

# REVIEW OF THE COCONUT LEAF MINER AND TREE HOPPER PROBLEMS IN PAPUA NEW GUINEA, WITH A REPORT ON THEIR INCIDENCE ON SOUTHERN NEW BRITAIN

G. M. Baloch\*

## ABSTRACT

A brief review is given of the coconut hispid leaf miner *Promecotheca papuana* Csiki and coconut tree hoppers (*Segestidea* spp., *Eumossula gracilis* Will. and *Pseudonicrocraza szentia* Will.) in Papua New Guinea. *P. papuana* is distributed throughout New Britain, Manus Island, Duke of York Islands, New Ireland District and the north-east of mainland New Guinea. However, serious outbreaks have occurred only on New Britain and the Duke of York and Manus Islands. It has never been of any importance on New Ireland and in the north-east of New Guinea. Tree hoppers are widely distributed in Papua New Guinea and their status as a pest varies from place to place.

Although a number of indigenous natural enemies have been responsible for a considerable degree of control of these two coconut pests in Papua New Guinea, the periodic occurrence of serious outbreaks necessitated the introduction of exotic parasites from the Indonesian area in the late 1930s. These introductions consisted of *Pediobius parvulus* Ferriere (*Eulophidae*) against the larvae and pupae of *P. papuana* and *Leefmansia bicolor* Waterst. (*Encyrtidae*), *Doirania leefmansii* Waterst. (*Trichogrammatidae*), and *Stethynium* sp. (*Mymaridae*) against the eggs of the various species of tree hoppers. In spite of successful establishment of and good control exerted by these parasites in most of the affected areas, periodic outbreaks of both *P. papuana* and tree hoppers still occur.

The recurrence of *Promecotheca* outbreaks could possibly arise through:

1. Population crashes of the beetle as a result of either unfavourable environmental conditions or disease followed by drastic reductions in parasite populations;
2. The lack of alternate hosts for the parasites; and
3. The existence of some host plants of *P. papuana* in which the larval and pupal parasites may not be able to successfully attack the host.

More detailed investigations on the ecology of tree hoppers and their natural enemies are necessary before an understanding of the tree hopper problem can be attained.

A survey of southern New Britain in April to May, 1969 revealed that the important parasites of *P. papuana*, with the exception of *Eurytoma promecothecae*, were fairly well distributed throughout the areas visited, but that those of *Eumossula gracilis* were mostly absent. Almost all the localities infested with *P. papuana* appeared to be those where the insect was accidentally brought in and the parasites became effective only after one and a half to two years after the pests' introduction.

\*Entomologist, Lowlands Agricultural Experiment Station, Keravat. Present address: Commonwealth

Institute of Biological Control, Pakistan Station, P.O. Box 8, Rawalpindi, Pakistan.

## INTRODUCTION

**C**OCONUT palm (*Cocos nucifera*) in Papua New Guinea is subject to attacks, to varying degrees, of about 80 species of insects belonging to 64 genera (Dumbleton 1954; Dun 1954; Froggatt 1940; Froggatt and O'Connor 1940; Lever 1969). Tree hoppers (*Eumossula gracilis* Willemse, *Segestidea* spp., and *Pseudonircraza szentia* Willemse) and the hispid leaf miner (*Promecotheca papuana* Csiki) are among the dozen or so more important insects which cause economic damage at high population densities (Froggatt and O'Connor 1940).

A brief review of both these problems and a report on the incidence of the tree hopper *Eumossula gracilis* and the leaf miner *P. papuana* in southern New Britain is given below.

## PROMECOTHECA PAPUANA

The genus *Promecotheca* and its geographical distribution have been well discussed by Gressitt (1959). Of about 35 species with a

Philippine—Papuan distribution, *P. papuana* Csiki is the only one which is a pest of coconut in Papua New Guinea.

*P. papuana* has been recorded from New Britain, Manus Island, Duke of York Islands, New Ireland and the north-east coast of mainland New Guinea (Figure 1). It has not been of any importance in the last two localities (Gressitt 1959), but the first three localities have suffered heavy damage from time to time. Outbreaks have been particularly severe both in intensity and frequency on New Britain, especially at Lindenhafen and Linga Linga Plantations on the south and north coasts, respectively.

Life-history studies on *P. papuana* have been reported by O'Connor (1940), Froggatt and O'Connor (1941) and Gressitt (1959). Eggs are mostly laid on the underside of leaflets in straw-coloured egg cases. The number of eggs per case varies from 1 to 6. On Manus Island and the Gazelle Peninsula the majority of

