harmful level of population. The mite, in destroying over a limited period all the individuals of the preadult stages — an activity which, if sustained, would be regarded as very satisfactory biological control, did in fact cause *Promecotheca* to become a much more serious pest than it would otherwise have been.

It became clear that to restore biological control a parasite fulfilling certain specifiable requirements was needed. Such a parasite was found in Java, in the form of *Pediobius parvulus* Ferrière (*Hym., Chalcidoidea, Eulophidae*) (at that time placed in the genus *Pleurotropis*); this insect, which was parasitizing *Promecotheca cumingii* Baly in Java, was introduced into Fiji, and there proved able immediately to bring *Promecotheca* under control, mainly through its ability to survive, unlike the indigenous parasites, from one *Promecotheca* generation to the next, even in the one-stage condition established by the mite. In the course of about a year, 26,000 individuals of *P. parvulus* were reared in the laboratory and were liberated in

[10] Formerly assigned to the genus *Pediculoides*.

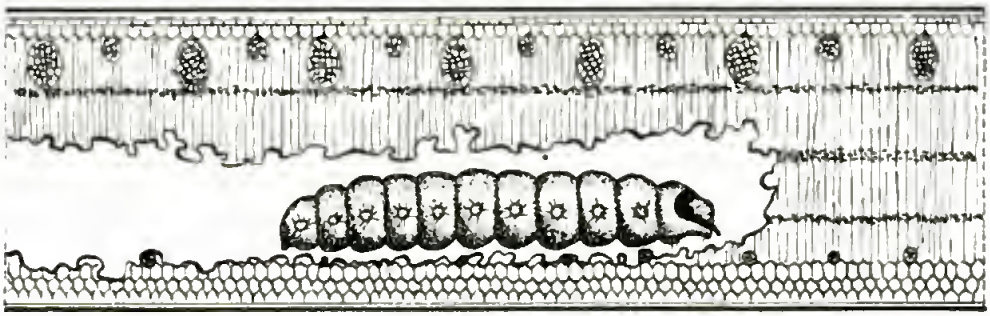


FIGURE 68. - *Promecotheca* species. Larva in mine (leaf cut lengthwise).

FIGURE 69. - Leaf mine of *P. coeruleipennis* Blanchard, showing egg capsule and subsequent development.

about 50 different localities; this proved more than sufficient (Taylor, 1937).

This became a classic example of planned biological control of a serious pest by a parasite specially chosen to fulfill the conditions prevailing in its new home.

Promecotheca papuana **Csiki** (also recorded as *P. antiqua* Weise)

Economic aspect

This is another species which, as a larva, mines in the leaves of the coconut palm. It is a pest in New Britain and Manus only, though it occurs over a much wider area. It is most abundant on mature palms. As in *P. coeruleipennis*, the adults feed on and kill the distal parts of the leaflets and they and the larvae are supplementary in causing serious defoliation and consequent loss of crop. The central shoot of the palm may be killed by constant attack by the adults as the new leaves unfurl. Constrictions in the trunks of old palms of known age indicate the dates of past outbreaks; it is judged that they have occurred at intervals of 10-15 years. *Metroxylon*, *Nypa*, *Areca* and *Elaeis* are also attacked.

FIGURE 70. - *Promecotheca* species. Apical frilling of fronds by feeding of larvae and adult beetles of *P. cumingi* Baly. Singapore.

(*Photo R.J.A.W. Lever*)

Geographic distribution

New Guinea, Manus (Admiralty Islands) and the Bismarck Archipelago.

Description/Biology

This species differs from *P. coeruleipennis* in that it lays 3-5 eggs together and covers them with a single capsule, but the capsules of the two species are similar in that they are composed of partially digested leaf fragments cemented together. The mean incubation period is 13½ days. The larvae

from each capsule mine together in the leaf tissues, making a large communal mine by feeding and advancing side by side. A typical completed mine is about 39 cm long. The larval stage lasts 17-30 days. When full-grown, the larva, being 12 mm long, is appreciably larger than that of *P. coeruleipennis*, but otherwise it is similar. Pupation takes place in the mine and the adults emerge from it 11-12 days later. The total development period, to emergence from the mine, including incubation, is thus about 45-48 days, which is considerably shorter than the corresponding period (70-91 days) for *P. coeruleipennis;* however, the following period, to commencement of egg laying, is much longer in *P. papuana* (4 weeks, as compared with about 2 weeks), and whereas the total duration of adult life in the Fiji species is about a month, that of *P. papuana* is about 5 months. The female lays 90-100 eggs in about 30 capsules. The coloration of the adult is black on the head and thorax, reddish on the anterior three fifths of the elytra (forewings) and greenish, purplish or bluish black on the remainder; in length the adult measures 7.5-9 mm. A peak population of 3,000 beetles per leaf and 35,000 per tree has been estimated (Froggatt, 1939a; O'Connor, 1940; Gressitt, 1959).

Control

As a result of a particularly severe outbreak of this pest in New Britain, *Pediobius parvulus* (the parasite used for the control of *Promecotheca* in Fiji) was introduced from Fiji to Rabaul in 1938. The parasite became established quickly and was entirely successful. The coconut crop, which had been greatly reduced, was restored to normal.

Several indigenous parasites of *P. papuana* exist in New Britain, the most important being an egg parasite, *Closterocerus splendens* Kowalski, and the larval parasites *Apleurotropis lalori* Girault and *Eurytoma promecothecae* Ferrière (*Hym., Chalcidoidea*).

Promecotheca opacicollis Gestro

Economic aspect

This species is considered the most important pest of coconut palms in the New Hebrides. The adults and larvae do the same type of damage as those of the other species of *Promecotheca* already described, and the damage to the tissues allows the entry of the fungus *Pestaloptiopsis palmarum*, which causes further injury. The greatest damage is done in the dry season. Risbec (1937) expressed the opinion that the injury due to this insect in the New Hebrides is much less than had previously been attributed to it. In the Santa Cruz Islands, to the north, it is certainly serious on occasion (Lever,

1933a); legislation promulgated in 1938 forbids the transportation of coconut leaves to the main Solomon Islands to the west. Other food plants of *P. opacicollis* are *Areca*, *Phoenix*, *Ravenala* and *Phytelephas*.

Geographic distribution

The New Hebrides and the Santa Cruz Islands of the Solomons.[11]

Description/Biology

The eggs are laid on the lower surface of the leaflets, under capsules, each of which usually contains 4 eggs. They hatch in 13 days. The larvae from each capsule feed communally in a single mine, and there are four larval instars in this species (unlike *P. coeruleipennis* and *P. papuana*, which have three only). Risbec (1935) estimated that the ratio of quantities of leaf tissue consumed by the larva in the four instars is 1:4:100:6,000. The larva is 8 mm long when fully grown, and the duration of this stage is 25 days and that of the pupal stage 10 days. The total period from egg to adult is thus about 48 days. The adult female is 10.5 mm long, the male a little smaller; the thorax is dark in color as in *P. papuana* and the coloration of the elytra is similar to that of *P. coeruleipennis*, except that the anterior border of the posterior purplish part bends forward in the middle like a circumflex accent instead of being straight.

Control

Chemical control should be used only in the absence of parasites.

The parasite *Oligosita utilis* Kowalski (*Hym., Chalcidoidea, Trichogrammatidae*) destroys up to 40 percent of the eggs; according to Risbec (1937) the lowest egg in the capsule cannot be reached by the ovipositor of the parasite. *Closterocerus splendens* Kowalski (*Hym., Chalcidoidea, Eulophidae*) destroys the larvae in the mines but parasitization by it reaches only 6 percent.

***Promecotheca cumingi* Baly** (also referred to as *P. nuciferae* Maulik)

Economic aspect

This is one of the most important pests (Fig. 70) of coconut palms in the Philippines. Damage has also occurred in the Malay Peninsula (Burkhill, 1918) and Singapore (Lever, 1951). The damage, again of two kinds, is the greater because it allows the entry of spores of the fungus *Pestaloptiopsis*.

[11] The statement by Kurian (1963) that this species occurs in the main islands of the Solomons group is erroneous.

The insect is also harmful to other palms, including *Areca*, *Elaeis*, *Nypa*, *Metroxylon* and *Roystonea*.

Geographic distribution

The Philippines, the Malay Peninsula, Singapore, Borneo, south Celebes, Java.

Description/Biology

Morphologically and biologically, *P. cumingi* is very similar to the other species of the genus already described. The incubation, larval and pupal periods are 13-15 days, 3-4 weeks and 8-12 days, and the total cycle from egg to adult emergence is 7-8 weeks. The length of the mine is about 20 cm. The beetles are uniformly reddish brown; they are 7-8 mm long.

Control

Chemical control is rarely undertaken, but Wyniger (1962) recommended a wettable powder of DDT or dieldrin at, respectively, 0.3 and 0.2 percent; alternatively, diazinon, guthion or parathion can be employed.

In Singapore, an outbreak which followed the inadvertent introduction of this pest in 1951/52 was rapidly brought under control by the parasite *Pediobius parvulus* Ferrière (*Hym., Chalcidoidea, Eulophidae*) which was evidently already present although previously unknown there. Other parasites which attacked it in Singapore were *Dimmockia javanica* Ferrière and *Achrysocharis promecothecae* Ferrière (both *Eulophidae*), the former parasitizing the larvae and the latter the eggs.

At the time of the outbreaks in the Philippines, some 35 years ago, it was recommended that ten old leaves (the 7th to the 16th) should be cut off from each affected tree; this drastic treatment was considered to be no more severe than the damage done by *P. cumingi* (Aldaba, 1931). This is mentioned here to illustrate the tolerance of the coconut palm to such measures. The trees recovered completely in two years.

Coelaenomenodera elaeidis Maulik

Certain species of the genus *Coelaenomenodera* occasionally mine as larvae in the leaves of the coconut palm in western Africa and in the Congo. The most important is *C. elaeidis* which, however, is more a pest of oil palms (*Elaeis*) than of coconut palms. It resembles *Promecotheca* both in behavior and in the complex of parasites which attack it; species of *Closterocerus* and *Achrysocharis* destroy up to 60 percent of the eggs, and other eulophids,

of the genera *Dimmockia* and *Cotterellia*, parasitize the larvae (Cotterell, 1925).

Dusting from the air with BHC and spraying from the ground with dieldrin, together with cutting and burning infested leaves, are effective.

Himatidium spp.

At least five species of *Himatidium* occur in Brazil, where they attack the central leaf bud, the young leaves and the fruits of the coconut palm. The fruits are particularly susceptible when they are in contact with one another. Dwarf palms are injured most severely, and may suffer a very heavy loss of crop (Bondar, 1940b).

Brontispa longissima Gestro (formerly called *B. froggatti* Sharp)

The genus *Brontispa* comprises at least a dozen species which have been recorded as actual or potential pests of the coconut palm. Some of these are probably merely local forms of more widely distributed species. All of them are similar in habits and natural enemies and the three species described below can be regarded as typical.

Economic aspect

B. longissima is a small, elongate, flattened beetle well adapted to live, as it does, as both adult and larva between adjacent leaflets in the central leaf bud (cabbage) before the leaves separate and the leaflets unfold. Thus, the species of this genus are not true miners even as larvae, and in this respect differ fundamentally from the species of *Promecotheca*. The adults and the larvae feed on both surfaces of the closely appressed leaflets, and both stages gnaw long incisions in the tissues, parallel to one another and to the veins of the leaflets. When the insects are numerous, these incisions are so close to one another that the whole of the attacked part of the leaflet dies; all the leaflets are similarly injured, and photosynthesis is reduced almost to zero (Figs. 75 and 76). Young palms less than about 8 years old suffer most. *B. longissima* has been recognized as a pest in Melanesia for more than half a century and, until the advent of persistent insecticides, was responsible for severe damage and sometimes total losses in most palm nurseries. It breeds on many other kinds of palms, including *Areca*, *Elaeis*, *Caryota*, *Latania*, *Metroxylon*, *Phoenix*, *Ptychosperma*, *Roystonea* and *Washingtonia*.

Geographic distribution

Indonesia (including the Moluccas), New Guinea, the Solomons, New Hebrides, New Caledonia, and (since 1961) Tahiti. The arrival of this insect in Tahiti constitutes a serious threat to all the coconut plantations of Polynesia (Cohic, 1961).[12]

Description/Biology

The eggs are brown and flat, and are laid in short chains of up to 4, and sometimes singly, on the unexpanded leaflets in the bud. They are not protected by a capsule but are loosely surrounded by leaf debris and excrement (Figs. 71 and 72). They hatch in 3-4 days. The whitish larva has a pair of prominent caliper-like hooks at the hind end (Fig. 73). It becomes fully fed in about 5 weeks, though the actual period varies greatly in different countries or seasons (probably with temperature), as is indicated by the following figures: 33-54 days in the New Hebrides (Risbec, 1935); 30-40 days in New Guinea (Froggatt and O'Connor, 1941); 30 days on average in the Solomons (Lever, 1935); and 23-43 days in Celebes (Awibowo, 1935). The pupa moves freely, by wriggling, between the apposed surfaces of the developing leaflets, and the adult (Fig. 74) emerges from it in 4-6 days. The whole cycle from egg to adult occupies about 5-7 weeks in Indonesia (Kalshoven, 1950-51, referring to observations made in Java and Celebes), but can extend to 9 weeks in some other (presumably cooler) places. The female matures sexually in about 2 more weeks, and then begins egg laying and produces on average 120 eggs in the course of several weeks (Kalshoven, 1950-51). The adult beetle is 8-12 mm long; its color varies geographically from reddish brown in Java to more or less black in the Solomons and New Guinea. The more extreme color forms were long regarded as distinct species: *selebensis* mainly in Celebes and the Moluccas, *froggatti* mainly in the Solomons, New Hebrides and New Caledonia, and *simmondsi* in the Bismarcks; but there is considerable overlapping in the distribution of these forms.

Control

Thirty years ago, it was usual to combat this pest by applying by hand a concoction of lead arsenate and bordeaux mixture or of tobacco and soap, but the results obtained were poor (Pagden and Lever, 1935). Nowadays, infested trees are sprayed every 4-6 weeks with a solution of 0.15 percent dieldrin by means of low-volume knapsack sprayers. Good results have also been obtained with DDT at 0.2 percent and chlordane at 0.16 percent, but

[12] The inclusion of Fiji in its range (Kalshoven, 1957) is incorrect.

these products are less persistent than dieldrin. Experience in the Solomon Islands has indicated that the annual cost of modern control procedure is the equivalent of U.S.$9 per hectare, of which 80 percent is the cost of labor; small palms 3-4 years old are sprayed once every two months with dieldrin at 0.15 percent by means of a pressurized sprayer and aluminum lances 4 meters long.

