The

Papua and New Guinea

Agricultural Journal

Vol. 13 March, 1961 No. 4

CONTENTS

Former Issues of *Gazette* and *Journal*

The following numbers of the *Agricultural Gazette* have been issued :

New Guinea Agricultural Gazette—

Volume 1, Number 1.
Volume 2, Numbers 1, 2 and 3.
Volume 3, Numbers 1 and 2.
Volume 4, Numbers 1, 2, 3 and 4.
Volume 5, Numbers 1, 2 and 3.
Volume 6, Numbers 1, 2 and 3.
Volume 7, Numbers 1, 2, 3 and 4.

The Papua and New Guinea Agricultural Gazette—

Volume 8, Numbers 1, 2, 3 and 4.

The Papua and New Guinea Agricultural Journal—

Volume 9, Numbers 1, 2, 3 and 4.
Volume 10, Numbers 1, 2, 3 and 4.
Volume 11, Numbers 1, 2, 3 and 4.
Volume 12, Numbers 1, 2, 3 and 4.
Volume 13, Numbers 1, 2 and 3.

Copies of all numbers of the *Gazette* to Volume 7, No. 4, are out of print.

INSECT PESTS OF THEOBROMA CACAO IN THE TERRITORY OF PAPUA AND NEW GUINEA*

By J. J. H. Szent-Ivany †

In this paper, an attempt is made to give a general picture of cacao insect problems in the Territory of Papua and New Guinea. To the best of the author's knowledge, all insects recorded in association with Theobroma cacao *are listed, besides several new unpublished records.*

In the chapter, " Major Pests ", three mirids (capsids), one coreid, three curculionids and two cerambycids are mentioned as major or important pests of cacao. More than 140 *minor pests are listed, representing the orders : Collembola, Isoptera, Orthoptera, Hemiptera, Lepidoptera, Coleoptera and Hymenoptera. Some of the minor pests are only identified to the genus. Twenty insect species are mentioned as parasites or predators of cacao pests in the Territory ;* 28 *of the* 41 *references refer to cacao pests in Papua and New Guinea.*

INTRODUCTION

As far as can be ascertained, the first printed records of insects associated with *Theobroma cacao* in the Territory of Papua and New Guinea were published more than 22 years ago by J. L. Froggatt (1938*a*, 1938*b*). Two new stem borer weevils were mentioned in the first publication (1938*a*) and some other insects (pests of the trunk, branches, pods and foliage) in the second paper (1938*b*). These and other papers written on cacao pests in Papua and New Guinea between 1938 and 1954 were recorded in a comprehensive list of insects of cultivated plants of the South Pacific Region by L. J. Dumbleton (1954).

As a result of investigations carried out during the past six years by the entomologists of the Department of Agriculture, Stock and Fisheries, many more insect pests became known from *Theobroma cacao* in the Territory of Papua and New Guinea. Some of these are mentioned in publications of E. B. Britton (1957), E. S. Brown (1958*a*, 1958*b*), G. S. Dun (1954*a*, 1954*b*, 1955), Sir Guy A. K. Marshall (1957), C. D. Michener and J. J. H. Szent-Ivany (1960), N. C. E. Miller (1957), J. J. H. Szent-Ivany (1954, 1956*a*, 1956*b*, 1959), J. J. H. Szent-Ivany and A. Catley (1960*a*, 1960*b*, 1960*c*) and D. J. Williams (1960). Szent-Ivany, in co-authorship with J. H. Ardley, presented a short paper on the main cacao insects of the Territory of Papua and New Guinea at the Ninth Pacific Science Congress, held in Bangkok in November, 1957.

Many cacao pests found in the Territory of Papua and New Guinea since the end of the last war have represented new genera and species. Some of these have been described and named (Britton 1957, Brown 1958*a*, China and Carvalho 1951, Marshall 1957, Miller 1957). Others, including a new genus of Limacodidae (Szent-Ivany, 1954), are still awaiting description by specialists.

So far no serious regional insect pest has been found in the Territory of Papua and New Guinea. In comparison with other parts of the world, such as West Africa with its *Pseudococcus*

---

* This paper was first presented at the First F.A.O. Technical Conference on Cacao, held in Accra (Ghana) in February, 1959. It has now been amended to include results of investigations carried out since that time.

† Senior Entomologist, Department of Agriculture, Stock and Fisheries, Port Moresby.

njalaensis Laing, the main vector of the swollen shoot disease, or South America with its leaf-cutting ants, this Territory is in a very favourable position. There are a few major or important cacao pests in the Territory of Papua and New Guinea, but most of them are restricted to relatively small areas.

The population density of some minor local pests has been kept under the level of economic injury by natural enemies for many years. However, it happens in some years that unusual weather conditions or some unknown density-regulating factors cause upsets in the balance of host and parasite sequences, and this results in sudden serious outbreaks. In most cases these outbreaks are restricted to relatively small areas, often to one or two plantations only, and usually they are of short duration.

Nearly all cacao pests found in the Territory of Papua and New Guinea are indigenous species of the coastal rain-forest zone. Most plantations were established in the coastal area by clearing of the virgin forest and many of them are still more or less surrounded by primary or secondary forest. Most plantations were abandoned during the last war, and for years no measures of plantation hygiene were carried out in them. Trees and shrubs of the neighbouring forest invaded the plantations. Tall grasses and undergrowth, consisting of various weeds, grew up in a short time and some cacao plantations have almost reverted to secondary forest. Simultaneously, with the spread of the forest plants into the abandoned cacao blocks, members of the forest insect associations appeared in the plantations and some of these became adapted to *Theobroma cacao* as a host plant. This is how a number of species of Curculionidae, Miridae and Cerambycidae invaded the cacao plantations and became the most important pests of *Theobroma cacao* in the Territory of Papua and New Guinea. Recently, the coreid, *Amblypelta theobromae* Brown, was observed causing severe damage to cacao pods (Brown, 1958*b*), and this also has to be considered a major pest.

To the best of the author's knowledge, all recorded cacao pests of the Territory of Papua and New Guinea are mentioned in this paper. It also includes many new unpublished records. The bibliography contains all publications on Territory cacao insects which are known to the author.

I. MAJOR PESTS

A. PANTORHYTES SPP.

("STEM BORER WEEVILS")

Curculionidae of the apterous genus *Pantorhytes* (subfamily Pachyrhynchinae) have to be considered major pests of cacao in Papua and New Guinea. This weevil genus has more than 20 known and probably another 15 to 20 undescribed species in the Papuan Zoogeographical Subregion, but so far only five species have been found causing injury to *Theobroma cacao*. The brightly-coloured species, *Pantorhytes plutus* Oberth. (Plate 1A), was first recorded more than 20 years ago (Froggatt, 1938*a*). The adult weevils feed on the leaves and on the bark of cacao trees. The main damage is caused by the larvae. The females lay their eggs in cracks and crevices on the bark of the trunk or branches and the larvae bore into the sapwood. They prefer to tunnel in the area of the jorquette, but they also attack laterals, some distance away from the jorquette. According to Froggatt (1938*a*), a fork between the branches is much favoured by the larvae of *Pantorhytes plutus*. The holes are easy to find because of the presence of frass or greyish-white, gummy exudate at the entrances of the tunnels. The tunnels are usually straight, but sometimes the larvae ringbark the branch and in such cases the tissues of the section above the injury die (Henderson, 1954). In healthy trees, the gumming may be effective because it may stop the development of the larvae. Diptera larvae are often found in the gum, but they are apparently scavengers (Froggatt, 1938*a*). A thorough study of the bionomics of *Pantorhytes plutus* was carried out by B. A. O'Connor and G. S. Dun shortly after the war (Dun, 1955).

The chemical control of *Pantorhytes plutus* is rather difficult. Banding experiments carried out by Dun in the 1940s were quite successful. Bands of Ostico [1] mixed with a 10 per cent. D.D.T. dust, spread for a distance of about six inches along the stem, resulted in a high mortality of adult weevils walking over the bands up to a year after treatment (Dun, 1955). For economic reasons, banding experiments were recently abandoned and a series of new experiments with various modern insecticides was commenced at Lowlands Agricultural Experiment Station, Keravat, New Britain.

[1] "Ostico" is the trade name for a sticky banding material.

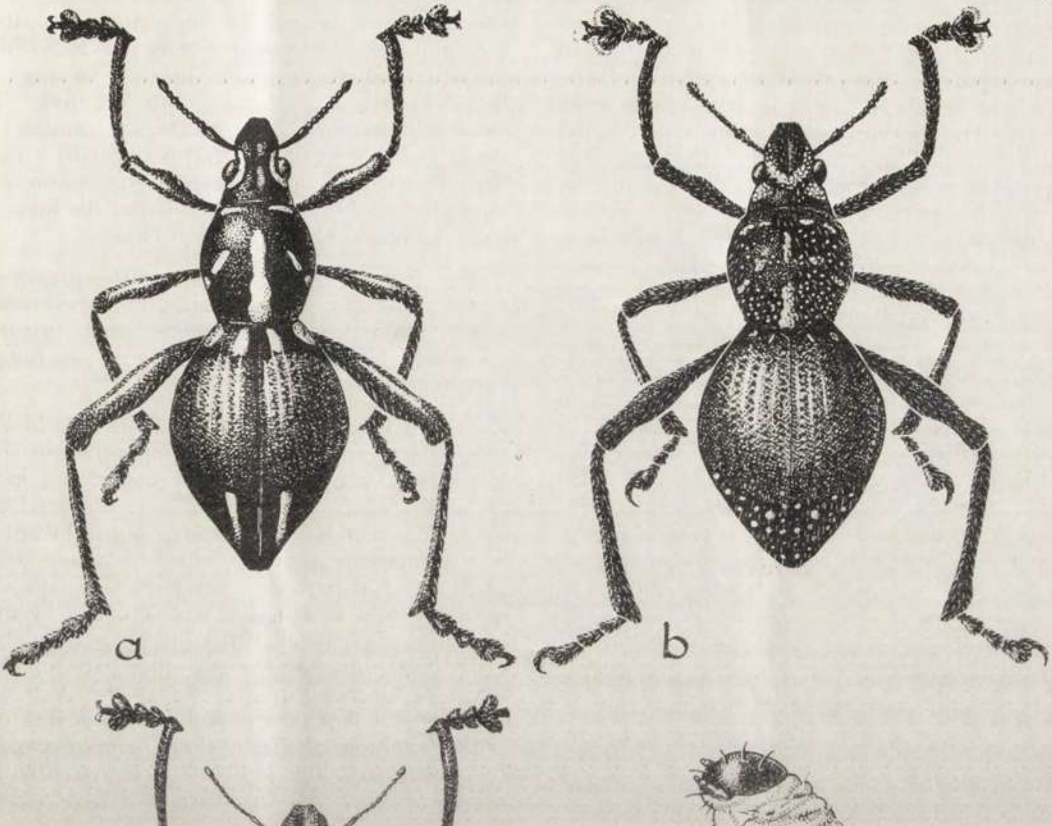


PLATE 1. [Drawings by M. L. Szent-Ivany]

(4 x Nat. Size)

a. *Pantorhytes plutus* Oberth. (adult). c. *Pantorhytes proximus* Fst. (adult).

b. *Pantorhytes szentivanyi* Mshl. (adult). d. *Pantorhytes proximus* Fst. (larva).