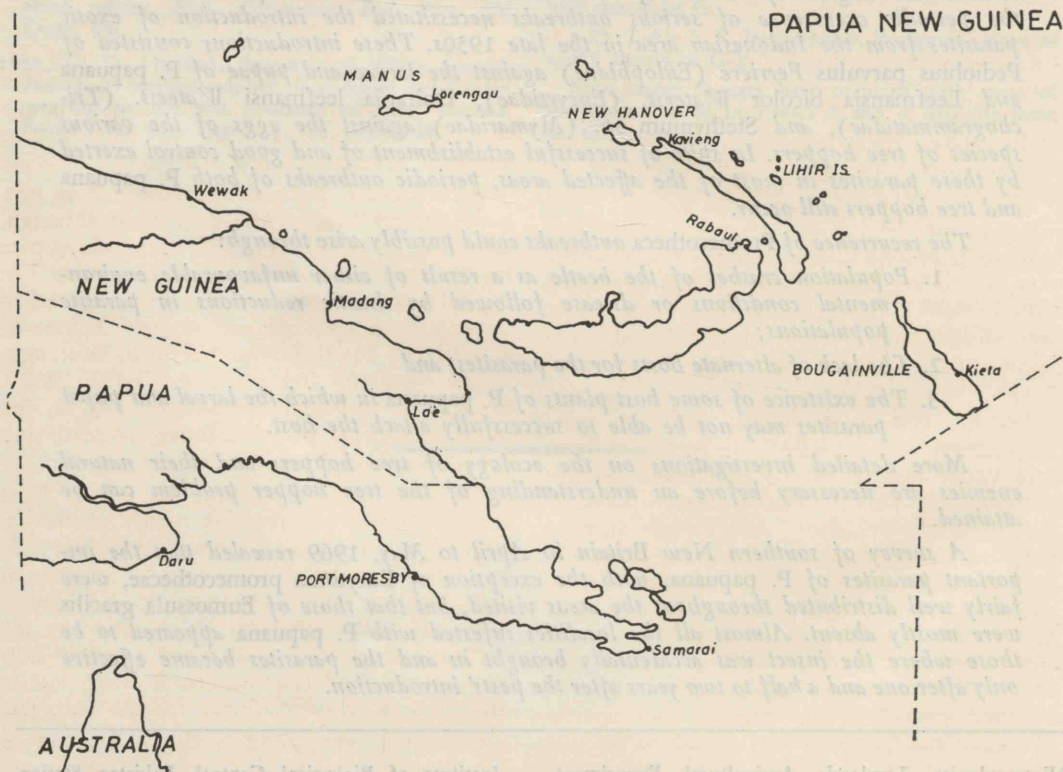


Figure 1.—Papua New Guinea

egg cases have 3 eggs, whilst 5 is the usual number in the Lindenhafen area. The egg stage lasts from 11 to 17 days.

The female of *P. papuana* chews a slit on the leaf surface before ovipositing. Thus, the young larvae, on hatching, enter directly into the inner leaf tissue and feed as leaf miners. The larvae arising from one egg case feed side by side in the same mine and also stop feeding at the same time to moult. There are three larval instars and the entire larval period varies from 17 to 30 days. On the completion of feeding, the fully grown larvae retreat from the end of the mine and pupate anywhere in the dry portion of it, as they do at each moult.

The pupae are to be found in the mines with their dorsal surface facing the underside of the leaf. The prepupal and pupal periods last for 13 days and the imagoes remain in the mines for another two days before emerging.

According to Froggatt and O'Connor (1941), copulation takes place two to three weeks after emergence and oviposition commences six to ten days later. Gressitt (1959), however, reports a pre-mating period of one week and a pre-oviposition period (excluding pre-mating) of two weeks. Both observations therefore agree that there is a period of three to four weeks from the emergence of adults to oviposition.

O'Connor (1940) has reported adult longevity to be as long as five months or more under cage conditions, but Gressitt (1959) suggested that longevity could be much shorter under natural conditions because of unfavourable environmental conditions and the incidence of disease.

On the Gazelle Peninsula, until the great volcanic eruption of 1937, the pest had been kept under control by the indigenous hymenopterous egg parasite *Closterocerus splendens* Kowalski (Eulophidae), and larval parasites *Eurytoma promecothecae* Ferriere (Eurytomidae) and *Apleurotropis lalori* Girault (Eulophidae). The eruption caused a serious upset in the natural balance through the destruction of parasites and was followed by a major outbreak of *P. papuana*. The parasites, however, regained control within three to four months (Froggatt and O'Connor 1941) and the position has since remained mostly unchanged except for periodic outbreaks in small pockets.

In Fiji, a related species, *Promecotheca coeruleipennis* Blanchard, became a serious pest in 1929 when dry weather encouraged the build-up of the predatory harvest mite *Pyemotes ventricosus* Newport which destroyed young stages of both *P. coeruleipennis* and its parasites. This caused a 'one-stage' condition to develop (one-stage condition according to Gressitt (1959) is the occurrence of a single cycle or generation at one time, i.e. when a population in a given area consists entirely of one stage or two successive stages such as adults and eggs, eggs and young larvae, mature larvae and pupae, or pupae and adults). Introduction of the pupal parasite *Pediobius parvulus* Ferriere (Eulophidae) from Java solved the Fijian leaf miner problem and no further outbreaks have been reported (Taylor 1937).

In view of the recurrence of outbreaks and the absence of pupal parasites of *P. papuana* in Papua New Guinea *P. parvulus* was introduced into New Britain, Manus Island and New Ireland in 1938 and soon became established (Froggatt and O'Connor 1941). Further outbreaks have continued to occur, however, especially at Linga Linga and Lindenhafen Plantations, sometimes simultaneously, although they are on opposite coasts of New Britain and have their seasons reversed.

Parasites of *P. papuana* apparently afford very good control over a period of time although, according to Gressitt (1959), outbreaks appear to develop once every 10 to 15 years. The egg parasite *C. splendens* has been reputed to cause a one-stage condition in New Britain as a result of its ability to parasitize host eggs to the extent of 100 per cent (DASF 1968). Because of the total destruction of eggs, the larval and pupal parasites starve to death and the one-stage condition develops.

The leaf miner problem in Papua New Guinea thus still remains partly unsolved. Population build-up cannot definitely be associated with either the effects of weather or the action of the harvest mite *P. ventricosus*. Very often the problem only comes to the attention of entomologists when a serious outbreak occurs, and consequently it is too late to study the factors responsible for the outbreak.

Gressitt (1958) studied the ecology of *P. papuana* and concluded that parasites are capable of keeping the insect under control,

but that from time to time unknown factors make them ineffective. By this he perhaps meant that the unknown factors caused an increased death rate for the natural enemies.

It is possible that environmental factors (high humidity?) at Linga Linga, and perhaps also at Lindenhafen, make the adults of *P. papuana* susceptible to disease which causes a rapid decline in their numbers. This would entail even faster reduction in the parasite populations, possibly to the point of near extinction. The pest populations, under favourable conditions, would increase faster than those of the parasites and an outbreak would result.