The parasite complex of *B. longissima* comprises three egg parasites, *Haeckeliana brontispae* Ferrière, *Trichogrammatoidea nana* Zehntner (both *Hym., Chalcidoidea, Trichogrammatidae*) and a species of *Ooencyrtus* (*Hym., Chalcidoidea, Encyrtidae*), and a parasite of the larvae and pupae, *Tetrastichus brontispae* Ferrière (*Hym., Chalcidoidea, Eulophidae*). The *Tetrastichus* is the most effective; control of the beetle was achieved in Celebes by introducing this parasite from Java (Awibowo, 1935), but an attempt to introduce it into the Solomons in 1936 failed (Lever, 1936). The developmental cycle of *Tetrastichus* occupies 16-23 days (half the period occupied by that of its host) and many *Tetrastichus* develop in each attacked individual of *Brontispa.* In Java there are two strains of *Brontispa*, of which only one permits the complete development of *Tetrastichus* (Mo, T.T., 1965).

Brontispa mariana **Spaeth**

Economic aspect

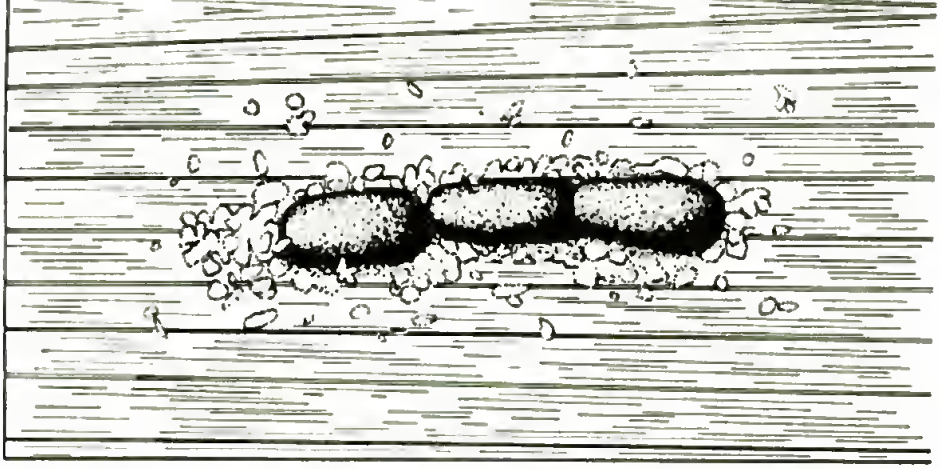
The species *mariana* is the representative of the genus *Brontispa* in Micronesia and causes serious damage to coconut palms in Saipan and Rota in the Mariana Islands, and in Truk, Yap and elsewhere in the Carolines. Between 1931 and 1936, it almost eliminated the copra and coconut oil industry of the islands. Coconut is the only known host plant in the field but it has been reared on *Areca* and *Eupritchardia* (Lange, 1950).

Geographic distribution

The Mariana and Caroline Islands.

Biology

The eggs are laid in groups of 2 to 6 between the unopened leaflets. They hatch in 6 days. The larval development occupies on average 22 days and the pupal 5 days, giving a total from egg to adult of about 33 days, which is less than that of *B. longissima.* The adults live for several months and the female lays over 100 eggs in the course of its life.



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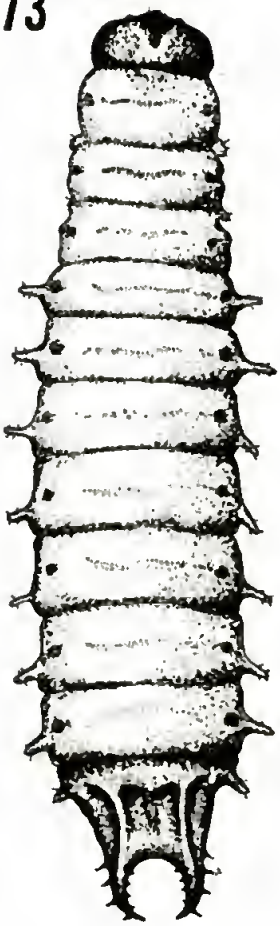

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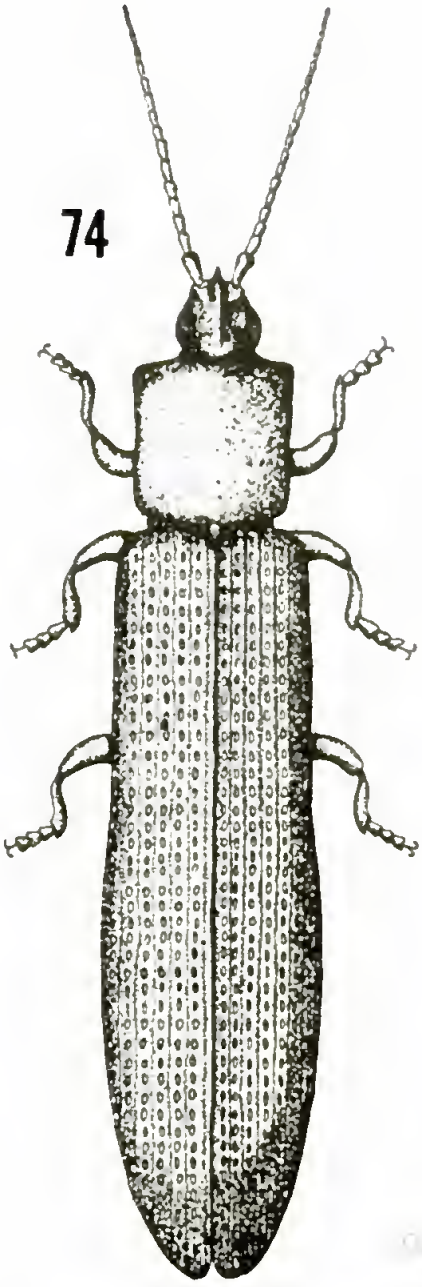


FIGURES 75-76. - *Brontispa longissima* Gestro. Fresh feeding scars on leaflet (75, above) and opened-out frond, showing damage to leaflet (76, below). Solomon Islands.

(*Photos E.S. Brown and H.A. Green, 1958*)

◄

FIGURES 71-74. - *Brontispa longissima* Gestro. Eggs and frass on leaflet (71); detail of pattern on chorion (72); and larva (73). According to E.S. Brown and H.A. Green, 1958, redrawn. Adult beetle (74).

Control

No chemical control measures have been recorded but spraying with dieldrin at 0.15 percent should be effective. For biological control, *Tetrastichus brontispae* and *Haeckeliana brontispae*, both already mentioned, were introduced into Saipan in 1948 from the Malay Peninsula and Java with successful results. Within a few months the overall parasitization reached 60 percent and this proved sufficient to check the outbreak.

Brontispa limbata Waterhouse (sometimes called *B. gleadowi* Weise)

Economic aspect

This species damages coconut palms in the same way as those already described. It also attacks *Dictyosperma* and *Acanthophoenix*.

Geographic distribution

Mauritius.

Biology

The egg stage lasts 6-8 days, the larval about 2 months, and the pupal stage 7 days. The complete cycle from egg to adult is 60-80 days.

Control

Spraying twice with phosdrin with an interval of a week between treatments is recommended. DDT at 0.1 percent ensures protection for 4-6 weeks, and dieldrin at 0.025 percent for 6-8 weeks. These two insecticides are more effective than chlordane or toxaphene (Orian, 1961).

Plesispa reichei Chapuis

Economic aspect

The larvae and adults of this insect are very harmful to young coconut palms, of which they gnaw the young unopened leaflets in a manner similar to *Brontispa*, so that when the leaves open much of the tissue dies and shrivels and the leaflets are torn by the wind. The larvae, like those of *Brontispa* and unlike those of *Promecotheca*, are not miners. The growth of infested young palms is delayed, and in prolonged outbreaks they may be killed. Less damage occurs in nursery beds under rubber or other shady

trees than under tall coconut palms. The insect breeds on *Nypa* and *Roystonea* also.

Geographic distribution

The Malay Peninsula, Indonesia.

Description/Biology

The developmental periods are: egg, 10 days; larva, 27-43 days; pupa, 6-11 days. The whole cycle from egg to adult has been recorded as 40-64 days (Corbett, 1923) and 6-7 weeks (Kalshoven, 1950-51). The female can live 6-8 months and lay 50-95 eggs (Kalshoven). The larva and pupa have a pair of caliper-like processes at the hind end, similar to those of *Brontispa*. The male adult is 6.5 mm long, the female 7.5 mm; the head and thorax are brownish orange, the elytra black.

Control

If chemical control should prove necessary, dieldrin, DDT or chlordane would be appropriate, at the concentrations indicated for use against *Brontispa*. The eggs of *P. reichei* are parasitized by *Ooencyrtus podontiae* Gahan (*Hym., Chalcidoidea, Encyrtidae*) and *Haeckeliana brontispae* Ferrière (*Hym., Chalcidoidea, Trichogrammatidae*).

CURCULIONIDAE

This vast family of insects, the weevils, is one of the most easily recognized, because of the characteristic rostrum or "snout" and the elbowed, clubbed antennae.

***Rhynchophorus ferrugineus* Olivier**

Economic aspect

This weevil is one of the most harmful and notorious pests of the coconut palm. The damage that it does is due entirely to the larvae, which feed in the trunk and also in the heart of the crown of the tree. Not infrequently the larvae damage the growing point seriously and the tree dies in consequence. This pest is often associated with *Oryctes*, whose activities provide it with niches suitable for egg laying. In severely infested plantations, many palms lose their crowns completely, so that only the dead trunks remain. On the Malabar coast of India, 5 percent of the young palms up to 10 years old are killed annually. Other palms attacked by this weevil

are: *Areca, Arenga, Caryota, Coelococcus, Corypha, Elaeis, Livistona, Metroxylon, Nypa, Oncosperma* and *Phoenix.*

Geographic distribution

India, Ceylon, Thailand, New Guinea, the Philippines.

Description/Biology

The eggs (Fig. 77) are laid in existing wounds in the crown or trunk of the palm, in holes made in the tissues with the rostrum. The duration of adult life is 3-4 months, in the course of which the female lays 200-500 eggs. The incubation period is 3 days. The larva (Figs. 78 and 82) lives entirely in the tissues of the tree, where it excavates galleries; the damage it does is therefore not apparent at the time and is not suspected until the consequent drooping of the leaves is recognized as a symptom. When fully grown, the larva is 65 mm long, and is stout, legless and yellowish, with the head and the first segment brown. The larval period varies in duration from 2 to 4 months. Pupation takes place under the bark, in a cylindrical cocoon (Fig. 83) coarsely constructed of tangled fibers and measuring up to 80 mm in length, and this stage lasts about 14 days. The adult (Fig. 79) remains in the cocoon to harden for 11-18 days after shedding the pupal skin. The whole cycle, from the egg to the emergence of the adult from the cocoon, occupies 3-6 months, varying with the amount of water contained in the tissues eaten. The adult is capable of flying strongly and is diurnal in its habits; its size varies greatly, from 25-50 mm. Its color is chestnut brown, with a few black spots on the thorax (Dammerman, 1929). The female is strongly attracted to fermenting sap oozing from wounds in the trunk or the leaf bases.

Control

Dieldrin at 0.1 percent should be applied to the damaged trunks or, in the case of new plantings, sprayed every three months on the crowns and bases of the trees (Vestal, 1956). This is advocated in Thailand where *R. ferrugineus*, often associated with *R. schach*, in the crowns of the palms is very difficult to combat when it gains entry into the bases of the trunks. As a prophylactic measure, the application of a mixture of 5 percent BHC or chlordane and sand to the axils of the leaves is recommended. Another method consists in pouring diluted Metasystox into a hole about 5 cm deep drilled in the trunk just above the injury.

Since most of the damage done by *Rhynchophorus* is secondary to that of *Oryctes*, control of the latter is an important aspect of control of the former. This requires strict attention to the destruction of logs and stumps by burn-

ing and to preventing the accumulation of dead vegetable matter which would decompose and provide breeding places for *Oryctes*. In Thailand, it is recommended that trees heavily infested in the crown with *Rhynchophorus* should be felled, the top 50-75 cm of the trunk cut off and split to expose the insects, and this infested part covered with diesel oil and then burned (Vestal, 1956). It is also necessary to prohibit the cutting of footholds in the trunks for climbing, the cutting of leaves for feeding to cattle, and any other injurious activities which provide sites for egg laying by the weevil (Child, 1964).

There is some parasitization of the larvae in Java by the large wasp *Scolia erratica* Smith and in India by the calliphorid fly *Sarcophaga fuscicauda* Bottcher (Lepesme, 1947). A mite, *Tetrapolypus rhynchophori* Ewing, of the family *Pyemotidae*, has been recorded as a predator of *Rhynchophorus* (Kurian, 1963). However, since these natural enemies do not play a significant part in the limitation of the weevil populations, it is necessary to rely on chemical treatment combined with efficient estate sanitation.

Rhynchophorus schach Olivier

Economic aspect

This species is often regarded as a form of *ferrugineus* but is here treated as a distinct species. The main behavioral difference between the two is that *ferrugineus* commonly attacks the trunk of the palm, while *schach* most frequently damages the terminal bud. Otherwise they are very similar and there is an association with *Oryctes* in both. Alternative host plants among the palms include *Sabal*, *Licuala* and *Verschaffeltia*, nonindigenous species, all of which were killed by *R. schach* in the Botanic Gardens at Singapore.

Geographic distribution

Sumatra, the Malay Peninsula, Borneo, southern Thailand, New Guinea.

Description/Biology

The beetle (Fig. 80) is shining black, except for a median stripe on the thorax and the "club" of the antenna, which are orange-red; its length is 45 mm. The duration of the developmental cycle, from egg to adult, is about 4 months.

Control

The measures recommended in Thailand against *R. ferrugineus* are applied against *R. schach* equally. In Sabah also, spraying with dieldrin is advocated,

in this case at 0.2 percent, and another treatment is injection into the galleries of paradichlorbenzene in ethyl acetate. These measures, however, are not sufficient in themselves; proper plantation management to ensure the maximum possible reduction of the breeding places of *Oryctes*, which attract *Rhynchophorus*, is a basic requirement.

Rhynchophorus papuanus Kirsch

This is another species (if indeed it is a distinct species) in the Southeast Asia-New Guinea complex. It occurs in eastern Indonesia and New Guinea (Kalshoven, 1950-51), and is particularly associated with the indigenous sago palm, *Metroxylon sagu*, but attacks coconut also. It is distinguishable from *R. ferrugineus* and *R. schach* in that it is entirely black; Kalshoven regards it as merely a form of *ferrugineus*.

Rhynchophorus palmarum Linnaeus

Economic aspect

In South America, this species has the same importance as the preceding species in Asia. It does the same type of damage, and is, in addition, the vector of a nematode of the genus *Rhadinaphelenchus*, which is responsible for red ring disease of coconut palms.