It has been noted that *Pantorhytes plutus* and the other *Pantorhytes* spp. tend to appear in dense populations in somewhat neglected plantations, and better plantation hygiene effects some relief. The author visited the experimental blocks at Lowlands Agricultural Experiment Station, Keravat, almost every day during his five-month stay at the station in 1954, but he was unable to find more than one adult specimen. In response to a request by the late Dr. F. I. van Emden, who intended to study the morphology of the larvae of *Pantorhytes plutus*, the author had to visit an old, entirely neglected cacao block (established in 1913) in the Bainings area of New Britain to collect sufficient number of larvae for study. However, there must be a certain fluctuation of population density of this curculionid in the Gazelle Peninsula of New Britain, because Dun (1954*a*) reported considerable numbers of *Pantorhytes plutus* on old cacao in 1951 and 1952 at Keravat, where plantation maintenance is always adequate. There was also a marked increase in populations since 1956 in some plantations of the Gazelle Peninsula.

During the past six years, four other species of *Pantorhytes* were found damaging cacao in the Territory of Papua and New Guinea. In 1955, *Pantorhytes proximus* Fst. appeared in mass populations in the Markham Valley (Morobe District of New Guinea). It appeared first in a very neglected plantation which was abandoned during the war and in which no plantation hygiene measures were carried out for many years. Many trees in this plantation were killed as a result of borer damage caused by *Pantorhytes proximus* and by various cerambycids. *Pantorhytes proximus* spread very rapidly into other plantations, including a cacao block at the Agricultural Experiment Station, Bubia. The borer damage caused a serious setback in growth and a reduction in yield at Bubia and in parts of some other cacao blocks in the Markham Valley.

Pantorhytes proximus (Plate 1C) is a more simply coloured weevil than *Pantorhytes plutus*. Its larva (Plate 1D) is a creamy-white grub with a reddish-brown head. The larvae of the other four species found damaging cacao trees in New Guinea are very similar in appearance to those of *Pantorhytes proximus*. The habits of *Pantorhytes proximus* are very similar to those of *Pantorhytes plutus*. It rarely attacks trees under three years of age. Most larvae are found in and around the jorquette. Repeated tunnelling by a dozen or more larvae in the jorquette sometimes results in the cracking of the stem, which eventually kills the tree. If there is a large quantity of gummy exudate at the entrance of a borer hole, this is usually a sign that the weevil has emerged and secondary saprophagous Diptera larvae colonize the hole in large numbers (Szent-Ivany, 1956*a*).

The chemical control of *Pantorhytes proximus* seems to be difficult. A series of experiments with chlorinated hydrocarbons and organic phosphate insecticides is in progress at Bubia Experiment Station.

A third species, *Pantorhytes szentivanyi* Mshl. (Plate 1B), was found damaging cacao in the Northern District of Papua in the second half of 1955. The first specimens were observed by Mr. F. C. Henderson and Mr. W. I. Fielding in a plantation in the Mount Lamington area, 1,000 to 1,100 feet above sea level. This species appeared to be new and it was described by the late Sir Guy A. K. Marshall (1957). Recently, it has been found in various other parts of the Northern District (in the area of the Agricultural Station, Popondetta, and in the vicinity of some plantations, lying at lower levels between Popondetta and the coast). More recently it has been found also in various village cacao blocks between Popondetta and Kokoda.

Pantorhytes szentivanyi has similar habits to the two aforementioned species, but there are certain differences in their ethological characteristics. A larger proportion of the larvae of this species can be found in the branches at a greater distance from the jorquette than is the case with the other species (Szent-Ivany, 1956*a*). The larvae of *P. szentivanyi* were observed feeding in cacao pods and the adults were observed chewing the surfaces of the pods. The same habit has also been recently developed by *P. proximus* in the Morobe District. Besides this, the adults were seen feeding on the bark of young shoots, as was observed in the case of *P. plutus* in New Britain (Henderson, 1954).

During a visit to the plantation, where Henderson and Fielding observed *P. szentivanyi* the first time, the author found that this plantation was infested with three potential pests (the mirid, *Helopeltis clavifer* Walk.; the coreid, *Amblypelta theobromae* Brown; and the curculionid, *P. szentivanyi*). The last was found in such dense populations in the plantation that 12 to 15 adults could be easily collected on one tree. Several cacao trees were killed as a result of the boring by this curculionid. Many adults were seen feeding on the pods. Their feeding marks were large, brownish scars (with a diameter up to an inch) usually found in rows on the longitudinal ridges of the pods. The scars were very different from the feeding marks caused by some other pod-eating insects (Lymantriidae, Noctuidae, Rutelidae).

The chemical control of *Pantorhytes szentivanyi* is probably as difficult as that of the closely related *P. proximus*. During the outbreak of *P. szentivanyi* and the two mirids, *Helopeltis clavifer* and *Pseudodoniella laensis*, at Sangara Estate (Northern District) in 1955-1956, Mr. W. A. van den Berk, the manager of the plantation, several times applied B.H.C. dust ("Gammexane 20 Powder") against the three potential cacao pests. It was easy to control the two mirids, but the relatively high concentrate of B.H.C. never had any effect on the populations of *Pantorhytes szentivanyi*. A plantation owner in the Northern District paid a fairly high premium to his employees for collecting *Pantorhytes szentivanyi*. At the same time, he cleared his plantation of *Pipturus argenteus*, a plant which was found by Ardley (personal communication) to be an indigenous host plant of *P. szentivanyi* in the Northern District and of *P. proximus* in the Morobe District. B. A. O'Connor had earlier found *Pipturus argenteus* to be an indigenous host plant of *Pantorhytes plutus* in New Britain. It is believed that the *Pantorhytes* spp. have more indigenous host plants in their original habitats. *Pantorhytes stanleyanus* White, an Australian species of the genus (also recorded from New Guinea), was observed defoliating *Hibiscus tiliaceus* at Cairns, North Queensland (Szent-Ivany, 1956*a*). It should be mentioned here that the above-described control measures against *Pantorhytes szentivanyi* (elimination of the indigenous host plant, collecting and killing of adult weevils) were very successful. During a subsequent visit of the author to the plantation where the mechanical and cultivation methods were carried out, the cacao blocks were found almost free of this pest. However, the mechanical control methods are too troublesome, and in the case of serious outbreaks, they are uneconomical. The chances of biological control are very small [2]. Experiments for the chemical control of *Pantorhytes szentivanyi* in the Northern District will be undertaken in the near future.

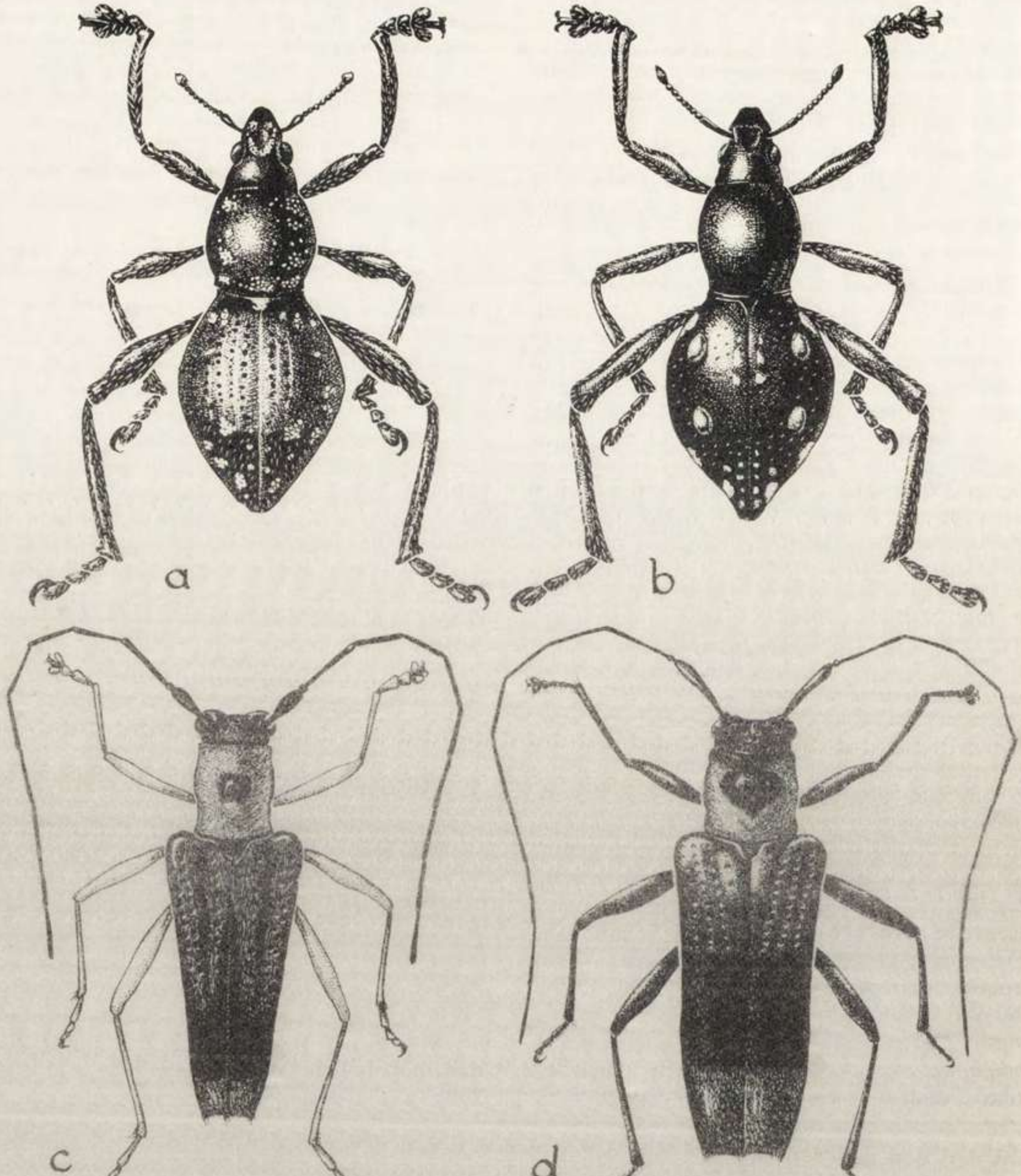
The two other *Pantorhytes* species found causing injury to cacao trees are of minor importance only. One of them, *Pantorhytes biplagiatus* Chevr. (Plate 2A), a species known earlier from the British Solomon Islands as a pest of cacao (personal communication by Mr. E. S. Brown), appeared to cause some damage to cacao trees in the Kieta Subdistrict of Bougainville. The fifth species (*P. quadripustulatus* Gestro) (Plate 2B) was found in dense populations in a small, abandoned cacao grove near Wewak in the Sepik District. The plantation was so badly damaged by the weevil that the trees had to be cut out. It should be mentioned here that the Sepik District is not a cacao-growing area. There are only about 18,000 trees planted in the whole district.