Although coconut palm is the preferred food plant of *P. papuana*, nipa palm (*Nipa fruticans*), is also fed on. Under outbreak conditions adults can also feed and deposit eggs on oil palm (*Elaeis guineensis*), but the larvae are unable to complete their development on it (Gressitt 1959). Recently all stages of this hispid have been found on a cluster palm (? *Ptychosperma* sp.) at the Lowlands Agricultural Experiment Station, Keravat, at a time when the populations in the area were low.

No signs of parasitism of any stage could be found on ? *Ptychosperma* sp., but it is not known whether this was due to the scarcity of eggs and larval mines or the unsuitability of this host plant for the parasites. However, it could well be that *P. papuana* parasites behave differently when the host insect develops in different host plants, as has been reported by Smee (1965) for the braconid larval parasite *Apanteles tirathabae* Wilkinson parasitizing *Tirathaba rufivena* Walker on nipa and coconut palms. Thus, it is possible that the host plant range of *P. papuana* is wider than that known at present, and some of these plants might have unfavourable morphological characteristics that prevent successful parasitism. Such plants could serve as potential foci for the development of outbreaks.

Under low population and multiple-stage conditions high adult numbers have almost always been observed on young palms (Gressitt 1959). Personal observations for over a year at Baliora Plantation on the Gazelle Peninsula support this. Mortality of eggs from natural enemies on this plantation remained comparatively higher on the older palms. To date, this be-

haviour pattern has not been considered to be of great significance in the population ecology *P. papuana* (Gressitt 1959) but it would appear that outbreaks could eventually arise from such situations.

Thus, factors responsible for *P. papuana* outbreaks in Papua New Guinea are still not definitely known. A long term study of population fluctuations and factors causing these fluctuations should be carried out in order to arrive at an understanding of the problem. However, population crashes of the pest resulting from unfavourable environmental conditions or diseases which lead to a drastic reduction in parasite populations, the possibility of the existence of some host plants of *P. papuana* in which the various stages of the pest may not be easily accessible to the parasites, and the possible lack of alternate hosts for the parasites (especially of *P. parvulus*), are suggested as possible reasons for the recurrence of *Promecotheca* outbreaks in Papua New Guinea.

Until the factors responsible are fully known, chemical control measures can only be recommended when the insect is in the one-stage condition and parasite activity is very low. DDT/BHC dust applied from the ground at the rate of  $\frac{1}{2}$  lb per palm has given good results under such conditions.

## COCONUT TREE HOPPERS

Coconut tree hoppers were previously known under the generic name of *Sexava* and two species, *nubila* and *novae-guineae*, were recorded from Papua New Guinea, the former from New Britain, New Ireland, New Hanover and Madang and the latter from Manus Island and New Hanover (Froggatt 1935; Froggatt and O'Connor 1940). A revision of Papua New Guinea material by Dr Willemse in 1953 and 1958 revealed that Papua New Guinea coconut tree hoppers comprised species belonging to the genera *Segestidea*, *Pseudonicraza* and *Eumossula*.

The species of tree hoppers in Papua New Guinea and their distribution are now known to be as follows:—

1. *Eumossula gracilis* Willemse—Morobe, New Britain and New Ireland Districts, Lihir Island, Masahat Island and Mahur Island;

2. *Segestidea hanoverana* Willemse—New Hanover and Tatau Island;
3. *S. insulana* Willemse—Pak Island, Lou Island, Manus Island, New Ireland, Masahat Island and Lihir Island;
4. *Pseudonicraza szentia* Willemse—Kerema (Gulf District).

As can be seen, tree hoppers are widely distributed throughout Papua New Guinea but their status as a pest varies from place to place. 'Outbreaks' have almost always occurred at irregular intervals and usually in areas lacking regular dry periods (Froggatt and O'Connor 1940).

Life-history studies have been reported by Froggatt (1935) and Froggatt and O'Connor (1940). According to these authors *Segestidea* spp. eggs are deposited singly in the soil to a depth of half an inch. Eggs are also laid in the fibre in the crowns of palms, in the epiphytic growths on the trunks, and, in severe infestations, in rotting bases of fronds, coconut husks and logs and amongst palm roots growing above the ground. However, moist, loosely compacted sandy soils are preferred oviposition sites.

The incubation period varies from 45 to 100 days, but under favourable conditions most of the eggs hatch within 60 days. Climatic conditions appear to exert a pronounced effect on the successful hatching of oothecae. Under dry conditions a considerable proportion of eggs may die. Many, however, enter diapause or aestivation and yield normal nymphs when moist conditions return. For example eggs kept in very dry soil for 110 days under laboratory conditions produced 40 per cent of nymphs after 10 days following application of water to the soil.

Table 1 from Froggatt and O'Connor (1940) gives the average duration of the various nymphal instars of *Segestidea insulana*.

The total nymphal period therefore lasts from 78 to 117 days for males and from 90 to 124 days for females.

Copulation takes place 10 to 12 days after emergence, usually at dusk but often at night. Oviposition commences 21 to 31 days after mating and continues almost throughout the life of a female *S. insulana*. The females volplane or glide down during the night to oviposit in the soil, and after ovipositing walk back up the trunk. Females can lay up to a maximum of 52 eggs during a lifetime but the average is usually 40. Eggs laid on the same night hatch at the same time, but a lot of variation occurs even in those laid on consecutive nights (Froggatt and O'Connor 1940).

Adult longevity under captivity was found to vary from 35 to 110 days (average 72.3) for males and from 28 to 91 days (average 67.1) for females.