Geographic distribution

Tropical South America, Mexico and the West Indies.[13]

Description/Biology

The eggs are laid in cracks and wounds in the bark, and the maximum number recorded for a single female in the course of its life is 718. The period of incubation is 3 days. The larva is fully grown in 52 days (Hagley, 1965b). According to Wilson (1962, 1963), larvae reared on coconut "cabbage" (the central leaf bud) are fully developed in 24-41 days, whereas in harder, woody tissues the corresponding period is 47-62 days. When the larva tunnels in the trunk it fills its galleries with a moist, sour-smelling mass of fragmented fibers, through which it moves with a gurgling noise (Wolcott, 1933). The cocoon is similar to that of the other species already described. The pupal period (including a prepupal stage in the cocoon)

[13] A record of this species from Hawaii (Lepesme, 1947) is erroneous.

has been variously estimated as 11-35 and 27 days, and the whole developmental cycle from egg to emergence of the adult from the pupa as 79 days in the laboratory and 72 in the field (Hagley), and 78 in the field (Maharaj, 1962). The adult (Fig. 81) does not commence to feed until 8 days after emergence from the pupa. It is attracted to sap oozing from wounds or burns on the palms. The local people eat the larvae; this applies also in Burma, the Malay Peninsula, the Philippines and New Guinea in respect of the congeneric species occurring there.

Control

Spraying with aldrin is reported to have proved effective in Guyana; dieldrin at 1 percent can be expected to be equally satisfactory. The problem of control of this species is less difficult because *Oryctes* is absent from the New World, but proper estate sanitation and avoidance of slashing the trunks and leaves are nevertheless important.

A tachinid parasite, *Parabillaea rhynchophorae* Blanchard, has been discovered which attacks the pupae of *R. palmarum* in the palm *Attalea princeps* in Bolivia (Candia and Simmonds, F.J., 1965). The young larvae of the fly seek out the *Rhynchophorus* pupae in the trunk.

Rhynchophorus phoenicis Fabricius

This is the African representative of the genus. It tunnels in the trunks of coconut palms, stops growth and even kills them (Saraiva, 1939). It occurs in tropical Africa and probably in Iraq (Lepesme, 1947). The cycle from egg to adult covers about 60 days, of which 26 are spent as a larva.

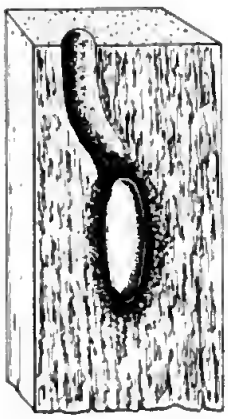
Rhabdoscelus obscurus Boisduval (formerly assigned to the genera *Rhabdocnemis* and *Sphenophorus*)

Economic aspect

This weevil is perhaps best known as a pest of sugarcane, but also does serious damage, of the same type as that done by *Rhynchophorus*, to coconut palms, and damages many other cultivated plants, including *Areca*, *Metroxylon*, banana and papaya.

Geographic distribution

Moluccas, New Guinea, the Pacific Islands (including Hawaii) and Queensland (Australia).



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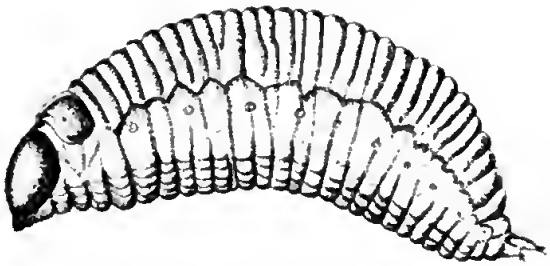

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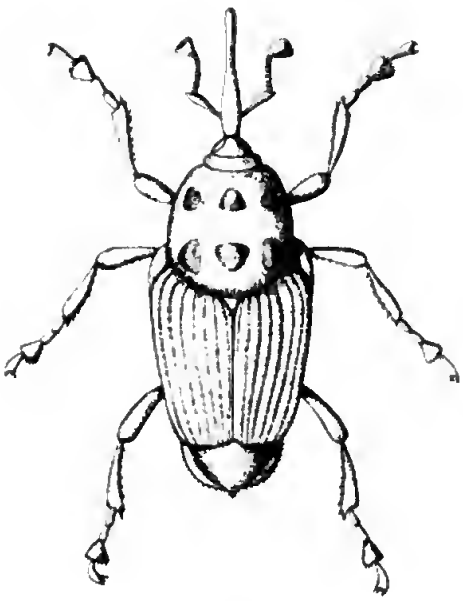

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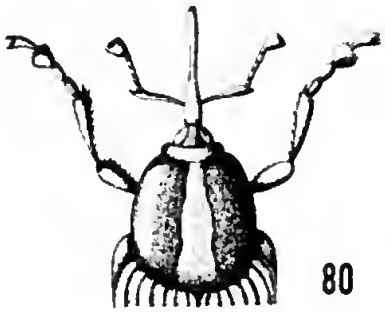

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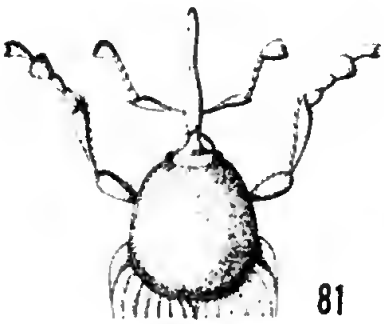

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FIGURES 77-81. - *Rhynchophorus* species. Egg (77); larva (78); and adult beetle (79) of *R. ferrugineus* Fabricius; heads and prothorax of *R. schach* Olivier (80) and of *R. palmarum* Linnaeus (81).

FIGURES 82-83. - *Rhynchophorus ferrugineus* Fabricius. Larvae and pupae of different developmental stage in a portion of damaged crown of coconut palm (82, above), and isolated cocoon (83, below).

(*Photos C. Kurian*)

Description/Biology

The adult weevil is reddish brown with the head darker and a vague longitudinal darker mark on the thorax and often on each elytron. It is about 15 mm long. The duration of the egg, larval and pupal stages are 6, 80 and 8-14 days, and the whole cycle occupies about 13 weeks. The adults are strongly attracted to the fermenting sap which exudes from wounds on the tree.

Control

In New Guinea, this pest is kept in check to a considerable extent by a dipterous parasite, *Ceromasia sphenophori* Villeneuve (*Tachinidae*), which has been introduced into Hawaii and other countries for control of the weevil, primarily as a pest of sugarcane, with useful results. As in the case of the other weevils already mentioned, it is necessary, in order to reduce damage to coconut palms, to avoid wounding the trunks as far as possible.

***Rhinostomus barbirostris* Fabricius** (formerly called *Rhina barbirostris*)

Economic aspect

The female lays its eggs in the trunk of healthy, mature palms but also attacks rotting palms. It is suspected of being a vector of the nematode *Rhadinaphelencus*, which is the causative agent of red ring disease, but its importance in this connection is small compared with that of *Rhynchophorus palmarum*. The foliage of trees infested by it turns yellow, their growth ceases and their trunks become liable to break in the wind (Wyniger, 1962). The weevil breeds also on *Arecastrum*, *Attalea*, *Diplothemium*, *Elaeis* and *Syagrus* (Lepesme, 1947).

Geographic distribution

Mexico and South America, including Trinidad.

Description/Biology

The eggs (Figs. 85 and 86) are laid in holes 2 mm wide made in the trunk by the female with its rostrum. The resulting larvae (Fig. 87) tunnel horizontally in the trunk. They are whitish with a yellow head and spots on the body. Pupation takes place in a cocoon of tangled fibers. The adult is blackish brown and 30-40 mm long, excluding the rostrum, which is itself 10-12 mm long (Wolcott, 1933). The rostrum has a bushy growth of brown hair; hence the name of the species.

Control

Young larvae can be detected by the presence of their excrement on the trunk; their further penetration into it, and the entry of other larvae nearby, can be prevented by the application of tar (Wolcott, 1933). Treatment of the trees with a solution of dieldrin at 5 percent, or with pyrethrum and piperonylbutoxyl at a similar concentration, is also recommended.

Rhinostomus afzelii Fåhraeus

This species (Fig. 84) occurs in tropical Africa and Zanzibar, where it does the same damage to coconut palms as *R. barbirostris* in South America (Saraiva, 1939). It attacks *Elaeis* and *Raphia* also.

Sparganobasis subcruciatus Marshall

Economic aspect

The larva tunnels in the trunk of the coconut palm, often at the point of junction of a leaf petiole. Infested trees are liable to be so severely weakened that they fall to the ground (Simmonds, H.W., 1938). Discoloration of the leaves and exudation of sap are characteristic symptoms.

Geographic distribution

New Guinea.

Description/Control

The adult is black and 18 mm long. It is readily attracted to damaged coconut trunks and trapping has therefore been recommended as a control measure, but unless this operation is carefully supervised and the trunks used to attract the weevils are inspected daily it can do more harm than good.

Diocalandra taitensis Guérin

Economic aspect

This weevil attacks all parts of the coconut palm (Lever, 1941b) but opinions as to its status as a pest vary greatly. Some entomologists assert that damage by it is purely secondary but others claim that it does serious primary damage to roots, leaves and fruit stalks, and that it is a cause of

premature shedding of nuts. Particularly severe injury has been reported from the Line Islands (Herms, 1926), Tahiti (Doane, 1909) and elsewhere in the Pacific (Zacher, 1913), where the larvae kill the young nuts and feed in the leaf bases, tunneling in the latter from the base toward the leaflets. In Madagascar, the larvae burrow in the trunk at all heights (Frappa, 1947). *D. taitensis* is not known to attack palms other than the coconut.

Geographic distribution

New Guinea, the Solomons, Melanesia, Polynesia; the species was inadvertently introduced into Hawaii in 1919 and Madagascar in 1943. It was one of the first coconut pests to be recorded in Tahiti in 1840.[14]

Description|Biology

The eggs are laid in crevices at the bases of the adventitious roots at the foot of the trunk, or in the inflorescences, or at the base of the peduncle or of the petiole. Incubation requires 4-8½ days. The larva penetrates into the tissues and causes gum to appear at the opening of the gallery. Larval development covers 8-10 weeks, and pupal 10-12 days (Herms, 1926). No cocoon is formed. The whole cycle from egg to adult occupies 2½-3 months. The adult is usually black with dark reddish markings on the thorax and elytra. It is 6-7 mm long.

Control

Chemical mesures are not usually employed but Wyniger (1962) recommends application of dieldrin at about 0.5 percent. The treatments generally adopted are painting with tar the wounds made by the insects and earthing up the bases of the trunks.

Diocalandra frumenti Fabricius

Economic aspect

D. frumenti does the same type of damage as *D. taitensis*, and there is similar diversity of opinion as to whether its attack is primary or secondary. It breeds on *Areca*, *Elaeis*, *Nypa* and *Borassus* as well as coconut, and has been recorded as attacking sorghum.

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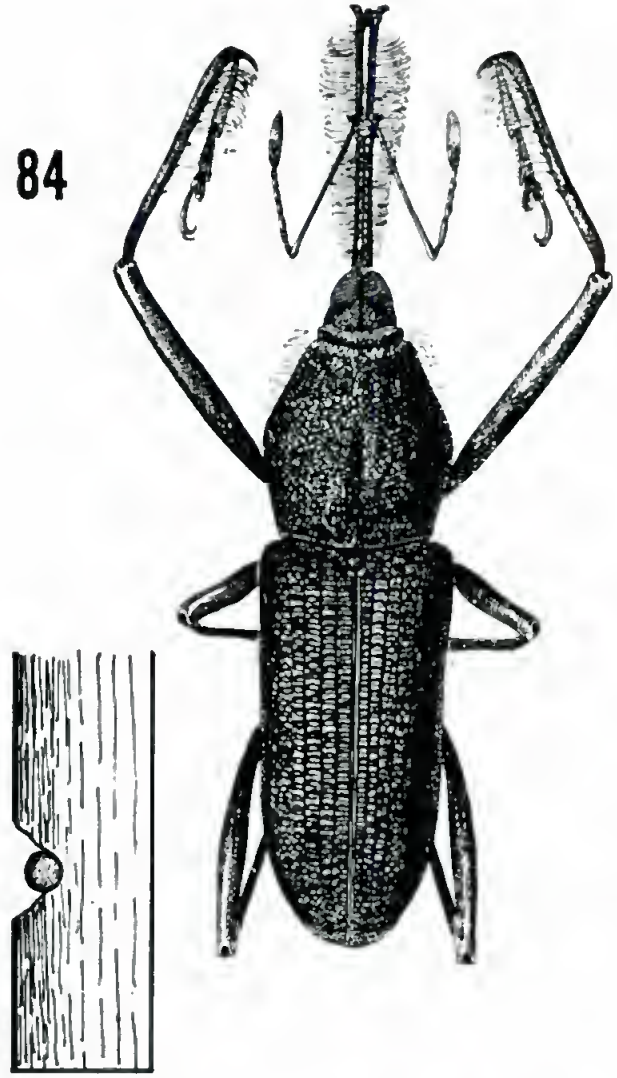
[14] Records of it from India, Ceylon, the Malay Peninsula and Indonesia are now known to refer to *D. frumenti* (also called *D. stigmaticollis* Gyllenhal)..



FIGURES 84-87. - *Rhinostomus* species. Adult beetle of *R. afzelii* Fåhraeus (84); egg of *R. barbirostris* Fabricius laid in the coconut palm trunk (85, cross-section; 86 front view); and larva (87). According to P. Lepesme, 1947, in part redrawn.
(*Courtesy P. Lechevalier, Paris, France*)

Geographic distribution

Zanzibar, Seychelles, India, Ceylon, the Malay Peninsula, Thailand, Indonesia, New Guinea, Solomons, Guam, Carolines, Gilbert and Ellis Islands.

Description/Biology

The habits of *D. frumenti* are almost identical with those of *D. taitensis.* The adults are often found at the base of a nut which is about to fall, and also in the accumulation of fallen male flowers at the base of a leaf (Corbett, 1932).

This beetle is not so dark in color as *D. taitensis* and has, on each elytron, four spots, two blackish brown and two yellowish brown.

Control

Spraying with dieldrin at about 0.5 percent is recommended. The application of tar to the base of the trunk is also useful. Efforts should be made to prevent slashing of the trunks with knives and to ensure that the adventitious roots are covered by earthing up.

The following natural enemies have been reported:

The parasite *Spathius apicalis* Westwood (*Hym., Braconidae*) which attacks the larvae and destroys up to 40 percent of them; the predatory beetle *Plaesius javanus* Erichson (*Col., Histeridae*), and the predatory fly *Chrysophilus ferruginosus* Wiedemann (*Dipt., Rhagionidae*).

Homalinotus coriaceus Gyllenhal

The adults of this species, which are about 20 mm long, attack the spathe of the coconut palm and the larvae tunnel in the petiole and midrib of the leaf and even in the trunk (Bondar, 1940a). It is found in Brazil and Argentina.

Suitable control measures are spraying with BHC at 0.06 percent in water and, for the petioles, with a mixture of tar in petrol at 1 kg in 8 liters (Fonseca, 1962).