B. MIRIDAE (CAPSIDAE)

The second important group of cacao pests in the Territory of Papua and New Guinea consists of certain species of the family Miridae (earlier known as Capsidae, Heteroptera). The first observations on mirid damage to *Theobroma cacao* were made at Kabeira plantation near Rabaul in New Britain in 1949 (Dun, 1954*b*). Further investigations in the Gazelle Peninsula of New Britain resulted in the finding of three distinct species of Miridae damaging cacao trees. They were forwarded for identification to the

[2] A braconid (genus and species unidentified) was observed parasitizing the larva of *Pantorhytes szentizanyi* Mshl. The observation was made by Dr. F. J. Simmonds and the author at Sangara Estate in August, 1959. Ardley found a large elaterid larva preying upon the larvae of *Pantorhytes szentivanyi*. Small curculionids, such as *Oribius* and *Paratactus* spp. (defoliators of cacao) are often seen attacked and carried by Green Tree Ants or "Kurukums" [*Oecophylla smaragdina* (F)]. Mr. W. J. Fielding mentioned to the author that he threw a large adult of *Pantorhytes szentivanyi* into a group of Kurukum Ants. The ants immediately attacked the weevil, grasping its head and its extremities with their strong mandibulae, but the *Pantorhytes* was able to free itself.

In the Gazelle Peninsula of New Britain (Vunapau Plantation), A. Catley observed *P. plutus* being attacked by Kurukum Ants on a cacao tree. The ants immobilized the weevil by seizing its extremities and it was carried off to the nest where it was presumably eaten.



[Drawings by M. L. Szent-Ivany]

PLATE 2.
(4 x Nat. Size)

a. *Pantorhytes biplagiatus* Chevr. (adult).
b. *Pantorhytes quadripustulatus* Gestro (adult).
c. *Glenea aluensis* Gah. (adult).
d. *Glenea lefebueri Guer.* (adult).

Commonwealth Institute of Entomology, and were examined by W. E. China at the British Museum. When Dr. China saw these insects, he first thought that some of the West African cacao mirids had been accidentally introduced to New Britain, but after closer study of the morphology with J. C. M. Carvalho it was found that they represented two new genera, closely related to some West African Bryocorinae. The two new genera were described by Dr. China and Dr. Carvalho (1951) as *Parabryocoropsis* and *Pseudodoniella*. The new species were named *Parabryocoropsis typicus* [3], *P. duni* and *Pseudodoniella pacifica*. A fourth species found in the collection of the British Museum, obtained earlier by Miss Evelyn Cheesman at Kokoda (Northern District of Papua), was added to the material and was described as *Parabryocoropsis cheesmanae* (China and Carvalho, 1951). A fifth species, collected by G. S. Dun and W. J. Hughes in the Markham Valley in 1951 was first thought to be a variety of *Pseudodoniella pacifica* China and Carv., but later it was described by N. C. E. Miller as *Pseudodoniella laensis* nov. spec. (Miller, 1957) (Plate 3B).

Of the aforementioned species, *Parabryocoropsis typicus* China and Carv. (known as Black Capsid in New Britain) (Plate 3A) appeared to be the most important pest. However, *Pseudodoniella pacifica* China and Carv. was found to be also quite numerous in some plantations, especially at somewhat higher levels (approximately 500 feet and above) (Dun, 1954*a*).

The bionomics of *Parabryocoropsis typicus* was thoroughly studied by Dun (1954*b*). The duration of the life cycle of this species is even shorter than that of the West African cacao mirids, *Sahlbergella singularis* (Hagl.) and *Distantiella theobroma* (Dist.) (Taylor, 1954).

The cacao mirids of New Britain feed mainly on pods, but *Parabryocoropsis typicus* was also observed attacking young shoots. Dun (1954*b*) recorded severe shoot and branch die-back in two plantations in New Britain. However, this type of damage by *Parabryocoropsis* is much less important than the injury to pods, and it is not connected with the attack of such serious pathogens as *Calonectria rigidiuscula*, which appears as a secondary fungus after the injury by *Sahlbergella singularis* and *Distantiella theobroma* in West Africa. The appearance of mirid damage in pockets of about 50 trees, as it is commonly observed in West Africa (Williams, 1953), is not so marked in the case of *Parabryocoropsis typicus* (Dun, 1954*b*).

The adults and neanides (nymphs) of *Parabryocoropsis typicus* and other New Britain cacao mirids suck the juice of the pods. Roundish black lesions appear on the surfaces of the pods as typical signs of dying tissue. This is apparently caused by a toxin injected into the plant tissues through the stylets of the insects (Henderson, 1954) (see figure 1). According to Dun (1954*b*) a large proportion of the damage is caused by the entry of a secondary fungus (*Gleosporium*, sp. ?) which is found in the punctures caused by the mirids.

Mirids, like most Heteroptera, are voracious feeders and a small number of individuals is sufficient to cause severe damage to a relatively large number of plants. According to Dun (1954*b*) the number of feeding scars per insect (in the case of *P. typicus*) varies from 40 to 80 a day. Thus, a population of 10 to 40 insects of *P. typicus* per tree is able to cause considerable damage. Reduction of yield in neglected and untreated blocks can be as much as 60 to 70 per cent. Fortunately *P. typicus* and all other cacao mirids of the Territory of Papua and New Guinea are susceptible to chlorinated hydrocarbon insecticides.

B.H.C. gives good control of *Parabryocoropsis typicus* (in the form of "Gammexane 10 Dust") and it can be applied with hand dusters or small hand power dusters because the trees are not very tall in New Britain. Such control would be impossible on West African cacao trees, but could be applied in some plantations in the Congo Republic (formerly Belgian Congo), where all chupons are removed above the first jorquette so that the trees very seldom exceed 12 feet in height. "Solvexane", an insecticide containing 2.2 per cent. of gamma isomer benzene hexachloride, is very effectively applied with hand dusters against *Sahlbergella singularis* Hagl. at Lukolela Plantations in the Congo Republic (Nicol and Taylor, 1956). *Distantiella theobroma* (Dist.), another African relative of the New Guinea cacao mirids, is also susceptible

[3] Recently G. S. Dun found this species on the Sogeri Plateau, in the Central District of Papua.

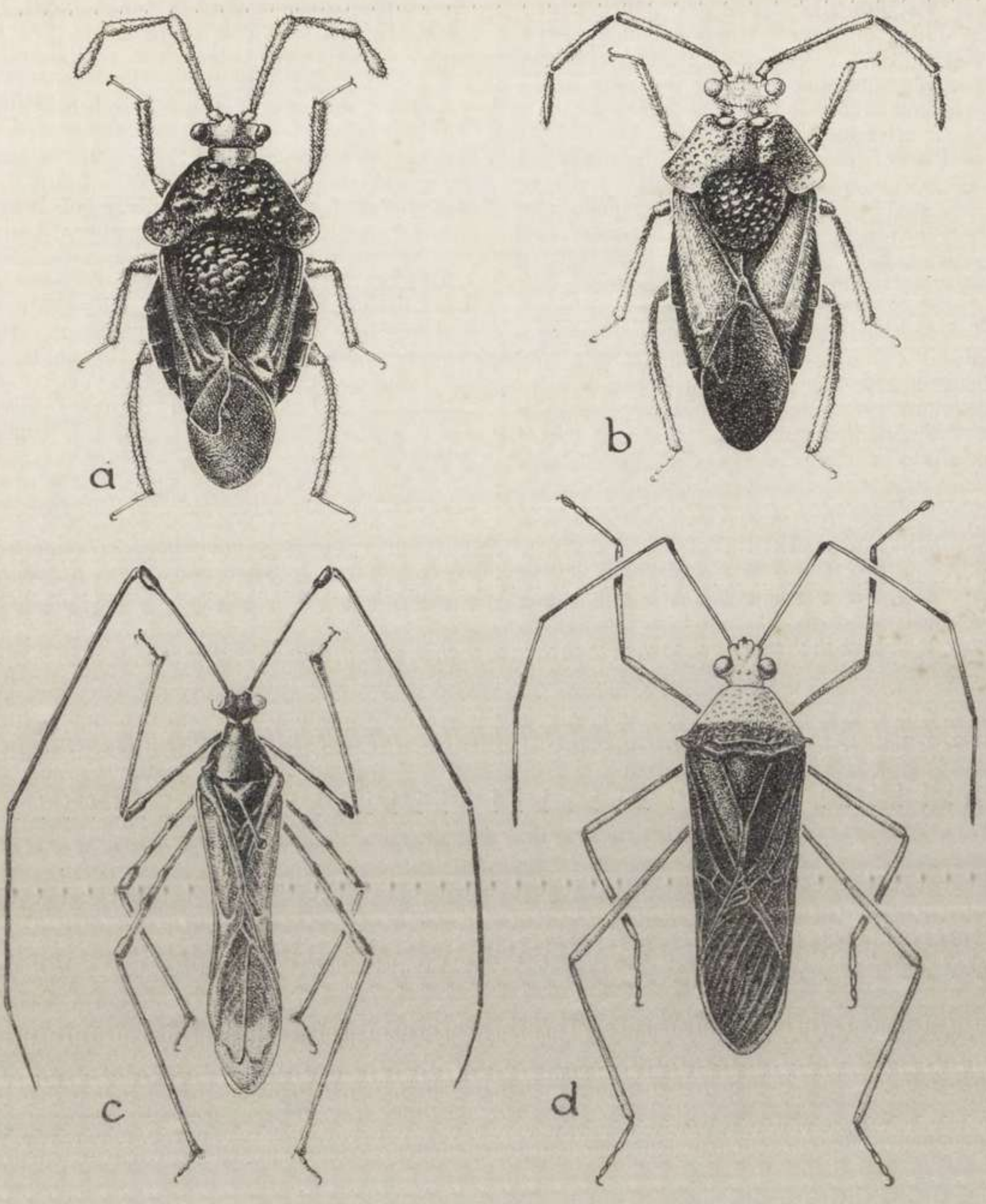
FIGURE 1.—*Injury to cacao pods by* Parabryocoropsis typicus *China & Carv.*

[Photograph L. Smee.]

to B.H.C., as was proved by field experiments carried out in 1955 and 1956 at the West African Cocoa Research Institute (Raw, *et al.*, 1956).