A number of indigenous egg parasites have been recorded from tree hopper eggs collected from various localities in Papua New Guinea, viz. *Leefmansia bicolor* Waterst. var. ? (Encyrtidae), *Doirania leefmansii* Waterst. (Trichogrammatidae), *Scelio* sp. (Scelionidae) and *Anaphes* sp. (Mymaridae) from Manus Island and New Hanover; *Prosaepus atrellus* Dodd. (Scelionidae) from Manus Island, New Hanover, New Britain, New Ireland and Lihir Island; *Ootetrastichus dubius* Waterst. (Eulophidae) from Manus Island, New Hanover and New Britain; an unidentified mymarid from Lihir Island; an unidentified eulophid from New Britain and Lihir Island (Froggatt 1937; Froggatt and O'Connor 1940); and *Tetrastichus* sp. (Eulophidae) from New Britain (Baloch, unpublished data). The status of the last species as a primary or secondary parasite has not yet been confirmed, although it would appear to be a primary parasite.

Table 1.—Mean duration in days for the various nymphal instars of *Segestidea* sp.

|                        | Nymphal Instar |      |      |      |      |      |      | Total Duration |         |
|------------------------|----------------|------|------|------|------|------|------|----------------|---------|
|                        | 1st            | 2nd  | 3rd  | 4th  | 5th  | 6th  | 7th  | Range          | Average |
| Macropterous male .... | 13.8           | 13.3 | 11.5 | 13.0 | 14.2 | 17.7 | —    | 78-91          | 83.5    |
| Micropterous male .... | 13.8           | 13.3 | 11.5 | 13.0 | 13.1 | 14.1 | 18.1 | 91-117         | 96.0    |
| Female ....            | 13.8           | 13.3 | 11.5 | 13.0 | 14.5 | 15.4 | 19.4 | 90-124         | 100.9   |

A strepsipteron, *Stichotrema delatoreanum* Hofender, has been bred from the adults in the Madang, Manus and Sepik Districts. Attempts to introduce it to other areas have met with failure as the male is known only as a parasite of an unidentified species of ant. Simmonds (1960) has mentioned the presence of tachinid eggs on museum specimens but no tachinids have ever been bred from field-collected material.

Prior to 1933, although appearing in appreciable numbers at times, the indigenous parasites did not appear to control the pest and it was therefore decided to introduce the Indonesian races of the egg parasites *L. bicolor*, *D. leefmansii* and *Stethynium* sp. (Mymaridae) from Amboina. All three became established at many areas throughout Papua New Guinea, but especially on New Hanover. However, in spite of this, outbreaks are often reported from New Hanover, though tree hopper numbers obviously fluctuate from year to year. Apparently the same position applies to New Ireland and Lihir Island where *L. bicolor* is also well established.

New Hanover has served and continues to serve as a source of supply for both *L. bicolor* and *D. leefmansii*. From here both parasites have been periodically sent to almost all tree hopper affected areas in Papua New Guinea, and in a majority of cases very good establishment and subsequent control have been reported. However, there are many areas where the parasites appear to be ineffective.

In contrast to New Hanover, New Ireland and Lihir Island, no recurrence of outbreaks has ever been reported from Abdingi and Arawe Plantations in the Gasmata area of New Britain after parasite releases in 1935. Similarly, tree hoppers have been almost non-existent on the Gazelle Peninsula since the releases of *L. bicolor* in 1948.

Environmental conditions would appear to play a significant part in the regulation of populations of both tree hoppers and their natural enemies. However, in view of the findings of Froggatt and O'Connor (1940) that highest parasitism of eggs by *L. bicolor* and *D. leefmansii* occurs in those eggs which are laid in epiphytes, followed by those in the fibre in the head of the palms, followed by those in the soil, a closer study of the parasitism

rates for the various oviposition sites in different localities throughout Papua New Guinea should be made. Simmonds (1960) has also commented on this point. It could be that in less affected areas the oviposition sites are such that the oothecae are easily accessible to parasites.

Thus, a great deal of work on the ecology of both the pest and its parasites remains to be carried out before a clear understanding of the problem can be gained. No adequate chemical control measures have yet been devised although good kills of adults and nymphs have been obtained with malathion and monocrotophos sprays and DDT/BHC dust. In areas where parasites have not yet been released, it would seem desirable to introduce them before attempting other methods of control. General observations have indicated that perhaps *L. bicolor* does not have good dispersal powers and therefore separate releases might be necessary for different areas located at a distance from one another.

#### REPORT ON THE SURVEY OF SOUTHERN NEW BRITAIN, 24th APRIL TO 4th MAY, 1969

The survey was undertaken in response to reports that *Eumossula gracilis* and *Promecotheca papuana* were causing damage to the coconut palms on the south and north coasts, West New Britain (Figure 2—localities not to scale). The primary purpose of the survey was to assess the severity of the damage, to investigate the role of parasites and predators as biocontrol agents, and in the case of *Promecotheca*, to see what stages were present.

With *Promecotheca*, old egg cases and larval mines were examined in the field for the presence of parasite emergence holes and samples of these stages of the present generation, wherever possible, were also collected for laboratory examination. With *Eumossula*, oothecae were collected for laboratory examination, usually from the soil around the bases of palms and occasionally from the fibre on the palm trunks.

Detailed observations for each locality visited are listed separately, although there are some general points which can be stated at the outset. Almost without exception the Local Government Councillors of *Promecotheca* affected areas stated that the initial infestation commenced



that the egg parasite was probably *C. splendens*. A few dead larvae of the previous generation showing parasite emergence holes were found in the old mines in the leaves and, although it is difficult to say with certainty, the pupal skins of the larval parasites suggested that they were *P. parvulus* and *A. lalori*. *A. lalori* is already known to occur on the south coast and since *P. parvulus* had been bred and released at Fulleborn and Lindenhafen Plantations, it is little wonder that this parasite, which has good powers of dispersal, should have spread to Amio.