SCOLYTIDAE

Xyleborus perforans Wollaston

The presence of this pest (or other related species) in coconut plantations is indicated by numerous small circular holes, all of the same size, in the

trunks of the trees. These are the ends of galleries made by the adult beetles, which lay eggs in them. The larvae excavate further galleries at right angles, and they and the adults feed on "ambrosia" fungus which grows on the walls. The duration of the life cycle is 2-3 weeks. The exact relation between this small beetle (only 2 mm long) and the host plant is still inadequately understood. In the Seychelles and Jamaica it is recorded as being harmful only to trees which are already unhealthy, while in Fiji it is considered to be a primary pest (Paine, 1934). *X. perforans* is very widely distributed, almost throughout the tropics and subtropics. It has a wide range of host plants, including *Elaeis*, *Lodoicea*, sugarcane and rubber. For control, DDT, dieldrin, endrin or thiodan, as a wettable powder or emulsifiable solution, are recommended (Wyniger, 1962).

DYNASTIDAE

Oryctes rhinoceros Linnaeus

Economic aspect

This is the notorious rhinoceros beetle, certainly one of the most serious pests of the coconut palm. The damage is done solely by the adults, which bite through the tightly packed unopened leaves in the central bud, with the result that when the leaves open they are seen to have great triangular gashes in them, as if the component leaflets had been cut with scissors. The midribs of the leaves are often severely injured, and the spathes and inflorescences less often so (Figs. 89 to 91). Much additional damage, and often the death of the trees, result from the attraction of the weevil *Rhynchophorus* to the wounds inflicted by *Oryctes*. This insect is best known as a pest of mature palms, but palms of all ages are attacked and, in 1957, one third of the seedling palms in the Chagos Islands were destroyed by it (Orian, 1959). It attacks numerous other plants, mainly but not only palms: *Areca*, *Arenga*, *Borassus*, *Corypha*, *Elaeis*, *Livistona*, *Metroxylon*, *Nypa*, *Oncosperma* and *Phoenix*, and also *Pandanus*, pineapple, *Colocasia*, banana and sugarcane.

Geographic distribution

O. rhinoceros is found throughout Southeast Asia and also in the Philippines and southern China. It reached Mauritius in or shortly before 1962, but it does not yet occur in Africa.[15] In the Pacific, it was discovered in

[15] All reports of it from Africa have proved erroneous.

Samoa in 1909; in Niuataputapu (Keppel Island) in 1924 and eradicated there in 1931; in Wallis in 1931; in New Britain and the Palau Islands in 1942; in Tonga in 1951; in Fiji and New Guinea in 1953; and in the Tokelau Islands in 1963 (Fig. 88). The date of discovery is likely to be a year or two later than the date of arrival of the insect.

It seems to have arrived in Samoa with rubber seedlings from Ceylon before the institution of phytosanitary legislation. The larvae are known to be capable of surviving in floating logs transported by ocean currents. Wartime shipping aided its spread, and the great number of palms felled or broken in the course of military operations provided it with unprecedented opportunities for breeding.

Description/Biology

The eggs are laid in moist, decomposing vegetable matter. Cow dung is said to be a usual breeding medium in India and Ceylon. The egg is whitish brown, tough, and 3-4 mm long. The incubation period is 7-18 days, the mean being 12 days. The larva (Figs. 95 and 96) develops entirely in the rotting vegetation. It is 7.5 mm long on hatching and attains a length of 60-105 mm when fully grown. Its color is whitish, but the head is brown and the hind part of the abdomen is grayish blue owing to the color of the rectal contents showing vaguely through the outer tissues; the body is permanently curved. The larval period is extremely variable but the mean is 130 days in India (Nirula *et al.*, 1955c) and in Ceylon (Goonewardene, 1958), and the range is 80 to more than 130 in the Palau Islands (Gressitt, 1953); the minimum duration is 72 days. There is a period of 6 days between cessation of feeding and pupation, and the pupal stage lasts 14-29 days, averaging 20 days. Pupation usually takes place in the soil but may occur in rotting vegetation or even in a rotting coconut trunk which is still standing (Gressitt, 1953). The pupa lies in a cocoon or cell composed of soil and agglomerated debris or, when inside the trunk, of fibers; it is 40-52 mm long, yellow-brown and, if male, with the " rhinoceros " horn already conspicuous on the head.

The adults (Figs. 92 to 94) do not leave the pupal cell until 11-20 days after emergence from the pupa. The total cycle, from egg to emergence from the cocoon, lasts from 4 to 9 months, the mean period being about 6 months; thus, at least two generations are possible per year. The beetles live mainly in the breeding sites, spending relatively short periods in the crowns of the palms, for feeding. The duration of adult life is at least 3 months. As the specific name indicates, they bear on the head a median horn curved backward; the horn is much longer in the male than in the female. The prothorax has a large concave area situated anterodorsally. The beetle is black,

with a fine reddish pubescence on the ventral surface, and is 30-57 mm long. It is believed to fly only short distances; the longest recorded flight is about 700 meters, in Samoa (O'Connor, 1953). The maximum number of eggs recorded from a single captive female is 70 (in Java) and 140 (in southern India) (Kalshoven, 1950-51).

Control

As a fundamental prophylactic measure, all possible breeding places must be eliminated and every effort made to ensure that no new ones are created. Dead plant material which is rotting or which will rot if accumulated must be burned or buried, and fallen trunks must be split and burned.

Where plant material is used for making compost, chemical treatment of it is necessary to prevent the breeding of the beetle in it. Work in India in 1951 showed that application of 0.001 percent gamma-BHC was effective, and subsequently this became normal practice there (Nirula *et al.*, 1951b); recently 0.01 percent aldrin has been used successfully for the treatment of compost (Kurian and Pillai, 1964). In Fiji, good results have been obtained by applying gamma-BHC at 0.075 percent or a mixture of 9 parts of damp sawdust and 1 part of gamma-BHC at 6.5, 10 or 13 percent active ingredient (O'Connor, 1954b). Diazinon at 32 percent, though more costly, was later advocated because of its more rapid action and longer persistence (O'Connor, 1957).

The first attempt to control the rhinoceros beetle by biological means was made in 1913 in Samoa by Friedrichs, who introduced a culture of the green muscardine fungus *Metarrhizium anisopliae* (Fig. 97) and spread cultures of it in compost heaps used at that time to serve as traps for *Oryctes*. The attempt was not successful, and no greater success attended similar attempts made later in Ceylon, Mauritius and the Malay Peninsula. However, further attempts on the same lines but in the light of modern experience have been made recently and are still in progress; results are awaited with much interest. The effect of the fungus is to make the larva crawl out of the breeding medium, with the result that it dies and dries, and is mummified by the development within it of a white fungous mass which soon forms a crust outside the body and gives rise to green conidia from which the spores are distributed by the wind. The pupa and adult are also liable to be attacked by the fungus (Nirula *et al.*, 1955a). Conditions favorable for the development of the fungus include fairly high relative humidity (over 70 percent), a temperature of about 27°C and overcast skies. These conditions occur in India during the season of the southwest monsoon, and it is hoped that it will prove possible during that season to infect *Oryctes* with the fungus on a scale sufficient to result in an epidemic (Nirula *et al.*, 1955c).

Bacteria from the United States (Cumber, 1957) and other micro-organisms from Sumatra, Ceylon, Pemba and Africa (Surany, 1960) have been used to infect larvae and have sometimes caused a high degree of mortality. Intensive investigations on these lines are continuing in Western Samoa.

Certain insect parasites of *Oryctes* larvae have been used in attempts at biological control. These are wasps of the family *Scoliidae* indigenous to eastern Africa and Madagascar. These insects are strong fliers, and they feed on the nectar of numerous flowers, including those of *Citrus*, *Urena*, *Cordia* and *Poinsettia* (Simmonds, H.W., 1941). The female wasp burrows deep into rotting vegetation to find *Oryctes* larvae and to lay eggs on them. Among the scoliid wasps utilized in the control of *Oryctes*, the following are the most important:

Scolia oryctophaga Coquillet, introduced from Madagascar to Mauritius in 1917, to Western Samoa in 1939, and to New Britain and Fiji in 1954, and from Mauritius to Indonesia in 1934 and 1936. The adult insect is reddish brown, has yellow antennae and measures up to 40 mm in length.

Scolia ruficornis Fabricius, introduced from Madagascar or Zanzibar to Mauritius and Western Samoa in 1945, to the Chagos Islands, New Britain and the Palaus in 1949, and to Fiji in 1958. This species is blue-black, and smaller than *oryctophaga*.

Elis romandi Saussure, introduced from Madagascar to Western Samoa in 1939. This wasp is blackish brown.

In general, the results of these introductions of scoliid wasps have been disappointing, and in some cases the species have failed to become established. It is yet too early, however, to attempt a final assessment of them, since their increase is very slow and investigations of them are continuing as part of the much wider campaign against *Oryctes* currently being conducted.

These wasps are very susceptible to most insecticides; consequently, chemical control must not be attempted in areas where they have been released and have not yet been evaluated.

Numerous species of predatory beetles have also been introduced into various countries in the hope that they will contribute to the control of *Oryctes*. These include species of the genera *Catascopus*, *Neochryopus* and *Mecopus* (*Carabidae*), *Pyrophorus*, *Lanelater* and *Alaus* (*Elateridae*), and *Hololeptis* (*Histeridae*). In addition, a species of predatory bug of the genus *Platymeris* (*Reduviidae*) has been imported from Zanzibar into India, Fiji and New Caledonia. This large bug, black with prominent orange-red patches, inserts its proboscis between the head and the thorax of *Oryctes* beetles and kills them; each individual *Platymeris* can destroy one beetle per day, and the duration of adult life is up to 4 months. Since the egg stage lasts about a month, this species can easily be transported by air (Vanderplank, 1958a).

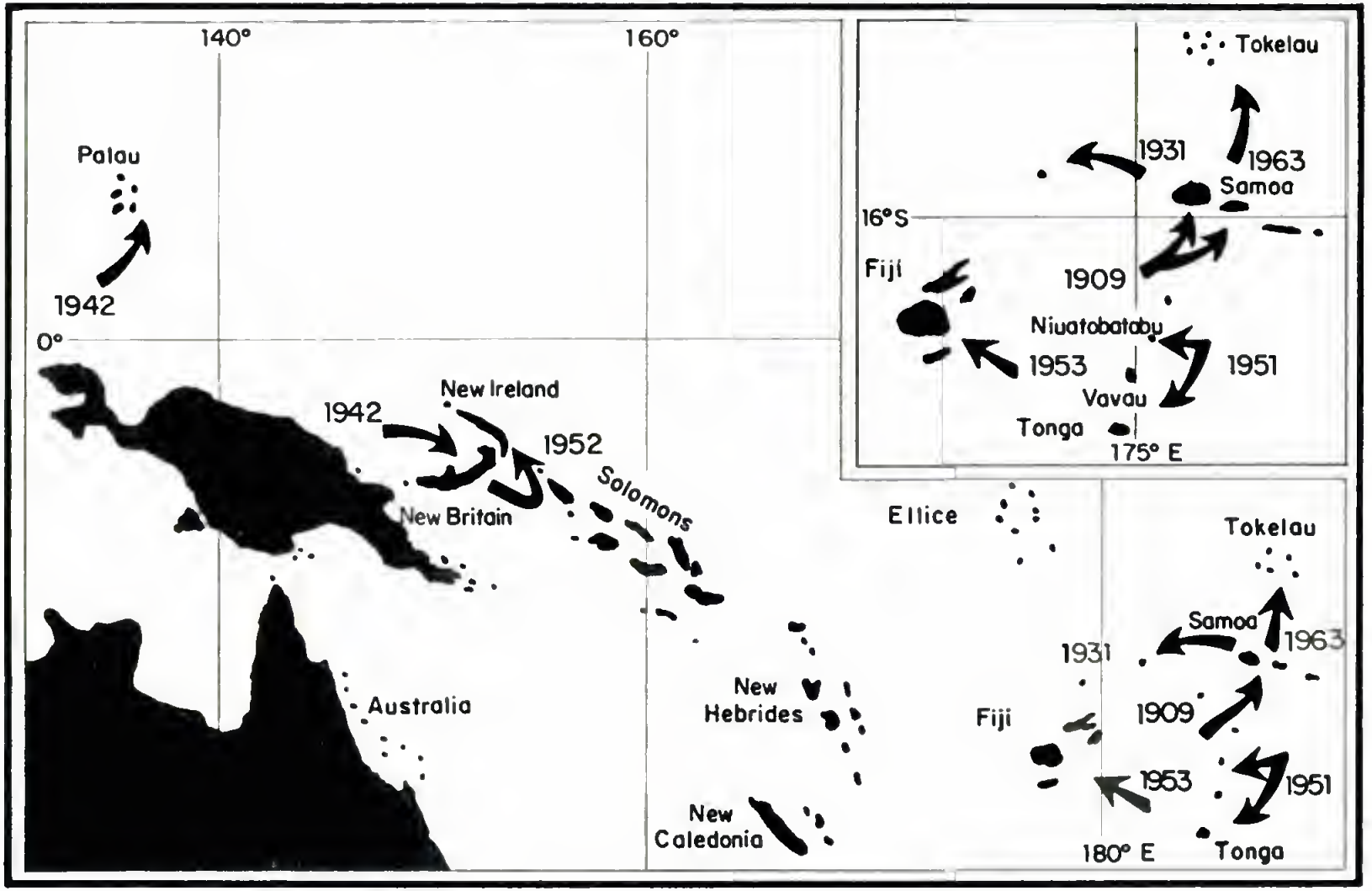


FIGURE 88. - *Oryctes rhinoceros* Linnaeus. Spread in the Pacific area with years when first noted.

FIGURE 89. - *Oryctes rhinoceros* Linnaeus. Typical damage caused by adult beetles.

FIGURE 90. - Breeding site in a plantation of Western Samoa which has been almost completely destroyed by the pest. (*Photos V.L. Delucchi*)

FIGURE 91. - *Oryctes rhinoceros* Linnaeus. Adult penetrating into the crown center of a young coconut palm. Western Samoa.
(*Photo K.J. Marschall*)

FIGURES 92-94. - *Oryctes rhinoceros* Linnaeus. Male (92, above); female (93, center); and mating (94, below).

►

FIGURES 95-97. - *Oryctes rhinoceros* Linnaeus. Larvae of first, second and third (last) instar (95, above); adult larvae removed from a rotted stump of coconut palm (96, center); and adult larvae infected by the fungus *Metarrhizium anisopliae* Metschnikoff (97, below).

(*Figures 92-97 courtesy Institut national de la recherche agronomique, Station de recherches de lutte biologique et de biocœnotique, La Minière, Versailles, France*)

Oryctes centaurus Sternberg

This large species, 50-60 mm long, inhabits New Guinea and the New Hebrides. It is more frequent in swampy areas where the sago palm (*Metroxylon rumphius*) grows than in coconut plantations. The eggs are laid in the inflorescences of *Metroxylon* after flowering is finished; since this palm dies and decays after flowering, it provides a large quantity of breeding material for *Oryctes* at this stage (Hoyt, 1963b).