Dun experimented with the application of D.D.T. against *Pseudodoniella pacifica* (Dun, 1954*b*). A thrice-repeated application of 0.2 per cent. water-dispersible D.D.T. emulsion gave good control. Under Territory conditions, because of the rough terrain, the use of insecticides in the form of sprays is difficult. As mentioned above, B.H.C. is very effective against *Parabryocoropsis typicus* [4]. A dusting programme was worked out at Keravat during the past few years and this is regularly adhered to. The insecticidal treatment of the cacao blocks has no serious effect on the cacao flower-visiting insects, especially if the dusting is carried out in sections. This was proved by L. A. Bridgland and the author in an experiment at Lowlands Agricultural Experiment Station, Keravat (August, 1954). Regular counts of the populations of flower-visiting insects were carried out on a number of cacao trees in an experimental block for several days, prior to the treatment of this block with B.H.C. against *Parabryocoropsis typicus*.

[4] As a result of more recent investigations in West Africa, it is suspected that B.H.C. causes a taint to cacao beans. No such observations were made in New Britain or any other part of the Territory of Papua and New Guinea. Investigations into this problem are in progress at Lowlands Agricultural Experiment Station, Keravat.



[Drawings by M. L. Szent-Ivany]

PLATE 3.

a. *Parabryocoropsis typicus* China & Carv. (adult).*
b. *Pseudodoniella laensis* Mill. (adult).*
c. *Helopeltis clavifer* Walk. (adult).†
d. *Amblypelta theobromae* Brown (adult).‡

* 6 x Nat. Size. † 9 x Nat. Size. ‡ 4 x Nat. Size.

There was little fluctuation of population densities during this time. The counts of the populations of the flower-visiting insects were continued for some time after the treatment of the experimental block. The first count was made an hour after the dusting of the trees and the population of insects was found to be almost nil. There was a remarkable increase in populations on the next day, and after this the population density increased rapidly, so that within seven days it reached a slightly higher level than on the day before the treatment of the block. The flower-visiting insects at Keravat, amongst others, include a *Forcipomyia* sp. (Family Ceratopogonidae) (identification, courtesy of Dr. W. W. Wirth of the United States Department of Agriculture, Washington), which appears to be the main pollinating insect there, as related species are in other cacao-growing areas (Trinidad, West Africa, Java)[5].

A few years after the appearance of the new cacao mirids in New Britain, another species of Bryocorinae, *Helopeltis clavifer* Walk. (Plate 3C), was found attacking cacao pods in Papua. The damage occurred at Paili Plantation (Dun, 1954*b*). During the past four years, this species has been found in many other plantations in the Central and Northern Districts of Papua and it was also found feeding on sweet potato at higher altitudes (up to 3,400 feet) in the Morobe District of New Guinea.

In 1955, *Pseudodoniella laensis* Mill. appeared in very dense populations in a plantation in the Northern District of Papua, where it caused serious injury to cacao pods. The specimens of *P. laensis* collected in this area were first considered to represent a new species which has been named *Pseudodoniella szentivanyi* (Miller, 1957)[6]. Recent investigations by T. Odhiambo (1960) showed that *P. szentivanyi* is conspecific with *P. laensis*. The damage caused by *P. laensis* in the above-mentioned plantation resulted in a 70 to 80 per cent. crop reduction.

Pseudodoniella laensis has feeding habits similar to those of the other cacao mirids of the Territory of Papua and New Guinea. Neanides are usually found on the bases of the pods, but adults feed on any part of the pods. At the beginning of 1957, Ardley made some interesting observations on the feeding habits of *Pseudodoniella laensis* in the Markham Valley. Adults and various instar neanides were found feeding on the trunks and the laterals of cacao trees and they were capable of causing considerable damage. In the initial stage of damage the trees reacted by forming longitudinal lesions and by exuding gum from the deeper punctures caused by the adults and the late instar neanides. Later the gummy exudate dried and crystallized, and the bark became rough and pitted. This type of damage appears somewhat similar to the injury caused by the mirid, *Helopeltis ceylonensis* De Silva. However, as mentioned by De Silva (1957) this species (like its Papuan relative, *Helopeltis clavifer*) favours the pods, and feeding on leaves and stems is usually associated with insufficient shade over the trees.

There was a serious joint attack on cacao trees by *Helopeltis clavifer* and *Pseudodoniella laensis* at Sangara Estate (Northern District) in 1955-1956. The whole cacao block was thoroughly dusted with B.H.C. ("Gammexane 20 Powder") and the treatment was repeated several times at six-week intervals. *Pseudodoniella laensis* appeared to be more susceptible to B.H.C. than *Helopeltis clavifer*. Its populations decreased rapidly and no specimens could be found in the cacao block after the second application of B.H.C. When the dusting programme was completed, no more *Helopeltis* could be seen in the plantation, but after some months small populations began to re-enter the cacao block from the neighbouring rain forest. There was no sign of *Pseudodoniella laensis*. However, in 1959 this species appeared in another plantation in the Northern District, where it caused damage to pods. It was found in pockets similar to *Parabryocoropsis typicus* and *Pseudodoniella pacifica* in New Britain. The application of dieldrin spray was quite successful against *Pseudodoniella laensis* and the coreid, *Amblypelta theobromae*, which was attacking the pods simultaneously with the mirids (see paragraph D

[5] Other insects found in cacao flowers which might be of minor importance in pollen carrying are the aphid *Cerataphis* sp. near *rappardi* (H.R.L.), the chloropids *Botanobia* (?) sp. and *Gaurax* (?) sp., the braconid *Lipolexus* sp. (?), the ceraphronid *Ceraphron* sp. and a springtail of the subfamily Paronellinae (Family Entomobryidae).

[6] In this paper Miller revised the genera *Parabryocoropsis* and *Pseudodoniella* and transferred *Parabryocoropsis duni* China & Carv., and *Parabryocoropsis cheesmanae* China & Carv. to the genus *Pseudodoniella*.

of this paper). In 1959 *Pseudodoniella laensis* appeared in dense populations in a plantation in the Madang District, where it caused severe damage to pods and to the growing points of laterals. This outbreak occurred in association with an attack by an *Amblypelta* sp. More recently (June, 1960) Mr. R. T. Simon Thomas (Hollandia) kindly informed the author that he found *Pseudodoniella laensis* in the Manokwari District of Netherlands New Guinea, where it caused serious injury to the pods of *Theobroma cacao*.

Mirids have various enemies amongst predacious insects, but none of these are host specific. Dun (1954*b*) mentioned an attid spider, a reduviid (*Pristhesancus* sp.) and the Green Tree Ant [*Oecophylla smaragdina* (F.)] as the most important predators of *Parabryocoropsis typicus*. The author found the reduviid *Aulacagonia cheesmanae* Mill. preying upon the neanides of *Parabryocoropsis typicus* at Keravat. Four predacious insects, the formicid *Oecophylla smaragdina*, the pentatomid, *Amyotea reciprocus* Walk., the reduviid, *Euagorus* sp. and the asilid *Maira* sp. were found preying upon *Pseudodoniella laensis* Mill. and *Helopeltis clavifer* Walk. in the Northern District.

There is some indication that the ants, *Oecophylla smaragdina* F. and *Anoplolepis longipes* Jerd., have a controlling effect on the populations of *Pseudodoniella laensis* on cacao pods. They mainly act as disturbing factors against the flying adults, but there is no doubt that neanides are sometimes caught by *Oecophylla smaragdina*.

Several species of *Ficus* were found to be indigenous host plants of cacao Bryocorinae in New Guinea.

C. CERAMBYCIDAE

Many species of the cerambycid subfamily Lamiinae ("Longicorn Beetles") invaded the cacao plantations of New Guinea from the surrounding rain forest during the last war. Some species attacked the stems of mature cacao trees, some smaller species were found as borers in the branches. The following species were identified by specialists of the Commonwealth Institute of Entomology, the British Museum and by Dr. J. L. Gressitt of the Bernice P. Bishop Museum: *Batocera nebulosa* Bates, *Batocera* sp., *Dihammus* sp. near *trigonus* Gressitt, *Dihammus strandiellus* Brng., *Dihammus* sp., *Glenea aluensis* Gah., *Glenea lefebueri* Guer., *Heteroclitomorpha punctata* Guen., *Monohammus* sp., *Oxymagis vitticollis* Fairm., *Pelargoderus arodensis* Thoms., *Sphingonotus* sp., *Tmesisternus yorkensis* Fairm. and *Tmesisternus* sp. The following species were collected on cacao trees and they are likely to be stem borers of *Theobroma cacao*: *Dihammus australis* Boisd., *Prosopus acuminipennis* Blanch, *Prosopus intermissus* Page, *Pterolophia mediochracea* Brng., *Tmesisternus bizonatus* Blanch and *Tmesisternus politus* Blanch.

Some years ago, Dr. J. L. Gressitt (Bernice P. Bishop Museum, Honolulu) began to study the taxonomy and distribution of Lamiinae in the Papuan Zoogeographical Subregion. Large collections were made by him and his field associates between the years 1955 and 1960 in the Territory of Papua and New Guinea. Another valuable collection of Lamiinae, obtained by the entomologists and other officers of the Department of Agriculture, Stock and Fisheries, was forwarded in 1959 to Dr. Gressitt for systematic study, and it is hoped that at the conclusion of his studies much more will be known of the taxonomy of the longicorn borers of Papua and New Guinea.

Serious damage by Lamiinae (especially by *Glenea aluensis*) was observed after the war in some cacao plantations in the Gazelle Peninsula of New Britain. The lack of plantation sanitation measures during the war resulted in the thickening of the shade. The Lamiinae are shade-loving species of the virgin rain forest. Most of the lamiid damage was found in cacao blocks, densely shaded by the foliage of fast-growing shrubs and trees of the rain forest, which rapidly invaded the plantations when they were abandoned by their owners.

Detailed observations on the damage by *Glenea aluensis* were made in the years after the war by Dun in New Britain. According to these, the larva of *G. aluensis* ringbarks the cacao branch, which dies or breaks off. On younger trees, borer damage occurs at the point of ramification. The end result is the complete collapse of the upper portion of the young tree, if subjected to light winds or heavy rain (Dun, 1951*b*).

Conditions similar to those found in the Gazelle Peninsula also occurred in some parts of the mainland of New Guinea. However, the general improvement of plantation sanitation after the war rapidly changed the whole picture.