With regard to other plants attacked by *P. papuana*, none of the *Pandanus* inspected were infested, but old broken egg-cases and old larval mines were found on one or two leaves of betel-nut palms growing under coconuts. Neither emergence holes nor pupal skins of parasites were found in these eggs and mines.

The presence of egg and adult stages only appeared to be suggestive of the 'one-stage' condition. However, O'Connor (1940) observed that there was very little overlapping of generations in *Promecotheca* and that this was due either to destruction of eggs by parasites and predators or to a shorter life span in the field than that observed in the laboratory. This last suggestion appeared to fit in well with the Amio situation, as the parasitism and predation rates were still low. During an outbreak period, two to three thousand adults are usually present on fronds. As the numbers present at Amio were much lower than this and as the palms were putting out new undamaged fronds, it appeared that the outbreak was already over.

Since the palms were recovering and parasites were also in evidence, the application of chemical control measures did not appear to be warranted. However, a careful watch on the situation for some time seemed to be necessary.

*Eumossula* damage was not in evidence at the time of the visit, but the villagers reported that the insect had almost defoliated a few shore-side palms near the village before the *Promecotheca* outbreak but that it disappeared shortly afterwards.

#### Fulleborn Plantation

The manager reported appreciable damage by *Promecotheca* on a shore-side palm in Novem-

ber, 1968. After some time many adults of the parasite *P. parvulus* were noted and apparently checked the spread of the pest. At the time of the visit, isolated mines were present on a few young palms near the site of the original infestation and quite a few larvae on these were parasitized.

No *Eumossula* damage was observed but the manager said that *Scapanes* sp. was responsible for considerable damage to palms.

#### Penlolo Village

*Promecotheca* damage was more pronounced at this village than at Amio. Many of the shore-side palms near the village had a burnt appearance and only the midribs of the leaflets were left. According to the villagers, the pest appeared about the end of the 1968 wet season on a couple of palms near houses at the anchorage point.

At the time of this visit the severity of damage seemed to have slackened and new undamaged fronds were unfolding. Palms for a distance of about a mile and a half along the coastal fringe appeared to be in the same condition, except that the shore-side palms (mostly old) had suffered more damage than the inland ones (mostly young).

Both eggs and adults were present but were less abundant than at Amio. As at Amio, parasite emergence holes and cast pupal skins were present in the egg cases and larval mines of the previous generations, but no parasites were seen.

A number of dead adults were found sticking to the underside of fronds. Whitish fungal mycelium protruded from underneath the beetles and from the head and thorax and from between the pleurites. A maximum of 14 dead adults was counted on a frond whilst an average of two dead adults was common. The fungus appeared to be *Synnematium jonesii*, as described by O'Connor (1940). Although O'Connor discounts this fungus as being of any importance in the control of *Promecotheca*, at Penlolo it certainly seemed to be one of the factors responsible for reduced adult populations.

No *Eumossula* damage was observed but there was a mild attack of *Scapanes* sp. evident.

### Atui Island

The *Promecotheca* attack on Atui Island was probably recent as the damage was negligible and mainly concentrated on the shore-side palms. However the villagers reported a severe outbreak on palms on the mainland side of the island a year or so ago.

The shore-side palms at the original infestation site carried heavy populations of all stages of the pest. In the inland areas, whilst numbers were much lower, all stages were also present. The larval parasites *P. parvulus* and *A. lalori* and the egg parasite *C. splendens* were recovered from field-collected samples.

On the mainland side of the island there had previously been some damage by *Promecotheca*, but at the time of the inspection new undamaged fronds were appearing and the pest was in the multiple-stage condition. Both egg and larval parasites were abundant and quite a few adults killed by the fungus (? *Synnematum jonesii*) were in evidence.

No *Eumossula* damage was observed.

### Lindenhafen Plantation

When inspected, *Promecotheca* were very rare and the ones present were in the multiple-stage condition. Some palms supporting kurukum ants (*Oecophylla smaragdina* F.) were entirely free of the pest while a few others nearby without kurukums were infested. Frond samples from randomly selected palms from different parts of the plantation were examined and most were found free of the pest, whilst a few had old larval mines showing parasite emergence holes. On almost all the infested palms cast pupal skins, pupae and dead adults of *P. parvulus* were to be found inside the *Promecotheca* larval mines.

A very mild attack of *Eumossula* was present in scattered, localized pockets.

Starting from Lindenhafen, palms on four small islands (Lue, Walanguo, Sivot and Kiwok) were scanned with field-glasses, but no evidence of attack by *Promecotheca* and *Eumossula* was observed.

### Avrin Island

This island appeared to be free from both *Promecotheca* and *Eumossula*. There were, however, a few old *Promecotheca* mines, but

most showed parasite emergence holes. From the cast pupal skins it appeared that both *P. parvulus* and *A. lalori* may have been present.

### Ring Ring, Akam and Avhan Villages

Although these villages are situated in close proximity to each other *Promecotheca* attained outbreak proportions at Ring Ring and Akam some two to three years previously. At Avhan it reached pest proportions in 1953, and since then apparently appeared in small numbers every wet season. It usually declined soon after the wet season finished. Transportation of a small number of older larvae or pupae from Avhan, possibly through the agency of local inhabitants carrying sago or nipa palm leaves or baskets made from coconut leaves, apparently spread it to the other two villages. However, it would appear that *Promecotheca* has been kept under check by natural enemies at Avhan following the initial 1953 outbreak.

At the time of the visit, the insect was in the multiple-stage condition at all three villages, the only difference being that the populations at the newly infested villages were greater than at Avhan. *P. parvulus* was the main larval parasite present, although *A. lalori* was also present in small numbers.