Oryctes gnu Mohner (also called *O. trituberculatus* Lansb.)

This is another close relative of *Oryctes rhinoceros*. It is even larger, being 60 mm long, and has three small teeth at the posterior margin of the thorax, whereas *O. rhinoceros* has only two. It occurs in Indonesia, the Malay Peninsula, Borneo and the Philippines. The life cycle and habits of the two species are very similar, and therefore the same control measures are required.

African species of Oryctes

There are several species of *Oryctes* in tropical Africa. *O. monoceros* Olivier (Fig. 98) is found in eastern Africa, Zanzibar, Madagascar and the Seychelles. Its eggs hatch in 7-9 days, the larval stage lasts 100-200 days and the pupal stage 14-21 days; the complete cycle from egg to adult occupies about 6 months. It breeds in much the same situations as *O. rhinoceros*, and the same control measures are required, especially a high standard of estate sanitation and supervision (Dry, 1922). In addition to coconut, it attacks *Hyphaene* and *Borassus* palms; in the Seychelles, coconut trunks previously damaged by *Melittomma* provide breeding places for it, and palms may even be killed by it. In the small coralline Farquhar Islands, northeast of Madagascar, *O. monoceros* has been exterminated (Piggott, 1961), as has *O. rhinoceros* in Niuataputapu in the Tonga group. It is worth noting that in Nigeria the deliberate destruction of oil palms by means of a herbicide, poured into holes in the trunks, unintentionally provided suitable breeding places for *O. monoceros* (Shelldrick, 1963).

Oryctes boas Fabricius (Figs. 99 and 100) of tropical Africa and Madagascar, and *O. sjöstedti* Kolbe and *O. gigas* Laporte de Castelneau of West Africa, are injurious to coconut and to oil palm, *Raphia* and *Hyphaene*. Investigations by Hoyt (1963a) have shown that the practice of trapping by means of split logs, as in Samoa, is not satisfactory in Africa.

Strategus anachoreta Burmeister

S. quadrifoveatus Palisot de Beauvois

S. aloeus Linnaeus

These three species attack coconut (and other) palms in, respectively: Cuba and Trinidad; Haiti, Puerto Rico and the Virgin Islands; and the Guianas, Venezuela and Brazil. They differ from the Old World species mentioned above in having no horn on the head. The adults (Figs. 101 and 102) burrow into the ground close to young palms and penetrate into the trunks below ground level, usually killing the palms, especially those about 2 years old. Good estate sanitation (burning accumulations of coconut husks, old palm trunks and other dead vegetable matter) is again essential as a control measure, since the larvae live in such situations. Development, from egg to adult, occupies 14 months in *S. quadrifoveatus* (Plank, 1948).

Other dynastid beetles

There are several other genera of dynastid beetles which contain species that occasionally attack coconut palm without, in general, doing much damage. These genera are *Scapanes* and *Trichogomphus* (in the Solomons and New Guinea), *Xylotrupes* (from the Malay Peninsula, Cambodia, Laos and Viet-Nam, through Indonesia to the Solomons and New Hebrides), *Papuana* (in the Moluccas, New Guinea, the Solomons and the New Hebrides), and *Chalcosoma* (from Burma to the Moluccas). The coconut palm cannot be regarded as the principal food plant of any of these species; when they do attack it, it is again the adults that do so, the larvae (so far as they are known) living in dead, decaying vegetation. The principle of efficient plantation sanitation is therefore important in the control of dynastid beetles in general, and also for the control of *Rhynchophorus*, since the damage done to various parts of the palms by the dynastids creates favorable breeding sites for the weevil.

Lucanidae

Several species of the genus *Eurytrachelus* are pests of coconut palms in New Guinea and the Solomons; the adults bore into the trunks near the leaf axils, and the larvae live in humus and rotting wood.

MELOLONTHIDAE

Leucopholis coneophora Burmeister

Economic aspect

This species was first recorded as a coconut pest in 1952 in southern India. The larvae damage the roots and reduce the yield of the palms, but severe damage is very localized and occurs principally on sandy soils and in association with areas in which various root crops are grown. Other plants attacked include cassava, sweet potato, yam and *Colocasia*.

Geographic distribution

Kerala in southern India.

Description/Biology

The eggs are laid, mainly in light soils, at a depth of 8-16 cm. The larvae come to the surface when the soil is moist and cool; heavy rain and a high water table are unfavorable to them. They attain a length of 60 mm. The beetles, which are chestnut brown and 30 mm long, appear suddenly in large numbers two weeks after the onset of the southwest monsoon (Nirula *et al.*, 1952).

Control

Dusting the soil with about 66 kg of 10 percent BHC or 33 kg of 5 percent chlordane per hectare and then plowing to a depth of 15 cm is recommended for destruction of the early stages (Menon and Pandelai, 1958). Aldrin, dieldrin, heptachlor and malathion are also effective and, for protecting the germinating nuts in nursery beds, covering the ground with a layer of sand is useful, as for avoidance of damage by termites.

Apogonia cribricollis Burmeister

This is mainly a pest of oil palms and cocoa, in the Malay Peninsula, but it attacks a very wide range of plants (Kalshoven, 1950-51), including the coconut palm occasionally (Lever, 1964a). The adults, which are dark brown and 8-10 mm long, are found on the leaves, and the larvae are in the soil, where they are general root feeders.

RUTELIDAE

Several species of this family, principally in the genus *Adoretus*, have occasionally been reported in Southeast Asia as being injurious to coconut

FIGURES 98-100. - *Oryctes* species. Male (left) and female (right) of *O. monoceros* Olivier (98, above); male (99, center); and female (100, below) of *O. boas* Fabricius.

(*Courtesy Institut national de la recherche agronomique, Station de recherches de lutte biologique et de biocanotique, La Minière, Versailles, France*)

palms, and to a wide range of other cultivated plants. It appears, however, that the damage done by them is almost always slight.

Hymenoptera

Formicidae

The role of ants in coconut palms varies greatly. Some species are beneficial because they prey on harmful insects, while others are noxious either because they destroy useful insects (including ants) or because they foster injurious scale insects. In rare instances, ants damage the tissues of the palm directly. Many species of ants occur in the palms but the part played by them in the balance of the palm fauna is, in most cases, very inadequately known.

Oecophylla smaragdina Fabricius

(*O. longinoda* Latreille)

Economic aspect

These aggressive ants, which build their nests in trees, are well known over a large region of the tropics. They are greatly disliked, because of their fierce bite, by the laborers working on plantations, and they encourage scale insects and aphids on whose honeydew they feed. At the same time they are useful, since they prey on various other harmful insects and prevent or limit the breeding of them in the palms. They live in many different cultivated trees, including, in addition to palms, citrus, coffee, cocoa, clove, *Ficus* and *Casuarina*, as well as numerous wild trees in the jungle. They are reputed not to attack pests of the coconut palm in the Malay Peninsula (Corbett, 1932), whereas in the Solomon Islands and Zanzibar they are very important as predators of the coreid bugs *Amblypelta* and *Pseudotheraptus*, respectively. Their precise economic status in each locality must therefore be assessed independently of the palms, in relation to the fauna as a whole, including other ant species.

Geographic distribution

In association with coconut palms, *O. smaragdina* occurs in Southeast Asia, New Guinea, the Bismarck Archipelago, the Solomon Islands and Queensland.[16] *O. longinoda* is present in Africa, from the west through the Congo to eastern Africa and Zanzibar, and up to an altitude of 1,200 meters.

[16] A record of India as the only Asian country in which this ant is found (Anon., 1962) is erroneous.

FIGURES 101-103. - *Strataegus aloeus* Linnaeus. Male (101, above); female (102, center); and larva infected by the fungus (*Cordyceps* (103, below).

(*Courtesy Institut national de la recherche agronomique, Station der ecberches de lutte biologique et de biocœnotique, La Minière, Versailles, France*)

Description/Biology

The nests are constructed in trees, of silk, in which living leaves are incorporated. Only the larvae can produce silk; ants of the worker caste hold larvae in their mandibles and use them as living silk-producing shuttles to spin together the edges of leaves held in place by other workers (Ridley, 1890). The leaves chosen have scale insects (e.g., *Aspidiotus destructor*) or aphids (e.g., *Astegopteryx nipae*) on them, which are fostered in the nest by the ants in order to serve as sources of honeydew for food. Bees, termites and other ants are also devoured.

The rate of development is highly susceptible to temperature level. The incubation period is 12½, 6½ and 5½ days, at 24, 28 and 30°C, respectively; the corresponding larval and pupal periods at the same temperatures are 25, 14 and 9 days, and 12, 5 and 3 days, and the total period from egg to adult is 49½, 25½ and 17½ days (Corbett *et al.*, 1937). The workers live for 68-140 days, and a colony may exist as long as 5 years. The female lays up to 930 eggs in a day. The nests are usually built in exposed positions, where they get ample sunshine (Vanderplank, 1960a).

Control

Where control of *Oecophylla* is considered desirable, spraying dieldrin at 0.4 percent around the base of the trunks and on the leaves can be expected to destroy it and also to keep the trees free from other species of ants for eight weeks; this treatment was applied in Zanzibar, where other tests, with gamma-BHC at 0.4 percent and 22.5 kg per hectare, gave similar results (Way, 1953a). DDT, dieldrin, malathion, diazinon and parathion are also recommended (Wyniger, 1962).

Oecophylla is a relatively slow-moving ant and is prone to attack by several species of smaller, more active ants, among which *Anoplolepis longipes* Jerdon is dominant in many of the countries concerned, including both Zanzibar in the west and the Solomon Islands in the east. The destruction of *Oecophylla* by these other ants permits the coreid bugs, *Pseudotheraptus* and *Amblypelta*, which are well controlled by *Oecophylla* in the absence of the others, to multiply to injurious proportions; the relations between these various ants have been studied by Way (1951, 1953a), Brown (1956, 1959) and Greenslade (1964).

Azteca cartifex Forel

This brownish black ant occurs in coconut palms in the Guianas and Trinidad, where it builds carton nests consisting of earth and wood fibers in the crowns of the trees. Its most injurious habit is that it fosters the scale

insect *Aspidiotus destructor*. Application of a 30-cm band of 15-20 percent dieldrin round the trunk about a meter above ground level, using about 0.3 liter per tree is said to prevent the ants from having access to the tree for one to two months.

Technomyrmex detorquens Walker (formerly often recorded as *T. albipes* Smith)

In the Seychelles, this ant fosters several scale insects, notably *Pinnaspis buxi*, on coconut palms, especially in dry weather, and in so doing prevents the introduced coccinellid beetles of the genera *Chilocorus* and *Exochomus* from destroying them (Vesey-Fitzgerald, 1941a, 1953). Treatment with chlordane, aldrin or dieldrin can be expected to be effective as a control measure.

Dorylus orientalis Westwood

This is the only ant recorded as doing direct damage to coconut palms. It excavates galleries in the leaf stalks and nuts in the nurseries in India and Ceylon. In this case also, it is suggested that control could be achieved by the application of chlordane, aldrin or dieldrin.

Diptera

Scholastidae

Species of Scholastes

Several species of flies of this genus have been recorded as damaging the meat of the ripe nuts, while it is still *in situ* (i.e., before it is converted into copra), in the Malay Peninsula, Melanesia and Polynesia including Hawaii. The flies, whose wings are heavily mottled with black, lay their eggs in the meat of the nuts, which the resulting maggots soon transform to an evil-smelling mass.

These flies are not pests unless the ripe nuts are left on the ground too long, before being collected for the extraction of the meat for the preparation of copra. Prompt and efficient gathering and splitting of the nuts is the remedy.

MITES

Tenuipalpidae (Phytoptipalpidae)

Raoiella indica Hirst

Economic aspect

This small mite, which may occur in great numbers and sucks sap from the leaves, has only recently been recognized as a coconut pest. It is harmful mainly to palms less than 5 years old, but older palms are susceptible if growing in soil that is ill-drained or lacking in nutrients. *Dictyosperma* and *Phoenix* are also attacked.

Geographic distribution

India, United Arab Republic, Mauritius.

Description/Biology

The eggs are red and are laid on the lower surface of the leaflets. They hatch in 5 days. The subsequent developmental stages occupy 17 days, so that the cycle from egg to adult lasts about 22 days; development is, however, much slower in cool weather (Moutia, 1958).

Control

Destruction of about 80 percent of the mites (but not the eggs) has been achieved by sprays of Trithion, Rogor 40 or parathion, at 0.3 percent (Shashi Kanta *et al.*, 1963).

A predacious mite, *Typhlodromus caudatus* (Berlese) feeds on the eggs of *Raoiella*; the use of persistent chemicals which would kill this beneficial mite must therefore be avoided in procedures designed to control *Raoiella*.

Pyemotidae

Pyemotes ventricosus Newport (recorded until recently as *Pediculoides ventricosus*)

This mite has a unique status in the fauna of the coconut palm, in that while it can destroy almost 100 percent of the larvae and pupae but not adults of certain pests in dry weather, in so doing it may cause extremely harmful one-stage outbreaks. Its role in the initiation of outbreaks of *Promecotheca* in Fiji has already been outlined, and this is the only continuous

investigation yet conducted of its effect as a component of the ecology of a pest over a period. It has also been recorded attacking *Levuana* in Fiji and *Nephantis* in India. It is nowadays almost cosmopolitan in its distribution; being commonly associated with insect pests of stored products, it is readily transported in ships. The male mite is 0.15 mm long, the female 0.22 mm, but when the female is gravid, part of its abdomen swells enormously and becomes a relatively huge sphere more than 500 times the volume of the whole body before fertilization. The female is viviparous and its progeny are adult at birth; about 90 offspring are produced by each female and almost all are themselves female. In view of this and the fact that the life cycle is very brief — only 6-8 days — the rate of multiplication when food is plentiful is phenomenal.

TETRANYCHIDAE

***Tetranychus fijiensis* Hirst**[17]

In Fiji, this mite is found on both seedling and mature coconut palms (Simmonds, H.W., 1938). It lives in great numbers under a web on the underside of the leaflets and, as a result of its mass feeding, the leaves are discolored. The adult mite is red, like its allies which are commonly known as "red spiders." It is devoured in Fiji by a coccinellid beetle of the genus *Scymnus*. For control purposes, spraying with malathion, Rogor or parathion at about 0.4, 0.8, and 0.8 percent, respectively, is effective.