With the gradual cleaning of the cacao blocks, the population density of Lamiinae in the plantations decreased from year to year and with the exception of *Glenea aluensis* (Plate 2C) in the Bismarck Archipelago and *Glenea lefebueri* (Plate 2D)[7] in the mainland of New Guinea many species of Lamiinae became minor pests of *Theobroma cacao* in the Territory. Odd specimens of the larger lamiids invade the plantations here and there; trees are attacked in small pockets on the borders of the plantations close to the rain forest and the secondary forest, causing setbacks in growth and even killing some trees if the symptoms are overlooked by the planter. Most plantation owners keep a close watch on the cacao trees near the edges of the plantations, and if they find trees attacked by Lamiinae they apply mechanical and chemical control measures.

D. AMBLYPELTA THEOBROMA BROWN

During the past five years some species of the coreid genus *Amblypelta* Stal. appeared as pests of various cultivated plants in the Territory of Papua and New Guinea. Five of them (*Amblypelta theobromae* Brown, *Amblypelta costalis szentivanyi* Brown, *Amblypelta ardleyi* Brown, *Amblypelta cocophaga* China and *Amblypelta* sp. near *ardleyi* Brown) were found feeding on cacao pods. The New Guinea subspecies of *Amblypelta costalis* Van Duzee (the name form is only known from the small island of Bellona in the British Solomon Islands Protectorate), *Amblypelta theobromae* and *Amblypelta ardleyi*, were described by E. S. Brown (Commonwealth Institute of Entomology) in a comprehensive monograph of the genus *Amblypelta* Stal. (Brown, 1958*a*).

Amblypelta costalis szentivanyi, although common in cacao-growing areas of New Britain and the Northern District of Papua, rarely feeds on *Theobroma cacao* and nothing is known about the effect of injury by this species to the surface tissues of cacao pods. It is more often found feeding on *Manihot utilissima* (cassava), but the damage caused to this plant is not as extensive as it is in the case of *Amblypelta lutescens papuensis* Brown (Szent-Ivany and Catley, 1960*a*).

Amblypelta theobromae (Plate 3D and Figure II) is considered by E. S. Brown (1958*b*) to be a potentially serious pest of cacao pods. Fortunately, it has not a very wide area of distribution (parts of the Morobe District of New Guinea and of the Northern District of Papua) and it is susceptible to B.H.C. in the form of Gammexane 20 Dust, as was proved by W. A. van den Berk at Sangara Estate in 1956. It is also susceptible to dieldrin spray which is usually applied at present against *A. theobromae* in some plantations in the Northern District. E. S. Brown studied the feeding habits of this coreid in two plantations in the Morobe District in 1956 and the author had the chance to investigate a major outbreak in November, 1958. The symptoms of damage were described by Brown in a comprehensive paper dealing with the feeding habits and host plants of the species of the genus *Amblypelta* (Brown, 1958*b*).

The injury caused by *Amblypelta theobromae* to cacao pods is similar to that caused by *Parabryocoropsis typicus* and *Pseudodoniella* spp. but the brown scars on the surface of the pods in the case of *Amblypelta theobromae* appear to be larger and they are more evenly distributed. In contrast, the lesions, caused by mirids, especially by the neanides, are mainly found on and around the base of the fruit, where the insects seek shelter from the various predatory insects. In cases of severe pod damage by *Amblypelta theobromae*, scars may run together, forming large necrotic areas and according to Brown (1958*b*) a secondary fungus (*Gleosporium* sp. ?) may enter the lesions. If younger pods are severely attacked, they may become distorted (Figure III). Similar damage to pods is sometimes caused by the mirids *Bryocoropsis laticollis* Schum. and *Helopeltis bergrothi* Reut. in West Africa (Williams, 1953).

[7] These two species are sometimes found in plantations where sanitation measures are adequate. During a visit to a cacao block in the Sepik District in March, 1960, the writer found a large percentage of 3½-year-old cacao trees ringbarked by the larvae of *Glenea lefebueri* Guer. At least every third tree showed recent or earlier signs of ringbarking near ground level on the main stem. Only a few trees died but many showed a setback in growth. The *Leucaena* shade was healthy, not too thick, and the undergrowth was cut short. Similar conditions were found by the writer in a cacao block in the Bougainville District in 1956. The damage there was caused by *Glenea aluensis* Gah.

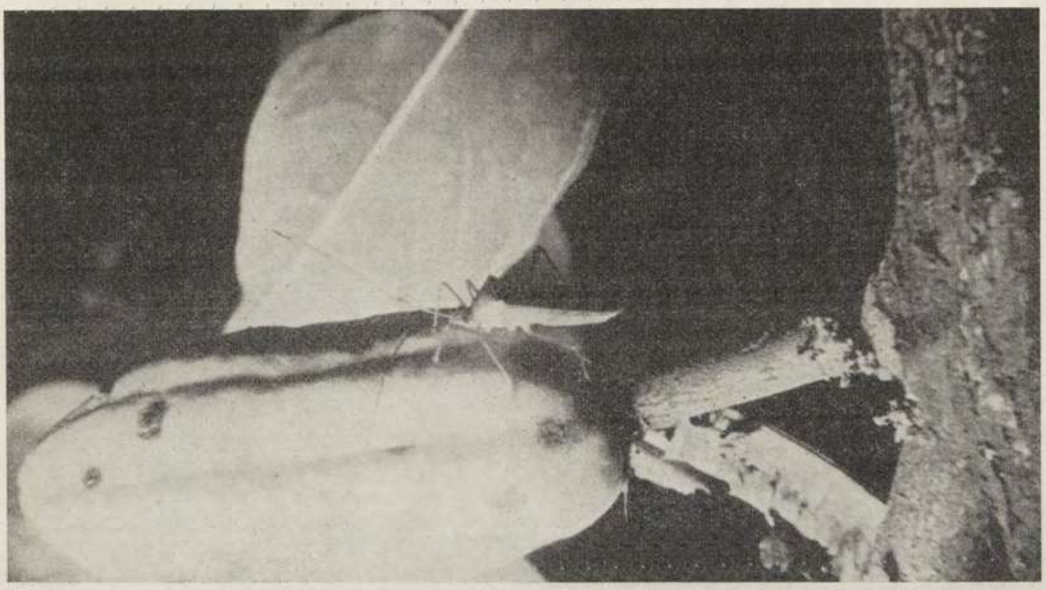


FIGURE II.—*Injury to cacao pod by* Amblypelta theobromae *Brown* (*with feeding adult*).

[Photograph C. S. Edwards.]

FIGURE III.—*Distortion of young cacao pods following attack by* Amblypela theobromae *Brown, with adult resting on the pod.*

[Photograph J. Stackhouse.]

Similar observations to those of Brown (1958*b*) regarding the protection of cacao trees by *Oecophylla smaragdina* against *Amblypelta theobromae* were made during a visit by the author to the Northern District in 1958. In the plantation where the above-mentioned major outbreak of *Amblypelta theobromae* occurred, only a very small percentage of cacao trees had *Oecophylla* populations. Most trees were occupied by the smallish, black, inoffensive ant, *Technomyrmex detorquens* (Wlk.). It was found that the few trees which were overrun by *Oecophylla* had healthy pods; they had very little or no *Amblypelta* damage.

Amblypelta theobromae did not appear in pockets in the above-mentioned plantation, as is the habit of certain mirids in Africa and in New Guinea; the species was fairly evenly distributed in the whole plantation. Both neanides and adults were feeding on cacao pods. Up to four adults were found feeding on one pod. Many copulating pairs were seen on pods. It was found that *Amblypelta theobromae*, being a native of the rain forest, is a heliofugus, shade-loving species. Thus, too thick shade can promote the increase of populations in cacao blocks. The outbreak described here was partly due to the excessive shade in the plantation. The owner recognized this fact at an early stage of the outbreak, because the thinning of the shade was in progress during the time of the author's visit.

In 1959, the author found a joint outbreak of *Pseudodoniella laensis* and an *Amblypelta* sp. at Amele village plantation in the Madang District. The latter was identified by Dr. Ghauri (Commonwealth Institute of Entomology, London) as a species near *Amblypelta ardleyi* Brown, which represents a new species. Thorough spraying of the plantation with dieldrin eliminated both the mirid and the coreid from the plantation area.

Recently (March, 1960) J. H. Ardley observed a specimen of *Amblypelta ardleyi* feeding on a cacao pod and G. S. Dun (June, 1960) found *Amblypelta cocophaga cocophaga* China feeding on cacao pods in a plantation in the Bougainville District (personal communication by Mr. Ardley and Mr. Dun). *A. cocophaga cocophaga* appeared on cacao pods in a plantation where cacao is planted under the shade of coconut palms. The palms showed symptoms of severe premature nutfall. Similar observations were made by E. S. Brown in the British Solomon Islands (Brown, 1958*b*).

II. LOCAL OUTBREAKS AND MINOR PESTS

A. COLLEMBOLA

The entomobryid, *Salina celebensis* Schaf., was observed causing some leaf shedding in New Britain (Dun, 1951*b*, 1954) and in the Markham Valley. According to Dun (1951*b*) both mature and immature stages feed on the under surfaces of the leaves. They etch away the lower epidermis and the leaves become yellow and may die. Similar observations were made by the author in the Markham Valley.

Two unidentified dolichopodids were observed preying upon this springtail at Keravat.

B. ORTHOPTERA

The polyphagous cricket, *Cardiodactylus novaeguineae* Haan, is a minor pest of the foliage of young cacao trees and a mole cricket (*Gryllotalpa* sp. near *borealis*) sometimes causes injury to seedlings. The phasmid, *Anchiale maculata* Oliv., is a widespread minor pest of cacao foliage in the Gazelle Peninsula of New Britain (personal communication by Mr. Dun). Recently, the acridiid, *Dermopterella onplicata* Kairsch, *Stenocatantops angustifrons* Walk. and *Valanga papuasica* Finot., were found defoliating cacao trees in a plantation in the Gulf District. The cacao trees were simultaneously attacked by the larvae of the limacodid, *Pinzulenza kukisch* Hering.

C. ISOPTERA

A large termite, *Calotermes papua* Desneux, was recorded 20 years ago by Froggatt (1938*b*) as attacking the trunks of mature trees (See also Hill, 1942). *Microtermes biroi* (Desn.) was found on one occasion attacking a cacao branch. This was most likely a secondary attack following *Pantorhytes* borer damage. At least two species of *Neotermes* were found in New Britain, New Ireland and in the Morobe district attacking cacao as primary pests; the taxonomy of these species is still under investigation by overseas specialists. These termites are the cause of considerable damage over quite extensive areas in the Bismarck Archipelago, but again their control is largely a matter of plantation hygiene and regular inspection and treatment.