Nipa palm was quite common in the area and appeared to be as attractive as coconut as a host for *Promecotheca*, as were the pest larvae in them as hosts for egg and larval parasites. Appreciable numbers of the present generation mines were dry and small in size, indicating that the *Promecotheca* larvae in them had either been attacked in the early stages by parasites or had been killed by a disease.

On the whole, the *Promecotheca* situation at these villages appeared to be good, with natural control of the pest species occurring.

No *Eumossula* damage was evident.

### Agur Island

As at the preceding three villages, *Promecotheca* was in a multiple-stage condition and under good natural control. *P. parvulus* was the main larval parasite present while the few specimens of egg parasites reared out appeared to be different from *C. splendens*. They could possibly be *Anastatus* sp.

No *Eumossula* damage was observed. *Scapanes* sp. and palm weevil (*Rhyncophorus* sp.) had been causing light damage since August, 1968.

#### Ablingi Plantation

The owner of the plantation stated that there had been no *Promecotheca* or *Eumossula* problem on the mainland plantation, but that a mild infestation of the latter had been in evidence on the island for quite some time. On inspection, the mainland plantation was found to be free from both insects except for one third-stage larva of *Promecotheca* which was obtained from a young palm.

The island palms showed a mild attack of *Eumossula* but this was restricted to a few shore-side palms. *Eumossula* oothecae were hard to find. *Leefmansia bicolor* was released on Ablingi in 1935, and since then no outbreak has been reported. However, it is not known whether the low numbers since 1935 are due to the activities of the parasite or to some other factors.

Coconut palms on Aivet Island were scanned with field-glasses. Most of the palms appeared to be healthy except for a patch of young palms at the end of the island. They looked as though they may have been infested by *Promecotheca* but it was not possible to have a close look to substantiate this.

#### Malenglo Island

According to the statements of the islanders, a *Promecotheca* infestation on Malenglo Island started about two years ago on a few shore-side palms near the school. When inspected, most of the palms were showing new, undamaged fronds. *Promecotheca* was present mainly as adults and eggs, although isolated first instar larval mines were also found.

Parasitism in the previous generation eggs appeared to be in the vicinity of 60 to 70 per cent and an appreciable number of old larval mines also showed evidence of parasite attack. The parasites reared out from the collected material were *P. parvulus* from larvae, and *C. splendens* from eggs.

No *Eumossula* damage was observed.

#### Sep Sep Island and Mainland

Although *Promecotheca* was present in adult, egg and larval stages, numbers have apparently

been so low that it has never been noticed by the people of the island. Some of the old mines showed evidence of parasite emergence holes.

*Eumossula* was said to have been quite serious both on the island and the mainland palms some two years ago. Present damage was moderate. On the mainland side of the island there were quite a few eggs present in the soil, of which about 80 per cent had already hatched. There was no evidence of parasite emergence from the eggs and intact oothecae obtained from the island failed to produce any parasites in the laboratory. Thus it would appear that egg parasites are absent from this area. Should the pest break out again, introduction of *L. bicolor* would be desirable.

#### Aliwa Plantation

This plantation appeared to be free from *Promecotheca* and *Eumossula*, but there was a mild attack of the leaf-eating hispid *Brontispa* sp.

From Aliwa Plantation to Kandrian, native coconut groves along the shore were scanned with field-glasses, but none appeared to have been affected by either *Promecotheca* or *Eumossula*.

#### Kandrian

As at Sep Sep, it was reported that *Eumossula* had been serious some time ago. At the time of inspection, little damage was evident. Oothecae samples received at Keravat from this area a month later only yielded one specimen of the scelionid egg parasite *Prosaepus atrellus*.

#### Demgalu Village

At Demgalu Village *Eumossula* damage was mild but was reported to have been serious some time ago. Most of the oothecae collected were intact and seemed to have developing nymphs inside. No parasites were obtained from the material collected.

Very few scattered adults, egg cases and larvae of *Promecotheca* were in evidence and the main larval parasite operating at this time was *A. lalori*.

Another village nearby, Messelia, was not actually visited but people at Demgalu described the *Eumossula* situation there as being similar to that at Demgalu.

### Pelilo Island

The first *Eumossula* outbreak on Pelilo Island is reported to have occurred some time in 1934-35. This was approximately the same time that tree hopper damage was bad at Arawe Plantation, and the egg parasites *L. bicolor*, *D. leefmansii*, an unidentified encyrtid and an unidentified mymarid were introduced to Arawe, of which only *L. bicolor* established (Department of Agriculture, New Guinea 1937).

The present outbreak at Pelilo Island started in 1968 when most of the palms were stripped bare of leaflets and many deaths followed.

During 1968, *L. bicolor* was introduced and *Eumossula* disappeared almost completely soon after. When inspected on this visit, most of the palms had already recovered from the attack and only isolated *Eumossula* adults could be found. Where hundreds of oothecae had been collected just by scraping the top soil around the base of the palms during the outbreak period, seven trained persons searching for eggs for about an hour obtained only nine eggs. Most of these were flattened, with a dead, hard, brittle embryo inside, indicating possible death by disease. Eggs so affected were also obtained from most of the *Eumossula* infested areas visited.

It is not known whether the immediate disappearance of *Eumossula* from Pelilo Island was due to the action of *L. bicolor* or to a population crash resulting from lack of food. The much improved condition of palms at this island compared to palms at other *Eumossula* outbreak areas visited earlier would seem to suggest that the introduction of *L. bicolor* has been successful.

*Promecotheca* was present but in very small numbers.