NEMATODES

TYLENCHIDAE

***Rhadinaphelenchus cocophilus* Cobb** (formerly placed in the genus *Aphelenchoides*)

Economic aspect/Description

In tropical America, this minute eelworm invades the woody tissues and causes the fatal red ring disease, especially in young palms. It is transmitted from one palm to another by the palm weevil, *Rhynchophorus palmarum*, and is worst in neglected areas where there are many dead and dying trees in which the weevil is breeding. Extensive new planting after wholesale

[17] A record of the occurrence of this mite in India (Anon., 1962) is erroneous.

felling of palms, practiced since 1925, has led to the increase of the nematode over a wide area in trees of the same age (Fenwick, 1959). Infected trees invariably die.

The symptoms of infection appear in the trunk in the form of a red band 2.5-4 cm wide and situated 2.5-5 cm from the outer surface, and starting about 1.2 meters above ground level. Red streaks appear in the leaf petioles also, and the roots become dry, flaky and discolored. There is always a yellowing and browning of the older leaves, starting at the tips, followed by shedding of leaves and nuts and secondary bacterial rot. Disintegration of the tissues is caused by a thermostable toxin associated with the nematodes but not directly caused by them (Goberdhan, 1963). In Trinidad, only 9.8 percent of the weevils are infected with living worms; the main sources of infection are fragments of infected tissue and, to a lesser extent, the excrement of *Rhynchophorus* in the larval galleries (Hagley, 1963, 1965a). It has been estimated that an infected trunk contains some 66,000 nematodes per meter of its length. The worm is only 1 mm long. *Roystonea*, *Elaeis* and *Phoenix* are also attacked.

Geographic distribution

Honduras, Panama, Brazil, Venezuela, Colombia, Trinidad, Tobago, Grenada, Saint Vincent; and probably elsewhere in Central America.

Control

The best results have been obtained by the application of endrin at 19.5 percent, with coumarone; this reduced the incidence of infection by one third. Dieldrin and parathion were less effective. In Venezuela, DD is applied to the soil and implements are treated to ensure disinfection (Medina Duno, 1959). Strict estate hygiene, particularly splitting and burning infected trunks, is essential to check the breeding of the vector *Rhynchophorus*. A promising method of control is the injection of Nemafos (EN 18133) at 0.1 percent into the roots; this treatment, applied daily for six consecutive days, gives protection to the tissues for 1.5 meters from the point of injection (Goberdhan, 1964).

CRUSTACEANS

PAGURIDAE

Birgus latro Linnaeus

Economic aspect

This is the so-called coconut or robber crab. The notion that it climbs coconut palms to obtain the nuts is largely due to an account by Darwin

based on information received indirectly from the Cocos Islands in 1836. It seems, however, that no factual evidence exists of this behavior, and that the crab attacks only nuts that have fallen to the ground and are already cracked. In captivity, it does not open nuts and does not even appear to be particularly attracted to them for food. Its status as a pest is probably not high, therefore, and it is included here mainly because of its notoriety. Most of the damage attributed to it is caused, in reality, by rats. The published descriptions of its habits mostly attribute to it an ability to tear away the strong, fibrous husk of the nut in order to reach the meat via the germination "eye," but Reyne (1939) and Gibson-Hill (1948), in Indonesia and Christmas Island (in the Indian Ocean), respectively, both concluded, after careful investigations, that the crab neither exposes the nuts in this way nor climbs tall trees to get them; nevertheless, both claims continue to be made, the latest being that of Eden (1963). It is to be hoped that the critical review of this problem by both Child (1964) and Tinker (1965) will dispel belief in this myth. The seeds of trees of the following genera are said to be eaten also: *Barringtonia*, *Calophyllum*, *Pandanus* and *Terminalia*.

Geographic distribution

The distribution of *B. latro* extends from the coast of eastern Africa to the Andamans and Nicobars, and also from Celebes, the Philippines and China (Taiwan) eastward via the north coast of New Guinea to Melanesia and Polynesia as far as the Gambier Islands in the Tuamotu Archipelago; in the region between these two great zones, that is, in western Indonesia and the Malay Peninsula, the crab is absent (Reyne, 1939).

Description/Biology

The eggs and young larvae (which hatch into the zoea stage) are marine, the later stages terrestrial. The first nine months of the terrestrial period are spent in the shell of a univalve mollusk (Harms, 1932). The adults are nocturnal in habit; by day they rest under boulders or roots of trees, where they feed on nuts, fruit and carrion, including corpses of their own species.

The color of the crab varies, not only according to age but also between individuals at the same stage of development. It is normally earthy yellow, with crimson and purple blotches. The adult weighs 2-2½ kg, and its length, including the pincers, may be as much as 45 cm. In inhabited islands it is scarce and seems to be decreasing in numbers, being coveted and captured for human consumption.

2. VERTEBRATE PESTS

BIRDS

Damage is caused in the Solomon Islands by a white cockatoo, *Cacatua ducorpsii*. This bird rips out large strips of the husk of young nuts, which consequently cease growing and fall off prematurely. The percentage of nuts thus caused to fall in a four-month period varied, among trees studied, from 2 to 40, and the maximum number that fell from one tree was 14 (Brown, 1957). This latter figure is seldom reached, and the damage in general is not serious. In New Guinea, another, congeneric species, *C. galerita triton*, causes the same damage (Simon Thomas, 1963).

In the Islands of São Tomé and Principe, off West Africa, the control of rats by kites depends on the degree of scarcity of parrots, which are very aggressive. In São Tomé, the parrot *Psittacus erithacus* is rare and the kite *Milvus migrans* can hunt the rats freely and thus limits the damage done by them to coconuts; in Principe, on the other hand, the kite is mobbed by the parrot and driven off (Simmonds, F.J., 1960).

In Asia, crows pierce the immature nuts, especially in periods of drought, to drink the contained liquid. In Africa, weaver birds (of the family *Ploceidae*) tear the leaflets of the coconut palm to make their nests (Fig. 104).

In general, damage by birds is only sporadic and is probably outweighed by the benefit which results from their eating harmful insects (Child, 1964).

The Indian mynah, *Acridotheres tristis*, was introduced into Mauritius in 1763, primarily for the control of the locust *Nomadacris septemfasciata*, which, with other insects, was eaten by it. It was introduced into Fiji, in the hope that it would attack *Levuana iridescens*, but its effect was negligible and there are few people today, even on the plantations, who regard it as an asset.

In addition to the direct damage done in some countries by birds, there is also the indirect harm done by them in transporting minute insects in their plumage; it has recently been shown (Cochereau, 1965) that the very harmful scale insect *Aspidiotus destructor* is transported in this way in the New Hebrides.

FIGURE 104. - Damage caused by weaver birds (*Ploceidae*) which tear the leaflets of the coconut palm to make their nests.

MAMMALS

MURIDAE

Rattus rattus rattus

R. r. alexandrinus

R. r. frugivorus

Economic aspect

Rats can breed every two months and produce litters of 8 to 12. They therefore multiply rapidly and cause grave damage to the numerous crops, including coconuts, which they attack. They invade the crowns of coconut palms, including very tall, old trees, primarily to reach the maturing nuts, which they gnaw at the base in order to extract the liquid. The holes thus formed are rather large and usually ragged (Fig. 105) (Taylor, 1930; Paine, 1934; Laird, 1963). Rats also damage the spathes and inflorescences, and eat the copra before it has been stored. It has been noticed that damage by rats is less severe where there are streams, swamps or other sources of moisture (such as sweet potatoes or cassava) nearby. In the Cocos Islands, it is now recognized that damage to coconuts which was attributed in the past to the crab *Birgus latro* was, in fact, done by rats.

The damage by rats is not easy to assess, and there is wide divergence in the available data. Two observers on the same island in Fiji but in different years (Taylor, 1930; Paine, 1934) estimated the loss of crop due to them as 6.8 percent and 28.7 percent, respectively. On the same island but much later, Simmonds, H.W. (1951) assessed the premature nutfall due to rats as 50 percent of the total premature nutfall. In the Philippines, the crop loss, calculated for a period of five years and for trees 45 years old, was 14 percent (Montenegro, 1962), while in French Polynesia it was 50 to 100 percent (Lassalle-Sere, 1955). The damage is greater in Polynesia and Micronesia than in Melanesia. In each archipelago, injury is more severe on the small flat coral islands than on the lofty volcanic ones.

Geographic distribution

This species is tropicopolitan, and occurs almost wherever the coconut palm grows.

Control

The various poisoned baits usually employed for the control of rodents in general cannot be used effectively in coconut plantations because of the arboreal habits of the rats. They can live almost entirely in the crowns of the trees high above the ground, leaping from one to another or making use of overlapping leaves, and seldom descending. However, in the lower islands of the Society group, a bait of 1 part of Warfarin (a blood anticoagulant) and 19 parts (by weight) of desiccated coconut, the latter lightly roasted to prevent mold formation, gave good results. The bait was placed in metal containers fixed to the trunks of the palms, at a spacing of only 3-5 baiting points per hectare and a rate of about 5 kg per hectare. The supply of bait in the containers should be maintained for a period of 10-14 days on each occasion (Dumbleton, 1955). Zinc phosphide can be used instead of Warfarin, but in this case unpoisoned bait should be used for several nights before the poison is incorporated in it. In the mountainous volcanic islands of the Society group, aluminum bands 40 cm wide, which last for 10-12 years, are fixed round the trunks about 4 meters above the ground to prevent rats from ascending. Zinc bands are less durable because of the corrosive effect of salt spray on the metal; they can, however, be treated with antirust paints. Plastic materials can be used but are more expensive. In Tahiti, the yield of copra has increased from 7-8 kg to 10-11 kg per tree as a result of banding (Lasalle-Sere, 1955). In Jamaica, banding has been practiced since 1884.

Special treatment is necessary to protect germinating nuts in nurseries. It is suggested in India that, since rats do not burrow into sand, a trench 15 cm deep should be dug round the beds and filled with sand (Naidu, 1960).

FIGURES 105-106. - Holes in young coconuts made by rats (105, above) and in older nuts by squirrels (106, below). Photos van Heurn, *in* L.G.E. Kalshoven, 1950-51.
(*Courtesy N.V. Uitgeverij W. van Hoeve, The Hague*)

Rattus exulans exulans

R. e. micronesiensis

These two subspecies of *Rattus exulans* also damage the nuts in the crown of the tree, in at least some of the islands where they occur, but elsewhere they are said to be less harmful to coconuts than *Rattus rattus* because they spend more time on the ground. A full account of their biology has been given by Strecker *et al.* (1962). In the Tokelau Islands, according to Laird (1963), *R. exulans* is active in the crowns of the trees and makes characteristic holes 2-3 cm in diameter in the nuts. Besides causing loss of copra, the rat is also responsible, though indirectly, for the spread of filariasis, since the mosquito vector (*Aedes* [*Stegomyia*] *polynesiensis* Marks) breeds in the liquid contained in the holed nuts. In those islands of the Tokelaus where the rat is absent, breeding of the mosquitoes is limited to holes and niches in trees with, in consequence, a lower incidence of filariasis.

Geographic distribution

R. exulans occurs in Southeast Asia and also throughout the Pacific from the Marshall Islands to Easter Island. The subspecies *micronesiensis* is in the Caroline Islands.

Control

As for *Rattus rattus*, bands of aluminum are fixed to the trunks of the trees; it is necessary to ensure that the branches of other trees do not come into contact with the trunks above the bands and so provide bridges for the rats.

The lizard, *Varanus indicus*, has been introduced into various Micronesian islands, and has checked the rats to some extent. Other vertebrate enemies of rats include snakes, birds (owls, kites) and mammals (civets) (Dammerman, 1929).

Sciuridae

Squirrels cause similar damage to rats (Fig. 106).

Pteropidae

Pteropus species

These are the fruit bats or flying foxes. Several species of fruit bats occur in the coconut-growing lands of the tropics and some have been reported

to cause damage to the palms. Well-known species include *Pteropus edwardsii* in south India, *P. vampyrus* (not the vampire) and *P. edulis* throughout Malaysia, *P. scapulatus* in Melanesia and *P. tonganus* in Polynesia. These bats are about 30 cm long (i.e., head and body) and have a wing span of 1½ meters. They roost by day, hanging from the trees in great numbers together, and fly in the evening in search of food, often traveling considerable distances and in large numbers. When they feed in coconut palms, they eat the male flowers and gnaw holes in the immature nuts to extract the liquid. All the species mentioned cause the same type of damage, and they attack the fruits of a great variety of trees, including, besides coconut, kapok, papaya, mango, jackfruit, *Lansium* and *Spondias* (Dammerman, 1929). Attacked coconuts have either a ragged hole 5 cm in diameter bitten out or an aperture extending some 8-10 cm round the shell, partly concealed by frayed ends of the chewed fibers of the husk (Brown, 1957).

The damage done is, in general, not great, but it may be severe locally; at one plantation in the Solomons the percentage of nuts caused to fail to develop varied from 16 to 46 among the trees studied, but this amount or damage is exceptionally high. It is interesting to note that 50 years earlier no damage due to bats was seen in native coconut groves, and it was at that time assumed that they would not invade the estates that were then being planted (Froggatt, 1911). In Fiji, independent observers have reported that the damage done to female flowers and nuts there is almost negligible.

In the New Hebrides, it has been shown that bats are responsible for spreading the scale insect *Aspidiotus destructor*, which is transported in their fur as it is in the feathers of birds (Cochereau, 1965).

Other mammals

Many different kinds of mammals, in addition to rats and bats, are injurious intermittently and locally to coconut palms. Seedling palms are particularly susceptible, the animals being attracted by the considerable amount of food available in a small area. Wild pigs are the most troublesome; they are killed by baits of cassava poisoned with zinc phosphide. Other harmful mammals are monkeys, elephant, deer, bears, squirrels, porcupines and bandicoots. In Principe Island, a monkey, *Cercopithecus mona*, picks the young nuts and is very difficult to control. Most of the larger mammals can be excluded from the plantations by fences of wire or wood or by stone walls.

Domestic animals also damage coconut palms occasionally, particularly by pulling down and breaking the leaves from the smaller trees (Child, 1964), and man himself, with his bad habits of cutting steps in the trunks to facilitate climbing and indiscriminately cutting the leaves and slashing the trunks, is also sometimes in the category of an animal injurious to the coconut palm.

3. INSECT PESTS OF COPRA

Lepidoptera

PHYCITIDAE

Cadra cautella Walker (widely known as *Ephestia cautella*)

Economic aspect

The caterpillar of this moth is very well known as a pest of oily vegetable products, such as cocoa beans, cottonseed, nuts and copra, and also of dried fruits, especially figs. As a pest of copra, it is injurious mainly when this product has not been properly dried and suitably stored; well-prepared copra is too hard for the caterpillars to attack (Corbett *et al.*, 1937). The insect is said to be strongly attracted to the molds which thrive on poor-quality copra, and crossinfestation occurs in the holds of ships between such consignments and cocoa. According to Bondar (1940b), in Brazil the caterpillars are commonly found in the crowns of the trees, feeding on both male and female flowers and on the ripe fruit; this seems to be the only record of this notorious pest of stored products feeding on growing palms.