D. HEMIPTERA

A few Heteroptera were recorded as minor pests of cacao. These are: the coreid, *Priocnemicoris flaviceps* Guer., the lygaeids, *Astacops flavicollis* Walk. and *Lygaeus pacificus* Boisd., and the pentatomids, *Austromalaya* sp. and *Nezara viridula* L. (Dun, 1951*a*). All of these feed only occasionally on cacao, mainly on young trees: they all have some other more important host plants. The coreids, *Brachylybas inflexus* Blote, *Acanthotyla* sp. and *Sciophyrus* sp., were frequently observed on the stems of cacao pods, attacked by *Amblypelta theobromae* and by mirids, but the damage caused by these three coreids is insignificant. The pentatomid, *Brachyplatys translineatus* Walk. (Subfamily Plataspidinae), was found by the author in very dense populations on cacao pods in a plantation on Lihir Island (New Ireland District) but the species has not caused serious damage to pods. The coreid, *Leptoglossus australis* (F.), is an occasional feeder on young shoots, leaves and stems of seedlings, but it has never been found on pods (Szent-Ivany and Catley 1960*b*).

Amongst the Homoptera, many species of various leafhopper families (Cercopidae, Cicadellidae, Delphacidae, Derbidae, Membracidae, Flatidae, Ricaniidae, etc.) are found feeding on the leaves, branches and pods of cacao trees in the Territory of Papua and New Guinea, but so far none of these have caused significant damage. Only a few were identified. Such are: *Armacia basigera* Walk., *Armacia* sp., *Clovinia fasciata* Lall., *Colgar tricolor* Dist., *Colgar* sp., *Euphanta pokiana* Dist., *Euricania splendida* F., *Euricania* sp., *Paratella miniata* Mel., *Paratella nivosa* Wath., *Ricania integra flavida* Mel., *Selenocephalus* spp., *Zoraida punctipennis* Walk. and *Zoraida* sp. Many more species were collected on cacao and these are awaiting identification by specialists.

It should be mentioned here that careful observations should be made on the spread and growth of the populations of these and other leafhoppers (especially Cicadellidae) in the cacao plantations in the Territory of Papua and New Guinea, because some species in other parts of the world (West Indies, South America, etc.) are major pests of cultivated plants, and recently one or two species of the genus *Selenocephalus* appeared to cause quite severe damage to the tissues of *Coffea arabica* plants in the Eastern Highlands of New Guinea.

Among the aphids, *Toxoptera aurantii* B. de Fons. was recorded by Dun (1954*a*) as a common and widely distributed species in New Britain on cacao foliage, but it never caused any serious damage. *Toxoptera aurantii* was found as a pest of cacao in other parts of the South Pacific region. Laing (1927) recorded it on cacao leaves from Apia, Western Samoa. The author found it on *Camellia sinensis* in the Eastern Highlands of New Guinea. Other aphids found on cacao are *Cerataphis* near *rappardi* (H.R.L.) and *Cerataphis variabilis* H.R.L.

Scales and mealy bugs (Coccidae) were recorded from various parts of the South Pacific region (Wallis, Tonga, Fiji) as minor pests of cacao leaves and pods (Cohic, 1950; O'Connor, 1949; Lever, 1946). The first mealy bug record in the Territory of Papua and New Guinea was by Froggatt in 1938 (a species feeding on cacao pods in New Britain). A few more species were found recently by entomologists of the Department of Agriculture, Stock and Fisheries (Szent-Ivany, 1956*b*).

Planococcus citri (Risso) and *Ferrisiana virgata* (Ckll.), known as vectors of the swollen shoot disease in West Africa (Strickland, 1951) and as vectors of a strain of this disease in Ceylon (Newton and Peiris, 1953; Carter, 1956), were found on *Theobroma cacao* in the Territory of Papua and New Guinea, but neither these nor any other species appeared to be virus carriers in the Territory. In a few isolated spots, *Planococcus citri* and *Planococcus lilacinus* (Ckll.) were observed causing some injury to the tips of laterals of cacao trees (Szent-Ivany and Catley, 1960*c*). The main predator of *Planococcus citri* in the Markham Valley (Morobe District) seems to be the coccinellid, *Cryptolaemus affinis* Crotch. The damage caused by mealy bugs to the growing points perhaps allows the entrance of secondary fungi. Investigations into this are being undertaken by the plant pathologists of the Department of Agriculture, Stock and Fisheries.

Other Coccidae, found in recent years in the Territory of Papua and New Guinea on cacao, are: *Ceroplastodes chiton* Green (mainly on stem of pods; Northern District, coll. F. J. Simmonds and J. J. H. Szent-Ivany), *Criniticoccus theobromae* Williams (Williams, 1960), *Eriochiton* sp. (Bainings, New Britain, coll. J. H. Ardley), *Maconellicoccus hirsutus* (Green) (growing point of young trees; Northern District, coll. J. J. H. Szent-Ivany), *Mutabilicoccus* sp. (on pods tended by *Oecophylla smaragdina*) *Planococcus* sp. (on pods; Bainings, New Britain, coll. J. J. H. Szent-Ivany) and *Pseudococcus* sp. (on pods; Bougainville, coll. J. H. Barrett).

Maconellicoccus hirsutus was associated with an *Iridomyrmex* sp. as a nursing ant. A *Planococcus* sp., covering cacao pods in a plantation in the Bainings Area of New Britain, was tended by large numbers of very offensive Kurukum Ants (*Oecophylla smaragdina*). The surfaces of some pods were completely covered with the mealy bugs, but, when opened, the pods were found to be perfectly healthy. *Iridomyrmex nitidus* Mayr. was found as a nursing ant on an unidentified pseudococcid in the Maprik Subdistrict of the Sepik District.

E. LEPIDOPTERA

A. LIMACODIDAE (LOCAL OUTBREAKS)

Some species of Limacodidae ("Cupmoths", "Nettle Caterpillars") at times cause serious defoliation of cacao trees in Papua and New Guinea. Fortunately, they appear as pests in relatively small areas and the outbreaks are usually of short duration. Control is achieved by the application of chlorinated hydrocarbon insecticides (most species are susceptible to D.D.T.) or the population density of the pest is kept below the level of economic importance by natural enemies.

A joint attack by a cassidid (*Aspidomorpha testudinaria* Montr.) and by the caterpillars of a minute limacodid, which appeared to represent a new genus (as yet undescribed), resulted in the complete defoliation of a 100-acre block of cacao trees (see figure IV). When the author visited the plantation in November, 1954, the cacao trees were leafless. Most larvae of the limacodid were killed by a D.D.T. spray applied by the owner one day earlier; many larvae were dying because of lack of food and concretions of 12 to 15 cocoons were found on the tips of the dry branches. Two hymenopterous parasites (*Brachymeris salomonis* Cam. and *Eurytoma albotibialis* Ashm.) were bred from cocoons collected on the cacao trees at the edge of the plantation. The outbreak lasted a few months only and the species has not been reported from the Bogia Subdistrict during the past six years.

FIGURE IV.—*Complete defoliation of mature cacao tree by Limacodid larvae.*

[Photograph J. J. Szent-Ivany.]

Another small limacodid, *Pinzulenza kukisch* Hering, appeared in the second half of 1958 as a serious defoliator of cacao trees in plantations at Kar Kar, a volcanic island near the coast of New Guinea in the Madang District. This species appeared also in vast populations in a plantation in the Gulf District of Papua where it attacked cacao foliage jointly with three acridiids (see also under " Orthoptera "), causing almost complete defoliation (Szent-Ivany, 1959). In December, 1959, *Pinzulenza kukisch* was found attacking cacao trees in a plantation on the North Coast of the mainland of New Guinea, opposite Kar Kar Island, in the Madang District. On Kar Kar and in this plantation, the cacao trees were planted under the shade of coconut palms. At the plantation on the North Coast of New Guinea there was a definite positive correlation between the high population density of *Pinzulenza kukisch* and inadequate shade conditions. The main foci of the outbreak were along the main road passing through the plantation, where the shade was insufficient and in a few areas where many coconut palms were killed by lightning, resulting in complete lack of shade. *Pinzulenza kukisch* is susceptible to dieldrin as was proved in this plantation, where it was applied with knapsack sprays and swing fog machines. The main parasite of *Pinzulenza kukisch* in the Madang District is the chalcidid, *Brachymeris salomonis*.

It is believed that *Pinzulenza kukisch* and the species found in the Bogia Subdistrict—similar to many other limacodids of the Indo-Australian Region—feed as a rule on coconut fronds, and at times dense populations of gravid females swarm down from the crowns of the palms to the cacao trees, covering almost every leaf with eggs.

The local outbreaks of two other larger limacodids (*Scopelodes* sp. and *Parasa lepida* Cr.) were earlier recorded by Froggatt (1940) and Dun (1953).

In recent years the limacodid, *Mambara inconspicua* B. Bak., appeared to cause defoliation of cacao trees in some plantations in the Markham Valley (Morobe District). The caterpillars virtually skeletonized the leaves. However, the damage seemed to have appeared in smaller or larger pockets and various predacious insects were observed by Ardley keeping the population density almost under the level of economic importance. The two main predators were the pentatomid, *Platynopus melacanthus* (Boisd.), and the pyrrhocorid, *Dindymus pyrochrous* (Boisd.).

B. Other Lepidoptera

The xyloryctid, *Pansepta teleturga* Meyr. (see damage figure V), and the cossid, *Zeuzera coffeae* Nietn. (and probably some other unidentified species of this genus), are found at times as minor pests of *Theobroma cacao* (feeding on the bark and boring in the branches). Dun (1951*b*, 1955) and the author found that *Pansepta teleturga* Meyr. mainly attacks cacao in insufficiently shaded plantations. It is recorded from the New Britain, Madang and Milne Bay Districts. The author found the braconid, *Ipobracon* sp., as a parasite of this species.

G. S. Dun and A. Catley found two aegeriid stemborers at Keravat in 1958. The species were identified in the British Museum as *Conopia theobroma* Brad. and *Conopia* sp. near *chrysophanes* Meyr., both representing new economic records for the Territory of Papua and New Guinea. A parasite associated with the two species was identified in the British Museum as *Apanteles* sp. near *abdominalis* F.

Various leaf and pod-eating caterpillars were recorded from cacao in the Territory of Papua and New Guinea. These are the geometrid, *Boarmia bhurmitra* Wlk. ; the noctuids, *Achaea janata* L., *Earias citrina* Saalm., *Heliothis armigera* Hb., *Prodenia litura* F. and *Tiracola plagiata* Wlk. ; the eucosmid, *Laspeyresia* sp. (recorded by Froggatt, 1938*b*, boring into the shells of pods) ; the lithosiid, *Lithosia* sp.; the lymantriids *Dasychira horsfieldi* Saund. (Subsp.?), *Euproctis* spp. and *Orgyia postica* Walk.; the tortricid, *Cacoecia* sp.; the olethreutid *Olethreutes* sp.; the lithocolletid, *Acrocercops cramerella* Smith, and a number of unidentified psychids.