### Arawe Plantation

A very short visit was paid to this plantation. The manager was not aware of any serious damage by *Eumossula* or *Promecotheca* and inspection of some of the coastal palms revealed only a mild attack of *Eumossula*. As already mentioned, *L. bicolor* was introduced and established in 1935.

### Kumbun Island

No detailed observations could be made at Kumbun Island as we arrived there late in

the evening and had to leave early in the morning. However, a brief inspection of the palms showed a moderate attack by *Eumossula*. The islanders stated that the pest appeared by the end of every wet season on the shore-side palms on one side of the village. It always disappeared of its own accord after three to four months but during this period the palms suffered considerably.

Only scattered mines and adults of *Promecotheca* were present.

### Sag Sag Village

Except for a completely stripped frond or two on a few scattered palms, *Eumossula* damage was only moderate at Sag Sag Village. The soil was a heavy, wet soil, and no oothecae were obtained, even from under those palms which had the few completely stripped fronds.

From Sag Sag we travelled to Kilengi Mission. All along the road moderate *Eumossula* damage could be seen on coconut palms, whilst damage to banana leaves was also observed.

No *Promecotheca* damage was noticed.

### Kilengi Mission

The *Eumossula* position at Kilengi Mission appeared to be the same as that at Pelilo, the insect having reached plague proportions some time in 1967. *L. bicolor* was liberated at the Mission in the same year. During the present inspection it was obvious that the situation was even better than that at Pelilo. Palms looked very healthy and hardly any trace of *Eumossula* could be found.

Efforts were made to collect oothecae to see if *L. bicolor* had established, but intensive search by nine people at sites where eggs had been plentiful before liberation of the parasite yielded two eggs only. It is possible that the lack of oothecae at most of the places visited could be due to the fact that this was not the proper breeding period for *Eumossula*. However, it is thought that the very low number of *Eumossula* at Pelilo Island and Kilengi Mission was due to the activities of *L. bicolor*. At least the villagers appeared to be very much impressed by the role of *Leefmansia* in reducing the pest population.

No *Promecotheca* was found.

### Cape Gloucester

A mild attack of *Eumossula* was evident on the coastal palms at Cape Gloucester, and a few eggs were collected, mostly from the fibre around the trunks. Some of the oothecae showed parasite emergence holes but no parasites were obtained from the eggs collected. Quite a few of the oothecae appeared to be diseased.

No *Promecotheca* damage was in evidence.

### Tavelei Village

*Eumossula* had been very serious at this village a year or so ago, so serious that some of the palms had been killed. However, when inspected on this visit, the palms had recovered, although some damage was still present. Comparatively more unhatched oothecae were collected than at any of the other localities visited so far. No parasites were bred from the oothecae collected.

Very few *Promecotheca* were present but a mild attack of *Brontispa* sp. was evident.

### Iboki Plantation

*Eumossula* is known to have been present at Iboki Plantation for more than 20 years and appeared to be responsible for a considerable amount of foliage damage during a certain period of each year (possibly the wet season). When inspected, damage was moderate and in fact was the heaviest observed at any locality visited, as were the number of oothecae present in the soil. Some of the eggs had obviously been parasitized by the scelionid *P. atrellus* while many appeared depressed and flat possibly indicating that they were diseased.

Of the 180 eggs collected and taken back to the laboratory, 120 appeared to be diseased. Of the remaining 60, 12 yielded 340 individuals of *Tetrastichus* sp. and 6 produced one individual each of *P. atrellus*. As mentioned earlier, it is not certain whether *Tetrastichus* sp. is a primary or secondary parasite, although it is considered likely to be primary.

*Promecotheca* was not present, but the coconut spathe bug, *Axiagastus cambelli* Dist., was found for the first time during the survey. It occurred in numbers on flowers but did not appear to be of economic importance.

### Poi Island and Mainland

*Promecotheca* was present on the mainland in small numbers as adults, eggs and larvae. Whilst parasite emergence holes were observed both in eggs and third-stage larvae of the previous generation, no specimens were obtained. The third-stage larvae of the present generation collected all turned into pupae from which adults successfully emerged.

The councillor for Poi Island, when questioned, said he had never seen *Promecotheca* damage on any palm on the island although its presence on the mainland was known. *Eumossula*, on the other hand, was well known as it had been responsible for damage to palms on the island over an extended period. It was not known to be present on the mainland. At the time of the visit, a moderate infestation of *Eumossula* was present on the island, while on the mainland it was rare. The few oothecae obtained from under island palms did not yield any parasites.

### Linga Linga Plantation

As at Lindenhafen, Linga Linga appeared to be free of both *Promecotheca* and *Eumossula*. Examination of old, tall palms with field-glasses failed to reveal the presence of any stages of *Promecotheca*. However, isolated third-stage larvae and pupae (very rarely first- and second-stage larvae also) were observed on scattered young palms. Pupae and larvae of *P. parvulus* were also recovered from larval mines on these palms.

Since the majority of the third-stage larvae and pupae collected from Linga Linga grew into adults in the laboratory, it would appear that there could well be a population increase in the near future, and *Promecotheca* could assume a one-stage condition. However, under normal circumstances and in the presence of *P. parvulus*, this should not occur unless unfavourable environmental conditions favour the build-up of the pest and hinder the parasites. At the time of the visit the position appeared to be normal with a balance existing between host and parasites.

## CONCLUSIONS

Generally speaking it can be said that in the area surveyed *Promecotheca* and *Eumossula* had been serious, mostly on native groves, about a year or two before the present visit. In April, 1969, the situation appeared to have improved considerably. It is not known whether this was just a seasonal phase (especially with *Eumossula*) or termination of the outbreak. Most of the plantations—Fulleborn, Lindenhafen, Ring Ring, Arawe, Ablingi and Linga Linga—were free from *Promecotheca* and *Eumossula*. However, Iboki Plantation was still affected to a moderate extent by *Eumossula*.