It should be noted that there has been some confusion in the past between this and certain other similar and related species, through misidentification; thus a statement from the Malay Peninsula to the effect that *C. cautella* prefers rice debris to copra probably refers to *Corcyra cephalonica* Stainton (*Galleriidae*), while *C. cautella* was probably responsible for damage to bagged copra in New Guinea, attributed at the time to *Ephestia elutella* Hubner (*Phycitidae*).

Geographic distribution (cosmopolitan)

C. cautella survives shipment from the tropics to much colder regions in Europe and North America, but since there is no diapause in its development it does not thrive at lower temperatures.

Description/Biology

The egg is pearly white, with a minute protuberance at one end. It hatches in 3-4 days. The caterpillar is pinkish, and is 12 mm long when fully grown. The chrysalis is enclosed in a whitish silken cocoon. The

duration of the caterpillar stage varies greatly from 22 to 49 days, according to the nature and condition of the food as well as to the temperature and humidity, and the chrysalis stage lasts 6-7 days; the cycle from egg to emergence of adult averages 45 days. All these figures refer to the rate of development in tropical conditions. The adult is pale grayish with a vague dark crossband on the forewing; the wing span is 16 mm.

Control

The prevention of serious infestation by *C. cautella* requires application of the measures outlined at the end of this chapter for the avoidance of damage by copra pests in general. However, the following recommendations made by Corbett *et al.* in 1937 with special reference to this pest are still applicable and worth stressing: the copra should not be bagged on the same day as it is removed from the drier; it should not be stored in bags that have been used for rice; copra that has been wetted by sea spray or rain should be well dried; and storage sheds should be disinfested by cleaning and fumigation.

The caterpillars of *C. cautella* are parasitized by *Bracon hebetor* Say (*Hym., Braconidae*). The degree of parasitization is low, however, and the parasite does not, in any case, become active until the population of *C. cautella* is already large and dense.

Coleoptera

Cleridae

Necrobia rufipes de Geer

Economic aspect

This beetle is common, especially in the wet season, in copra stores (but not in driers); in many countries of Southeast Asia and the Pacific, it is popularly known as "the copra bug." In addition to copra, it feeds and breeds on both animal and vegetable commodities, including salted meats, dried fish, prawns, bones, skins, cheese, cocoa beans and nutmegs; it also devours larvae of the fly *Piophila casei* Linnaeus (*Piophilidae*) in cheese, and of the beetle *Carpophilis dimidiatus* Fabricius (*Nitidulidae*) in copra, as well as molds. It is a serious pest of badly prepared, moldy copra but not of high-quality, properly prepared copra, on which its larval mortality is high. This insect can serve as an indicator of the degree of inefficiency and uncleanliness of copra stores; since the beetles fly by day in the sheds they are easily observed, and their presence in large numbers indicates inferior management in both the preparation of the copra and the hygiene of the stores.

Geographic distribution

N. rufipes occurs throughout the tropics, and is virtually cosmopolitan.[1]

Description/Biology

The beetle is iridescent blue-green, with reddish brown legs and antennae. The life cycle occupies about 66 days in tropical temperatures when the insects are fed solely on copra, but the addition of fish to their diet reduced the duration of the cycle to about 43 days and when larvae of *Carpophilus* were included, it was only 38 days (Ashman, 1963); these supplemented diets increased not only the rate of development but also the length of life and fecundity of the adults.

CUCUJIDAE

Oryzaephilus mercator Fauvel

This insect is primarily a pest of oilseeds, spices and dried fruit. There has been confusion in the past between this species and the very closely related *O. surinamensis* Linnaeus, but it is now generally agreed that nearly all the past records of the latter on copra actually refer to *mercator*. The life cycle varies very greatly in duration in tropical conditions, from 17 to 97 days, according to the nature of the food. This is another species which does not seriously infest well-dried copra.

Ahasverus advena Waltl.

Like *Necrobia rufipes*, this small beetle frequents the copra stores but not the driers. It does not feed on high-quality copra but only on copra on which the mold *Penicillium* is growing; it also consumes coconut meat (i.e., the product before it is converted into copra) on which the mold *Aspergillus* is present (Corbett *et al.*, 1937). On good-quality copra the beetles, after eating what little mold there is, leave it for inferior samples. *A. advena* occurs in all tropical regions and attacks cocoa beans, ginger, nutmegs, bulbs and yams, as well as copra (Richards and Herford, 1930). In the Malay Peninsula the life cycle can be completed in less than 3 weeks but may require as long as 55 days.

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[1] A statement indicating that in Asia and the Paeifie it is confined to the Philippines, the Malay Peninsula and the British Solomons (Anon., 1962) is erroneous.

NITIDULIDAE

Carpophilus dim diátus Fabricius

This is a rather flattened beetle with short wing cases (elytra) which do not cover the last two or three abdominal segments. It frequents the copra driers rather than the storage sheds. In the tropics, it attacks, besides copra, cocoa beans, ginger, nutmegs, groundnuts and palm kernels. It is seldom found on copra of good quality. It develops through all its early stages in about 5 weeks, with a range of 26-44 days. This is another cosmopolitan species; in the cooler countries it is established in flour mills, particularly in rice mills in North America.[2]

TENEBRIONIDAE

Tribolium castaneum Herbst

This is a very well-known pest of stored products. Though regarded primarily as a pest of cereal products, including flour and bran, it is also destructive, in circumstances favorable to it, to oilseeds and copra. Like all the other insects that damage copra commonly, it shows a marked preference for poor-quality material with an abundance of the mold *Penicillium* (Corbett *et al.*, 1937). Its distribution is tropicopolitan. When it is provided with suitable food, its life cycle at 30°C is 26 days on average.

DERMESTIDAE

Dermestes ater de Geer

This is another widespread beetle that is liable to infest copra, though it is probably best known in association with animal products, such as hides, horns, hooves and bones. The length of the adult is 8 mm; it is much larger than any of the other beetles mentioned here as pests of copra. The life cycle covers about 6 weeks at 30°C.

Avoidance of insect infestation of copra

SUITABLE PREPARATION OF COPRA

The insect pests of copra are attracted by the molds which grow on poor-quality copra rather than by the copra itself. Consequently, severe infesta-

[2] A statement (Anon., 1962) indicating that in Asia and the Pacific it is confined to the Malay Peninsula and the British Solomon Islands is erroneous.

tion can best be avoided by producing copra of high quality. This is mainly a question of uniform drying to reduce the water content to or below a specified level which, following much experience and experiment, has been stated to be 6 percent. Efficient drying to this specification is most easily achieved by utilizing kilns constructed for this purpose; a good deal of copra, however, is still prepared by drying on racks in the sun, and in this case much effort and supervision are necessary, particularly in unfavorable weather, if the required standard is to be attained. A water content of not less than 7 percent is conducive to the growth of molds and results in the creation of a medium ideal for the feeding and breeding of the whole gamut of insect species. The partial decomposition and increased acidity of moldy copra are in themselves highly undesirable; the insect infestations which accompany them further depreciate the product by contaminating it with silk, excrement and larval skins and reducing much of it to powder (Child, 1964).

Proper storage hygiene

To ensure that serious infestation does not develop in copra during storage, the following recommendations should always be put into practice:

1. Clean, noninfested sacks should always be employed; if the sacks have been used they should be treated with steam to ensure disinfestation.
2. The floors, corners, ledges and as much of the walls as can be reached should be brushed regularly and thoroughly, and all the dust and debris thus displaced should be collected and burned.
3. The bags should be piled neatly and systematically, and a space left between the piles and the walls to increase ventilation and facilitate inspection and cleaning.
4. The copra must be removed from the stores for shipment in the order in which it was put in, the oldest batch always being removed first.
5. The store must be maintained in a sound structural condition, so that the floor is reasonably free from rising ground moisture and the roof, walls and eaves are waterproof.

Chemical treatment

For the disinfestation of storage sheds and to ensure that the insect populations in them are maintained at a very low and virtually harmless level, regular chemical treatment of the floor and walls is recommended. To every 100 m^2, 5 liters of a mixture of 170 grams of 25 percent lindane (BHC) dispersible powder and 225 grams of 50 percent DDT wettable powder in water should be applied by spraying. If *Cadra cautella* is absent, the lindane can

be omitted. A malathion spray can be used as an alternative, at 450 grams of 25 percent malathion dispersible powder in 5 liters of water per 100 m^2 of floor and walls, but this must be applied monthly. In severe cases, additional treatment with lindane smoke as a fumigant or pyrethrum and piperonyl butoxide as a fog may be necessary (Lloyd and Hewitt, 1958).

In India, good results have been obtained in the disinfestation of stored grain by the utilization of calcium phosphate at 2 or 3 percent (Majumder and Bano, 1964). This material is harmless to man but toxic to numerous stored product insects, notably *Tribolium castaneum* and *Cadra cautella*; the success obtained with it against pests of grain suggests that it should be tested in copra stores also.

The degree of severity of the problem of the control of copra pests in driers, small stores and large warehouses is, however, largely determined by those responsible for preparing and storing the commodity. Good-quality copra, stored in sheds that are well managed and maintained, will remain virtually free from pests for an indefinite period, certainly long enough to ensure that it is still in good condition when removed from storage for shipment.

4. PRACTICAL ASPECTS OF PESTICIDAL APPLICATION

To obtain efficient pest control by chemical treatments it is necessary not only to apply a well-selected pesticide at the most convenient doses, but also to determine the correct formulation, the time of application, and the type of spraying or dusting machine.

Formulation

An insecticide is normally manufactured in several different formulations, i.e., dusts, wettable powders, emulsifiable concentrates and aerosols. Care is required in selecting the suitable formulation type for the pest being treated. In the case of *Oryctes rhinoceros*, for example, O'Connor (1957) observed that a miscible concentrate of 50 percent BHC had a better repellent action against the larvae than the wettable powder of the same concentration.

An insecticide treatment requires one or several applications, the timing of which is very important.

Applications

It is important to follow the manufacturer's stated concentration and doses. The increase of the concentration does not always give expected better results. Pillai and Kurian (1960) indicate, for example, that spraying with dieldrin at 0.05 percent against *Nephantis serinopa* in India gave a 77 percent mortality of caterpillars, whereas the same insecticide at four times higher concentration caused only a 5 percent increase in mortality (82 percent).

The commercial products contain rather high percentages of active ingredients. It is therefore necessary to dilute them to obtain solutions ready for application. The quantity of commercial product to be diluted is calculated by the "rule of three." If a 0.05 percent malathion water solution has to be prepared by using a commercial product with 45 percent active ingredient, the quantity of commercial product needed for 100 liters of water will be:

$$\frac{50 \times 100}{45} = 110 \text{ cm}^3$$

50 representing the quantity of malathion, in cubic centimeters, that should be found in 100 liters of the prepared solution.

As wettable powders contain a filler and/or a sticker, it is best to make up the amount of insecticide in a paste and then add the balance of the water, in order to avoid lumping. Spray nozzles should always be checked to ensure that their aperture is not too small for the powder in suspension. The container should be shaken, or its contents often agitated, to prevent the mixture from settling in the tank.

Owing to the necessity of getting an adequate cover of insecticide in the crown of tall palms, it is usually necessary to employ power sprayers or dusters. Airplanes have been successfully used to deal both with the Phasmid *Graeffea crouani* in Fiji and with *Locusta migratoria manilensis* in the Philippines. The more general use of aluminum now permits the choice of long telescopic lances and light extension ladders. Furthermore, in view of the reasonable price and great convenience of portable fogging machines, their use seems worthy of trial in nurseries where a fine, persistent deposit on the leaves is easy to obtain.

The choice of the best sprayer or duster is important. In Zanzibar, three types of sprayer were used in control operations against *Pseudotheraptus*: a micron atomizer, a pressure sprayer and a swing fog machine. The results obtained were as follows:

Type of sprayer	Average number of insects (10 palms)	Average number of insects killed per liter of pyrethrum emulsion applied
Micron atomizer	628	200
Pressure sprayer	343	4.5
Swing fog machine	57	5.3

The higher mortality caused by the micron atomizer was due to a large number of droplets of uniform size (50 to 80 microns) carried on a strong blast of air into the crown of the 10-meter-tall palms. The atomizer was further equipped with a multipurpose nozzle enabling emulsions, suspensions and wettable powders to be used without any changeover (Vanderplank, 1954).

Similar care in the selection of spray machinery was used in the control of *Brontispa longissima* in the Solomon Islands. By choosing small hand sprayers with an efficient trigger grip, it was found possible to apply only 6 cm^3 of insecticide per young palm and to obtain excellent results in the

control of larvae and adults, the center of the unfolded leaves having been conveniently wetted (Brown and Green, 1958).

Effects of insecticides on parasites

With the exception of the scoliids parasitic upon dynastid beetles, most entomophagous insects are of small size. They belong mainly to the orders *Hymenoptera, Diptera* and *Coleoptera* and are very susceptible to pesticides. The residual effect of 0.2 percent DDT applications against *Nephantis serinopa*, for instance, lasts more than two months, even with 450 mm rain, and the caterpillar parasite *Trichospilus* is also killed (Nirula, 1958; Pillai and Kurian, 1960). In Malaysia, recommendation is made to avoid treatments against *Brachartona catoxantha* where parasitism by the tachinid *Bessa remota* exceeds 70 percent, unless pesticides can be applied against the very early stages of development of the pest (Anon., 1951). In one instance where part of the infested area was sprayed with BHC, the rate of parasitism by the fly was reduced from 80 to about 45 percent, thus enabling the pest to get a good hold.

These examples show that while modern pesticides, by virtue of their high toxicity and long persistence, are a considerable improvement on the prewar ones, they can be a two-edged weapon in their effect on the beneficial insects which, by themselves, often give a greater reduction of the pest.

Safety precautions in connection with pesticide application

Concentrated pesticides are toxic to man; therefore, certain precautions have to be adopted in handling them. The most elementary one concerns the keeping of pesticides in a room to which only one authorized person has access. Accidents are more likely in opening tins of the " press-down " type of lids than in field spraying with diluted chemicals. In case of contact with the pesticide by accident, the part of the body involved has to be immediately washed with water and soap, and the clothing removed and also cleaned. The empty tins or packages have to be destroyed or buried. Spraying or dusting must be carried out across-wind or downwind, so that the pesticide doesn't blow back on the laborer. The lightness of the sprayers' containers has to be checked. Protective clothing, gumboots, gauntlets, goggles, etc., have to be worn any time it is recommended by the pesticide manufacturer. Smoking and eating must be strictly forbidden during spray operations; laborers must wash their hands with soap and remove their clothing as soon as the treatment is completed. Care is also needed to avoid spraying ponds or streams which may contaminate drinking water

for men and stock, besides killing fish which are very susceptible to chlorinated hydrocarbons such as DDT, BHC or dieldrin.