Achea janata L. was found by Dun (1951*b*) defoliating young trees 18 to 36 months old. This, and most other leaf-eating caterpillars of cacao, can be controlled with D.D.T.

F. COLEOPTERA

Beetles were found damaging almost every part of the cacao plant in the Territory of Papua and New Guinea. The most important stem and branch borers were mentioned amongst the major pests. Froggatt (1938*a*, 1938*b*) recorded the curculionid, *Orthorhinus patruelis* (Pasc.), as an occasional borer in the branches of

FIGURE V.—*Injury to cacao branches by* Pansepta teleturga *Meyr.*

[Photograph L. Smee.]

Theobroma cacao. This species was also found as a borer in the branches and stems of *Coffea canephora*. Larvae of the curculionid, *Meroleptus squalidus* Mshl., were found as borers in the branches of mature cacao trees, severely attacked by *Pantorhytes szentivanyi*. Adults of this species are often found chewing the surface tissues of cacao pods, but both larva and adult can be considered minor pests only. The curculionid, *Nechyrus notatus* Pasc., has been bred from a dead cacao branch by B. A. O'Connor at Keravat.

The dynastids, *Oryctes rhinoceros* (L.), introduced about 1943, and *Xylotrupes* spp., were recorded feeding on the bark of cacao trees. A scoliid, *Scolia ruficornis* F., was introduced from Zanzibar in 1953 for the control of *Oryctes rhinoceros* (L.) which is a major pest of coconuts in some areas of the Bismarck Archipelago. Suspected indigenous parasites of *Oryctes* and *Xylotrupes spp.* are *Triscolia sausserei* Grib. and *Scolia schlechteri* Betrem. (identified by J. van der Vecht). Another suspected indigenous parasite is *Scolia pulchripennis* Cam.

Roots of young cacao trees are sometimes attacked by the larvae of Melolonthidae. Eighty per cent. of one-year-old seedlings in a cacao block in the Northern District of Papua were killed in a relatively short time by the root-eating larvae of a cockchafer in 1956. The melolonthid represented a new species and it was described as *Dermolepida noxium* Brit. (Britton, 1957). A *Campsomeris* sp. (Scoliidae) was found as an ectoparasite. The chemical control of this beetle is very difficult because the larvae of *Dermolepida noxium* can be found as deep as three feet under the surface of the ground. On account of the great loss, the above-mentioned cacao block had to be abandoned. Fortunately, this was a local outbreak, restricted to a small area and the damage by *Dermolepida noxium* to cacao roots has never been observed again. However, the species was collected recently in the Madang District. A. Catley found another *Dermolepida* sp. damaging cacao roots in a plantation near Abau (Central District, Papua) in March, 1959.

Beetles of various families are found feeding on the surfaces of pods. The rutelids, *Parastasia inconstans* Fairm. and *Parastasia marmorata* Gestro, were mentioned by Froggatt (1940), chewing the surface tissues of cacao pods. The curculionids, *Mecopus doryphorus* Quoy and Gaim. and *Pantorhytes* spp., and some unidentified anthribids, bruchids and curculionids were observed feeding on the surfaces of pods, in many cases as secondary pests after mirid (capsid) damage (Dun, 1954*b*).

Many beetles attack the foliage of *Theobroma cacao* in the Territory of Papua and New Guinea, but they are all minor pests which can be easily controlled with chlorinated hydrocarbon insecticides. These are the curculionids, *Apirocalus cornutus* Pasc., *Balaninus* sp., *Exophthalmida glauca* Fst., *Elytrocheilus coeruleatus* Pasc., *Eupholus browni* Bates, *E. schonherri* Guer. (var.), *Idiopsis coerulea* Fst., *Idiopsis grisea* Fst., *Oribius cruciatus* Fst., *Paratactus lihirensis* Mshl., *Paratactus* sp., *Platyachus papuana* Oberth., *Platyachus ruralis* Fst., *Pseudoporopterus* sp., *Rhinoscapha bifasciata* Chev., *Rhinoscapha schmeltzi* Fairm. and *Rhinoscapha thomsoni* Waterh. ; the cetoniid, *Glycyphana* sp. ; the rutelids, *anomala aenotincta* Fairm., *Parastasia inconstans* Fairm. and *P. marmorata* Gestro ; and the chrysomelids, *Rhyparida basalis* Baly, *Rhyparida coriacea* Jac., *Rhyparida impressipennis* Bry., *Rhyparida impuncticollis, Rhyparida obscuripennis* Bry., *Rhyparida* sp. near *quadraticollis* Arrow, *Stethotes* sp. (Subfamily Eumolpinae), *Microlepta* sp., *Monolepta semiviolacea* Fauv., *Prasyptera antennata* Jac. (Subfamily Galerucinae), *Podagrica* sp. near *psyche* Baly, *Sutrea* sp. (Subfamily Alticinae), *Aspidomorpha socia* Montr. and *Aspidomorpha testudinaria* Montr. (Subfamily Cassidinae.)

The tortoise beetle, *Aspidomorpha testudinaria* Montr., and other Cassidinae in the Territory of Papua and New Guinea prefer *Ipomoea batatas* and other *Ipomoea* species as host plants. In some years there is competition between the large caterpillars of the sphingid *Herse convolvuli* L. and the larvae and adults of Cassidinae in areas where sweet potato is grown. The Cassidinae are forced to look for subsidiary host plants. This was observed in 1953 and 1954 in some parts of the Madang District (personal communication by Mr. R. Vicary). The adults of *Aspidomorpha testudinaria* Montr. found their way to *Theobroma cacao* as a subsidiary host plant and they caused quite severe defoliation (Szent-Ivany, 1954).

The celeuthetin weevil, *Apirocalus cornutus* Pasc., one of the most polyphagous and eurythermous curculionids on the mainland of New Guinea, is able to cause severe setback in growth to young cacao and coffee trees by feeding on the growing points. A very extreme case was observed by Fielding, Henderson and the author in a cacao block in the Northern District of Papua. A joint attack by *Apirocalus cornutus* Pasc. and by two other unidentified celeuthetin weevils caused a very serious setback in growth to one-year-old cacao trees in this plantation. The area under the growing point was simultaneously attacked by the mealy bug, *Maconellicoccus hirsutus* (Green). The portion of the top shoot underneath the dying growing point was completely distorted as a result of the damage by the pseudococcid. Similar damage to the growing points of young cacao trees by the curculionid, *Platyachus ruralis* Fst., was recorded from New Britain (Dun, 1951*b*).

Paratactus lihirensis Mshl. appeared in very dense populations in cacao blocks on Lihir Island (New Ireland District) in 1955, causing considerable damage to the foliage of young trees.

Many more leaf-eating chrysomelids and curculionids found on the foliage of *Theobroma cacao* in the Territory of Papua and New Guinea are awaiting identification and description by specialist taxonomists.

G. HYMENOPTERA

The Leafcutter Bee, *Megachile frontalis* F., was observed causing damage to cacao foliage in a plantation on Lihir Island in the New Ireland District (Michener and Szent-Ivany, 1960).

A small ant (*Pheidologeton* sp.) was found feeding on cacao seeds in the ground in the Northern District of Papua. The role of ants in the control of Heteroptera and their activities as "Nursing Insects" of Coccidae was mentioned in other paragraphs of this paper.

SUMMARY

The intensive study of insect pests of cacao in the Territory of Papua and New Guinea began after the last war, although a few records were published some years earlier.

There is no serious regional pest of *Theobroma cacao* in the Territory. Some insects have to be considered major or important pests, but their occurrence is restricted to certain limited areas. All these are indigenous species of the lowlands rain forest and many of them invaded the cacao blocks during the war, when the plantations were abandoned and there was complete lack of plantation hygiene.

The most important cacao pests of the Territory of Papua and New Guinea are three Stem Borer Weevils, species of the Pachyrrhinchine genus *Pantorhytes* (*P. plutus* Oberth., *P. proximus* Fst. and *P. szentivanyi* Mshl.). *Pantorhytes plutus* Oberth. was recorded from various parts of the Territory, but, as a pest, it is restricted to New Britain. *P. proximus* Fst. is restricted to the Morobe District and *Pantorhytes szentivanyi* Mshl. to the Northern District. The *Pantorhytes* spp. have no known effective parasites and their chemical control is difficult. Experiments with chlorinated hydrocarbon and organic phosphate insecticides are in progress at two experiment stations of the Department of Agriculture, Stock and Fisheries. The species of the genus *Pantorhytes* are inclined to build up large populations in somewhat neglected cacao blocks and improvement in plantation sanitation helps greatly to reduce their population densities.

Another group of important pests consists of four species of Miridae (Capsidae) of the subfamily Bryocorinae. These mainly attack cacao pods. Some of these, under certain conditions, are able to cause up to 70 to 80 per cent. reduction in yield. One species (*Helopeltis clavifer* Walk.) is known from various parts of Papua and it was found on host plants other than cacao in the Morobe District of New Guinea up to an altitude of 4,000 feet above sea level. The species *Pseudodoniella pacifica* China and Carv., is restricted to New Britain. *Pseudodoniella laensis* Mill. was found in the Northern, Morobe and Madang Districts and recently it was also reported from the Manokwari District of Netherlands New Guinea. *Parabryocoropsis typicus* China and Carv. is the main cacao mirid of New Britain, but recently it was found also in the Central District on a native host plant. All cacao mirids of Papua and New Guinea are susceptible to B.H.C. and their population density can be kept under the level of economic injury by regular dusting of the affected plantations. *Pseudodoniella laensis* was proved to be susceptible to dieldrin and *Pseudodoniella pacifica* to D.D.T.

Cerambycidae of the subfamily Lamiinae appeared in dense populations in many cacao plantations during the last war, causing severe damage to stems and branches. Their appearance was mainly connected with the increasing shade as a result of lack of plantation hygiene. Better sanitation measures, however, changed the conditions during the years after the war and at present only two species can be considered major pests. These are *Glenea aluensis* Gah. in the Bismarck Archipelago and Bougainville and *Glenea lefebueri* Guer. in the mainland of New Guinea.

In recent years, a coreid, *Amblypelta theobromae* Brown, became adapted to *Theobroma cacao* as a host plant, and it appears to be quite troublesome in the Morobe District of New Guinea and in the Northern District of Papua. It attacks the pods. *Amblypelta theobromae* is susceptible to B.H.C. and dieldrin and the Green Tree Ant or "Kurukum" (*Oecophylla smaragdina* F.) gives some protection to cacao trees against this pest.

All other cacao insects found in the Territory of Papua and New Guinea can be considered minor pests. Some of them (Limacodidae, Melolonthidae, Curculionidae) appear at times in sudden severe outbreaks, but these outbreaks are usually of short duration and they are restricted to small areas, often to one or two plantations only.