Most of the natural enemies of *Promecotheca*, with the exception of *Eurytoma promecothecae*, appeared to be fairly well distributed throughout the areas visited, while the egg parasites of *Eumossula* (as determined from the very small samples of eggs available) appeared to be absent. At Iboki Plantation a eulophid, *Tetrastichus* sp., was obtained from about 20 per cent of eggs collected whereas the scelionid *Prosapegus atrellus* was only rarely obtained.

The healthy-looking condition of palms and the almost complete absence of both oothecae and adults at a couple of groves where the egg parasite *Leefmansia bicolor* had been liberated against *Eumossula* a couple of years ago could possibly be taken as a guide to the successful role of this parasite under similar ecological conditions. However, it would appear that because of its apparently poor dispersal rate, separate liberations for each of the affected localities may be necessary, should the need for introductions arise.

The most likely mode of *Promecotheca* spread to new areas in Papua New Guinea is through the agency of the local inhabitants themselves through transportation of infested sago or nipa palm leaves for use in house-making and other purposes. Even coconut leaves used for basket-making would serve the same purpose. Work boats coming from infested areas also appeared to have been partly responsible for transporting adults from one place to another.

Whilst the factors responsible for the recurrence of outbreaks of *Promecotheca papuana* in Papua New Guinea, even where the parasites are well established, are partly unknown, it would appear that sudden population crashes

possibly resulting from unfavourable environmental conditions and diseases (thus causing drastic reductions in parasite populations) may be one of the reasons. Perhaps there are no alternate hosts for the parasites to maintain reasonable populations when sudden crashes in *P. papuana* populations occur. It could well be that the host plant range of *P. papuana* in Papua New Guinea is not fully known and that some of these unknown host plants may be unsuitable for the successful parasitization of the larvae and pupae within the mines on these plants.

The causes of the periodic outbreaks of tree hoppers are also not fully known, but environmental conditions appear to play a significant role in the regulation of populations. Outbreaks are more frequent in areas where no regular dry periods occur. It would also seem that the oviposition behaviour of the tree hopper, in different localities of Papua New Guinea, may be important. Highest parasitism rate of eggs by *Leefmansia bicolor* and *Doirania leefmansii* is to be found in those oothecae which were laid in epiphytes, followed by those in the fibre in the crown of palms. It could be that in the seriously affected areas oviposition by tree hoppers occurs in sites where the eggs are not easily accessible to the egg parasites.

As the *Promecotheca* outbreaks at all the infested localities, except for Atui Island where the outbreak was only recent, had greatly declined and the parasites were present at the time of the visit, it was considered that the destructive phase of the insect attack was over and no other control measures were deemed necessary. Because of the apparent absence of tree hopper egg parasites from most of the affected areas, introduction of *L. bicolor* into these localities was considered worthwhile.

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## REFERENCES

- Department of Agriculture, New Guinea (1937). Report of the Entomologist. Year ending 30th June, 1936. *New Guinea agric. Gaz.*, 3:8-10.
- DASF (1968). *Rep. Dep. Agric. Stk Fish., Papua New Guinea*, 1965-66.
- DUMBLETON, L. J. (1954). A list of insect pests recorded in South Pacific Territories. *Tech. Pap. S. Pacif. Commn.*, 79:1-196.
- DUN, G. S. (1954). Annual Report of the Senior Entomologist. Department of Agriculture, Stock and Fisheries, 1952-53. *Papua New Guin. agric. Gaz.*, 8:18-27.
- FROGGATT, J. L. (1935). The long-horned tree-hopper of coconuts, *Sexava* spp. *New Guinea agric. Gaz.*, 1:16-27.
- FROGGATT, J. L. (1937). Egg parasites of *Sexava* spp. in the Territory of New Guinea. *New Guinea agric. Gaz.*, 3:24-25.
- FROGGATT, J. L. (1940). Entomologist's Report in Annual Report of the Department of Agriculture for the year ending 30th June, 1939. *New Guinea agric. Gaz.*, 6:9-13.
- FROGGATT, J. L. AND O'CONNOR, B. A. (1940). Insects associated with the coconut palm. *New Guinea agric. Gaz.*, 6:16-32.
- FROGGATT, J. L. AND O'CONNOR, B. A. (1941). Insects associated with the coconut palm. pt. 2. *New Guinea agric. Gaz.*, 7:125-33.
- GREENSLADE, P. J. M. (1965). *Promecotheca opacicollis* Gestro (Coleoptera: Chrysomelidae) on the island of Tikopia. *Pacif. Insects*, 7:661-64.
- GRESSITT, J. L. (1958). Ecology of *Promecotheca papuana* Csiki, a coconut beetle. *Int. Congr. Ent.*, 10:747-53.
- GRESSITT, J. L. (1959). The coconut leaf-mining beetle, *Promecotheca papuana*. *Papua New Guin. agric. J.*, 12:119-47.
- LEVER, R. J. A. W. (1969). Pests of the coconut palm. *FAO agric. Stud.*, 77:1-190.
- O'CONNOR, B. A. (1940). The coconut leaf-miner, *Promecotheca papuana* Csiki, and its parasites. *New Guinea agric. Gaz.*, 6:20-30.
- SIMMONDS, F. J. (1960). Report on a tour of Commonwealth countries April-November, 1959 (Commonwealth Agricultural Bureaux: London) pp. 1-108.
- SMEE, L. (1965). Insect pests of *Cocos nucifera* in the Territory of Papua and New Guinea: their habits and control. *Papua New Guin. agric. J.*, 17: 51-64.
- TAYLOR, T. H. C., (1937). The biological control of an insect in Fiji (Imp. Inst. Ent.: London) 239 pp.

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