First-aid measures

A full account of this subject, with medical treatment, is included in Wyniger (1962). When poisoning is provoked by the ingestion of chlorinated hydrocarbons (DDT, BHC, dieldrin, aldrin, etc.), the stomach must be emptied and a saline purgative should be given; oily purgatives and milk must be avoided. In the case of poisoning with arsenicals and fluorides, the patient must have his clothing removed, lie on his side and be kept warm, quiet, and receive emetics. If intoxication is due to nicotine, the same care has to be given to the patient, except that he should receive coffee or alcohol instead of emetics, and fomentations on the abdomen.

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INDEX

ADDENDUM [1]

Agonoxena argaula Meyrick (p. 69)

In Fiji, damage by larvae may cause a 5 percent tissue loss in young fronds, equal to 10 percent in mature fronds. The total number of larvae present during the life of the frond varies from 400 to 1 000. Damage is serious in palms up to two years of age, less at seven, and negligible in mature palms (O'Connor, 1967).

Amblypelta cocophaga China (p. 36)

The final progress report by Greenslade (1968) confirms previous work in the Solomon Islands, that chemical control, either aerial or from the ground, seems unlikely to be effective. The problems of locating the most serious nutfall areas, and the high cost of moving spraying equipment through the plantations, are serious. Unless systemic insecticides prove effective, the most promising results seem to be by "brushing" ground vegetation, the use of combined herbicides and insecticides, aided by new planting of palms under old stands. The last is contingent on the eradication and limitation, respectively, of the harmful ants *Pheidole megacephala* (F.) and *Iridomyrmex cordarus* F. Smith and their replacement by the predaceous ant *Oecophylla smaragdina* (F.). Similar conclusions have been made in New Guinea by Smee (1965), who also favours encouragement of the last-named beneficial ant (see text, p. 38).

Aspidiotus destructor Signoret (p. 46)

Dinther (1956) in Surinam states that heavy rains can check development of the scale, which is controlled with oil emulsion from a high-power pressure sprayer directed especially on the lower surface of the fronds. Arkotine oil with either 0.2 percent DDT or chlordane were used.

Attention is drawn to a paper by Fennah (1954), showing that large populations of this scale in the West Indies are usually associated with faulty agronomy and unfavourable weather. The combination of these two factors,

[1] The present addendum, submitted by the author, brings the data on *Pests of the coconut palm* up to 1968.

when severe, may make chemical control an uneconomic proposition. Basic research is needed to study the association between mass attacks of the scale and the cropping and growth of the palms. For distribution, reference is made to Map No. 218 of the Commonwealth Institute of Entomology, 1966.

Axiagastus cambelli Distant (p. 43)

In New Guinea, Smee (1965) reports that crop losses follow a drain of sap resulting from heavy attacks. See the peculiar, elongate shape of young nuts damaged by feeding in the New Hebrides (Fig. 37, p. 44).

Azteca cartifex Forel (p. 140)

Besides its injury by propagating the coconut scale, Dinther (1956) states that, in Surinam, this ant may be persistent enough in the crowns to prevent the nuts from being harvested.

Brassolis sophorae Linnaeus (p. 56)

The larval stage lasts from 73 to 90 days.

Brontispa longissima Gestro (p. 107)

Life history studies in New Guinea reveal that the preoviposition period lasts 74 days, thus giving a total cycle of 4 months (Smee, 1965). Chemical control with 0.1 percent dieldrin should aim at application of 28 millilitres of fluid to palms up to three years of age. Similar results in the New Hebrides (Manciot, 1965) with 0.15 percent dieldrin were obtained using 2 litres per hectare, enough for 143 palms. For distribution, see Map No. 227 of the Commonwealth Institute of Entomology, 1966. In Tahiti and Moorea, the egg parasite *Tetrastichodes brontispae* Ferr. has not yet been recovered in the field. The failure of the introduction is attributed to attacks by the ant *Pheidole megacephala* (F.), coupled with dry weather at the period of release (Cochereau, 1965).

Castnia daedalus Cramer (p. 84)

Additional palms attacked are date, oil and sabal palms, *Pritchardia*, *Livistona* and *Maximiliana*. The insect also occurs in Panama (Dinther, 1956). The pink, spindle-shaped eggs measure 4.3 by 4.7 millimetres. The larval stage occupies one year. The best, but not very effective, control is 0.5 percent DDT spray.

Castnia licus Drury (p. 85)

Dinther (1956) reports that the life cycle takes four months.

Diocalandra stigmaticollis Gyllenhall (see footnote, p. 122)

Synonym of *D. frumenti* (p. 122).

Graeffea crouani Le Guillou (p. 27)

Detailed studies of this phasmid have been made by Paine (1968) who forwarded 960 puparia of a tachinid from the Solomons to Fiji. The fly, *Myeteromyiella laetifica* (Mesnil), is a parasite of the larger phasmid *Ophicrania leveri* Günther. However, there has been no recovery of the parasite to date.

Leucopholis coneophora Burmeister (p. 136)

Later tests by Mathen, Kurian and Mathew (1964) show that BHC, dieldrin and aldrin, respectively at 90, 30 and 288 grammes per hectare, are preferable to malathion (at the first rate) or heptachlor.

Nephantis serinopa Meyrick (p. 66)

Large populations of the mite *Pyemotes ventricosus* have been found on larvae in south India by Mathen, Sathiamma and Kurian (1968). There is small hope of economic control, so that mass breeding for field release is not planned.

For distribution of *N. serinopa*, see Map No. 211 of the Commonwealth Institute of Entomology, 1966.

Ophicrania leveri Günther (p. 29)

A paper by Paine (1968) deals in detail with bionomics, and shows that the life cycle occupies five months, two of which are spent in the egg stage. Nymphs feeding on coconut produce larger adults than those on betel palms. A number of jungle plants are also eaten.

African species of *Oryctes* (p. 134).

Oryctes owariensis P. de B. and *Oryctes erebus* Burm. are two additional west African species. The latter is a serious pest in Sierra Leone.

The bionomics of these pests have been studied by Mariau (1966, 1968a), especially on the Ivory Coast. As usual with these dynastids, damage is most serious to palms up to four years of age, which are frequently

killed. Besides routine clean cultivation, it is important to establish as large blocks of palms as possible, so as to have the smallest perimeter against which protective measures are facilitated. Dealing in particular with *O. monoceros* and *O. boas*, Mariau shows that the former attack higher up in the palms, of which 75 percent may be invaded. The adults tunnel into the central whorl of unexpanded leaves toward the terminal bud, which in two-year-old palms can be reached by tunnels 45 centimetres long. Nursery seedlings are often killed but nut-bearing palms are little affected.

Oryctes rhinoceros Linnaeus (p. 125)

Control in New Guinea was obtained with 0.01 percent BHC spray or 5 percent DDT dust. With the latter, a mixture of equal parts of sand or sawdust is placed in the leaf axils (Smee, 1965). Similar treatment was recommended in India by Mathen and Kurian (1966) for this dynastid as well as for the red palm weevil.

Biological control with the reduviid *Platymeris rhadamanthus* Gerst. is being maintained in Fiji (Swaine, 1966), although recovery of this Zanzibar bug has not occurred. Research on control by viruses is reported by Huger (1966a and 1966b), who finds that in Western Malaysia, Sabah, Fiji and Samoa *Rhabdionvirus oryctes* may account for the death of 60 to 88 percent of the larvae, compared with only 1 to 3 percent due to the fungus *Metarrhizium anisopliae*. The virus may exist in the form of spherical particles 160 mμ in diameter, or as rods 195 mμ in length. These are in the body fat and prove very toxic when injected into the body cavity of larvae. Artificial culture and release in the field may become standard control; best results are obtained with third-instar larvae. Similar work in the Philippines showed that two conditions exist known as histolytic disease, in which the larva develops a translucent body, and blue disease in which it changes from steel blue to black, followed by a flaccid and then dry state (Fandialan and Ibañéz, 1966).

Further details of the spread of the rhinoceros beetle are given in Map No. 54 (revised), published by the Commonwealth Institute of Entomology in 1967. Details of its spread in Fiji are given by Swaine (1966).

Patanga succincta Linnaeus (p. 23)

Severe damage by the Bombay locust was reported in the Laccadive Islands by Menon (1967), who stated that 25 percent of the fronds were injured. Young leaves in the crown as well as ground vegetation were attacked. Control was effected by spraying with 50 percent dieldrin (1 kilogramme per 50 litres of water) or 20 percent endrin (3 millilitres per litre), or folidol (1.5 millilitres per litre); a power sprayer was used. Against hoppers, dusting with 10 percent BHC at 25 kilogrammes per hectare was effective.

Promecotheca opacicollis Gestro (p. 104)

An outbreak in 1962 in the isolated Tikopia Island of the Santa Cruz Group is assumed to have arisen through transport of adults by air currents from a distance of 240 kilometres (Greenslade, 1965). Unlike the 1933 occurrence, which was controlled by an egg parasite (p. 105), the later outbreak was checked by the transport (from the main Solomon Islands lying to the west) of the predaceous tree ant *Oecophylla smaragdina* (F.). It is noted, however, that there had been severe competition by the beetle for oviposition sites and a shortage of larval food.

Promecotheca papuana Csiki (p. 102)

The " one-stage " condition has arisen in New Guinea from an incorrect application of insecticides. This development is, therefore, quite apart from the usual external factors such as weather or failure of parasites. That injudicious chemical " control " can bring about an increase in a hispid pest is most interesting, as the same result was reported in the zygaenid moth *Brachartona catoxantha* in Malaysia (see p. 90).

Pseudotheraptus devastans (Dist.) (to be added to section on Rhynchota)

This species, previously known from rubber, cocoa and cassava, occurs throughout tropical Africa and has recently been reported from coconut. It was formerly placed in the genus *Pendulinus*.

Pseudotheraptus wayi Brown (p. 38)

The somewhat complex relationship between insect feeding and crop yield has been studied in Tanzania by McKinlay (1965), who draws attention to the compensating mechanism by which the palm sheds excess nuts when a figure is reached beyond which they can be carried to maturity. The critical age for natural shedding of nuts is just under three months, when they are about 7 centimetres in length. Plots sprayed with a mixture of 0.1 percent DDT and 0.1 percent malathion showed an increased crop for the first two years but not for the third.

RATS (p. 147)

A practical method of control is described by Smith (1967) in Jamaica, in which 8 parts of melted paraffin wax are mixed with 11 parts of maize meal, 2 parts of sugar and 1.25 parts of 0.5 percent warfarin. After setting, the blocks are cut into pieces of 225-gramme weight, one placed between

every five or six palms. When this method was used on the Ivory Coast, the damaged nuts fell from 18.4 to 8.2 percent in one month, 1.9 percent in three months, to nil after six months (Mariau, 1967).

Rhabdoscelus obscurus Boisduval (p. 117)

The range should include Celebes, Java, Sumatra, Borneo and many Polynesian and Micronesian records. The larger *R. asperipennis* Frm. is a coconut pest in the Caroline Islands.

Rhadinaphelenchus cocophilus Cobb (p. 143)

Experiments in Trinidad with sevin (carbaryl) show that this chemical did not actually kill the eelworms but only discoordinated their movements. The LD 50 was about 20 parts per million. However, both solutions and dusts prevented the petiolar tissue of the palm from being penetrated by the mouth parts (Fenwick, 1968).

Rhinostomus barbirostris Fabricius (p. 120)

Contrary to some earlier workers, Dinther (1956) found that, in Surinam, healthy palms were not attacked.

Rhynchophorus ferrugineus Olivier (p. 113)

The publication of a monograph on this genus by Wattanapongsiri (1966) has resolved the synonymy, a task long overdue. However, his distributional record for Victoria (Australia), when followed up by the present writer showed, from records in the British Museum (Natural History), a solitary record dating back to 1862: the temperature in winter would rule out the survival of this tropical weevil.

In south India, Mathen and Kurian (1966) have obtained prophylactic control by placing 225 grammes of either 5 percent chlordane or BHC powder mixed with an equal volume of sand in the leaf axils. A reduction in numbers from 80 to 90 percent was secured.

Rhynchophorus palmarum Linnaeus (Montr.) (p. 116)

Good results have been obtained in Trinidad by the use of chemical lures of 1 percent skatole and 1 percent teramyl acetate (Hagley, 1965). Another lure was 100 millilitres of 6.25 percent skatole, 100 millilitres of 0.5 percent iso-amyl acetate and 300 millilitres of 5.5 percent liquid malt extract. This concoction, mixed with about 1 kilogramme of maize meal into a paste, attracted three times as many weevils as coconut sap. Also

in Trinidad, Maharaj (1965) described an efficient trap made from polished aluminium with side apertures of 18-gauge galvanized wire set, 2.5 centimetres apart, which prevented the escape of the weevils that entered the trap. The latter contained a bait of coconut tissue.

Rhynchophorus papuanus Kirsch (p. 116) is now *R. pilineatus.*

Rhynchophorus phoenicis Fabricius (p. 117)

Recent studies by Mariau (1968b) stress the difficulty of dealing with attacks in the crown, as the damage is done internally before it is noticed; in the trunk, however, frass is apparent. Application of 0.08 percent dimethoate from 50 to 200 millilitres is recommended, or brushing trunk wounds with wood tar. It is important to avoid or reduce injury to trunks as this attracts ovipositing weevils (from 100 to 200 eggs are laid per adult). Attacks on the terminal bud result in the death of palms a few weeks later.

Rynchophorus schach Olivier (p. 115)

According to Wattanapongsiri (1966), this species should be *R. vulneratus* (Pantz.).

Stephanitis typicus Distant (banana lacewing bug) (p. 44)

Results in south India (Mathen, Mathew and Kurian [1968]) indicate that adult and nymph numbers are positively correlated with temperature and sunshine and negatively with relative humidity and rainfall. There is a maximum peak in April, with minima in June and December.

Strategus aloeus Linnaeus (p. 135)

This species measures from 40 to 58 millimetres. It also extends into Surinam, where its larval period lasts one year. Dinther (1956) suggests control by applying a ring of chlordane or aldrin at a distance of 0.5 metre from the base of the trunk. Vayssière (1965) in Colombia suggests 2.5 percent heptachlor at 300 grammes per palm in the first year, increased to 300-600 grammes subsequently.

S. jugurtha Burm. is the Brazilian species against which the soil at the base of palms is drenched with 20 percent endrin at 2 litres per palm at a 1 percent concentration.

Tirathaba rufivena Walker (p. 73)

It is considered uneconomic to use chemical control in New Guinea, as any reduction of the larvae would result in only a small crop increase

(Smee, 1965). This is due to the fact that many nuts attacked by larvae would be shed normally, even in the absence of the insect.

Trigona hyalineata branneri Ckll. (to be added to section on *Hymenoptera*)

This is a stingless social bee, black in colour. It is 6 millimetres in length. The deep holes bored in the soft tissues of the inflorescence may cause enough decay to prevent nuts from setting. Spraying with 0.2 percent DDT is not effective, as the bee nests in the nearby jungle (Dinther, 1956). This is the first known case of a nonmyrmecine hymenopterous pest of coconut.

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ISBN 92-5-100857-4