REFERENCES

BRITTON, E. B. (1957). A Revision of the genus Dermolepida (Coleoptera, Melolonthidae). Proc. R. ent. Soc. Lond. 26: 51-59.

BROWN, E. S. (1958*a*). Revision of the genus Amblypelta Stal. (Hemiptera, Coreidae). Bull. ent. Res. 49: 509-541.

BROWN, E. S. (1958*b*). Injury to cacao by Amblypelta Stal. (Hemiptera, Coreidae), with a summary of food plants of species of this genus. Bull. ent. Res. 49: 543-554.

CARTER, W. (1956). Notes on some mealy bugs (Coccidae) of economic importance in Ceylon. FAO Plant Protection Bull. 4: 49-52.

CHINA, W. E. and CARVALHO, J. C. M. (1951). Four new species representing two new genera of Bryocorinae associated with cacao in New Britain (Hemiptera, Miridae). Bull. ent. Res. 42 : 465-471.

COHIC, F. (1950). Les insectes nuisibles aux plantes cultivees dans le Wallis et Futuna. Agron. Trop., Nogent. 5 : 563-581.

DE SILVA, M. D. (1957). A new species of Helopeltis (Hemiptera-Heteroptera, Miridae) found in Ceylon. Bull. ent. Res. 48 : 459-461.

DUMBLETON, L. J. (1954). A list of insect pests recorded in South Pacific Territories. SPC Tech. Paper No. 79 : 202 pp.

DUN, G. S. (1951*a*). List of insect pests in Papua-New Guinea. Cyclostyled paper submitted to P.A.Q. conference, Suva.

DUN, G. S. (1951*b*). Pests of cacao in the Territory of Papua-New Guinea : 32-35 in : Prospects of extending the growing of cacao in Papua and New Guinea. D. H. Urquhart and R.E.P. Dwyer. Bournville : Cadbury Bros. Ltd.

DUN, G. S. (1953). Interesting identifications. Papua-New Guinea agric. Gaz. 8(4) : 7-11.

DUN, G. S. (1954*a*). Annual report of the Senior Entomologist 1952-53. Papua-New Guinea agric. Gaz. 8(3) : 18-27.

DUN, G. S. (1954*b*). Notes on cacao capsids in New Guinea. Papua-New Guinea agric. Gaz. 8(4) : 7-11.

DUN, G. S. (1955). Economic entomology in Papua and New Guinea. 1948-1954. Papua-New Guinea agric. J. 9 : 109-119.

FROGGATT, J. L. (1938*a*). Weevil pests of cocoa New Guinea agric. Gaz. 4(3) : 6.

FROGGATT, J. L. (1938*b*). Pests of cocoa in the Territory of New Guinea. New Guinea agric. Gaz. 4(4) : 66-68.

FROGGATT, J. L. (1940). Entomologist's report. New Guinea agric. Gaz. 6(2) : 9-13.

HENDERSON, F. C. (1954). Cacao as a crop for the owner-manager in Papua and New Guinea. Papua-New Guinea agric. J. 9 : 45-74.

HILL, G. F. (1942). Termites (Isoptera) from the Australian Region. Melbourne : C.S.I.R. 479 pp.

LAING, B. F. (1927). Coccidae, Aphididae and Aleyrodidae. Insects of Samoa Part II, fasc. 1 : 35-45. London : British Museum.

LEVER, R. J. A. W. (1946). Insect pests in Fiji. Bull. Dep. Agric. Fiji. No. 23.

MARSHALL, G. A. K. (1957). Some injurious Curculionidae (Col.) from New Guinea. Bull. ent. Res. 48 : 1-7.

MICHENER, C. D. and SZENT-IVANY, J. J. H. (1960). Observations on the biology of a leaf-cutter bee, Megachile frontalis, in New Guinea. Papua-New Guinea agric. J. 13 : 22-35.

MILLER, N. C. E. (1957). Two new species of Pseudodoniella China and Carv. (Hemiptera, Miridae). Bull. ent. Res. 48 : 57, 58.

NEWTON, W. and PEIRIS, J. W. L. (1953). Virus disease of plants in Ceylon. FAO Plant Protection Bull. 2 : 17-21.

NICOL, J. and TAYLOR, D. J. (1956). Capsids and capsid control in the Belgian Congo with special reference to Lukolela Plantations. Tech. Bull. W. Afr. Cocoa Res. Inst. No. 2.

O'CONNOR, B. A. (1949). Some insect pests of Tonga. Agric. J. Fiji. 20 : 47-57.

ODHIAMBO, T. E. (1960). The identity of Pseudodoniella laensis Miller (Hemiptera, Miridae) associated with cacao in New Guinea and Papua. Bull. ent. Res. 51 : 519-521.

RAW, F., TAYLOR, D. J., ENTWISTLE, P. F. and USHER, G. (1956). Capsid studies. W. Afr. Cocoa Res. Inst. 1955-56 : 48-59.

STRICKLAND, A. H. (1951). The entomology of Swollen Shoot of cacao. I. The insect species involved with notes on their biology. Bull. ent. Res. 41 : 725-748.

STRICKLAND, A. H. (1952). The entomology of the Swollen Shoot of cacao. II. The bionomics and ecology of the species involved. Bull. ent. Res. 42 : 65-103.

SZENT-IVANY, J. J. H. (1954). Two new insects of Theobroma cacao in New Guinea. Papua-New Guinea agric. J. 9 : 35-37.

SZENT-IVANY, J. J. H. (1956*a*). Two new stem borers of cacao in New Guinea. FAO Plant Protection Bull. 4(12) : 177-178.

SZENT-IVANY, J. J. H. (1956*b*). New insect pest and host plant records in the Territory of Papua and New Guinea. Papua-New Guinea agric. J. 11 : 82-87.

SZENT-IVANY, J. J. H. (1959). Host plant and distribution records of some insects in New Guinea. Pacific Insects. 1 : 423-429.

SZENT-IVANY, J. J. H. and CATLEY, A. (1960*a*). Notes on the distribution and economic importance of the Papuan Tip-wilt Bug, Amblypelta lutescens papuensis Brown (Heteroptera, Coreidae). Papua-New Guinea agric. J. 13 : 59-65.

SZENT-IVANY, J. J. H. and CATLEY, A. (1960*b*). Observations on the Black Leaf-footed Bug, Leptoglossus australis (F) (Heteroptera, Coreidae) in the Territory of Papua and New Guinea. Papua-New Guinea agric. J. 13 : 70-75.

SZENT-IVANY, J. J. H. and CATLEY, A. (1960*c*). Host plant and distribution records of some insects in New Guinea and adjacent islands. Pacific Insects. 2 : 255-261.

TAYLOR, D. J. (1954). A summary of the results of Capsid research in the Gold Coast. W. Afr. Cacao Res. Inst. Tech. Bull. No. 1 : 20 pp.

WILLIAMS, D. J. (1960). The Pseudococcidae (Coccoidea, Homoptera) of the Solomon Islands. Bull. Brit. Mus. (nat. Hist.) Entom. 8 : 387-430.

WILLIAMS, G. (1953). Field observations on the cacao mirids Sahlbergella singularis and Distantiella theobroma (Dist.) on the Gold Coast. Part 1. Mirid damage. Bull. ent. Res. 44 : 101-119.

TROLLING RESULTS OF F. R. V. "TAGULA" IN PAPUAN WATERS FROM AUGUST, 1957, TO FEBRUARY, 1959.

By D. J. Dunstan *

INTRODUCTION

SINCE its acquisition in September, 1957, by the Division of Fisheries, Department of Agriculture, Stock and Fisheries, of the Territory of Papua and New Guinea, the 60-foot F.R.V. *Tagula* has been engaged mainly on trolling investigations in Papuan waters. Besides the *Tagula,* two 16-foot motor tenders have been used. The *Tagula's* complement comprises a European fishing master, a biologist or technical assistant, and eight native fisheries trainees.

For the purpose of comparison, the region investigated may be divided into three areas :—

Area 1. Inshore reefs and coastal waters between Port Moresby and Samarai.

Area 2. Shoal and reef waters and open sea east of Samarai, but excluding Misima Island where no work was carried out. The Sunken Barrier Reef which extends from Suau Island, 30 miles to the west of Samarai, to Quessant Island has been included in this area.

Area 3. The reefs, coastal stretches and open sea north of Samarai including the north-east Papuan coastline as far as the New Guinea border. The Trobriand and Woodlark Islands are not included as no investigations were undertaken there.

These areas are shown in Figure 1.

In the 18 months to February, 1959, 26 fishing voyages were made. Of these, 14 were restricted to trolling investigations and four comprised trolling in conjunction with longlining. The duration of the fishing voyages ranged from nine days to four weeks.

FISHING METHODS

Gear

During trolling, the *Tagula* carried two 18-foot trolling booms each with two troll lines and generally three troll lines from the stern. Each dory normally carried one fisheries trainee trolling with one line, although, in some cases, two trainees trolled one line each.

The troll lines comprised approximately 60 to 150 feet of No. 210, 240 or 300 seine cotton thread attached through two swivels, and a half-pound trolling sinker to 15-26 feet of wire trace. Depending on whether artificial lures or bait were used, either one or two 12/0 trolling hooks were attached to the end of the wire trace. In the latter case, the eye of the second hook was fitted over the barb and shank of the first and allowed to swing free. On all occasions, rubber shock absorbers were used to lessen the initial tension on the lines after strikes.

At the start of the investigations, 20-gauge piano wire with packing case wire to connect the two swivels through the sinker and small brass box swivels were used. With this gear, many strikes, believed to be large dog-toothed tuna, were lost. The improved gear and that at present in use is either 12 mm. heavy brass swivels or 4/0 or larger brass box swivels, and either preformed five cwt. aircraft control cable or 0.045 trolling wire for traces with the sinker moulded onto the trace. This gear has held mackerel weighing 95 lb., trevally 90 lb., and dog-tooth tuna exceeding 100 lb. (cleaned weights). Green braided nylon fishing line was tried for troll lines, but proved unsatisfactory owing to its tendency to fray when hauled over the stern of the *Tagula.*

* Marine Biologist, Department of Agriculture, Stock and Fisheries, Port Moresby.

Lures and Bait

Three different types of lures or bait, depending on availability, were used when trolling.

(a) *Artificial Lures*

These comprised pieces of coloured rope, shaped into the form of a squid and the white sheaths of swamp lilies cut into the shape of a fish.

(a) *Garfish*

At the commencement of operations, this bait was generally used. The point of the trolling hook was passed through the body of the fish and the eye of the hook tied with wire to the head in the vicinity of the mouth. A second hook was allowed to hang free from the shaft of the embedded hook.

(c) *Belly strips of Mackerel and Tuna*

The hook was attached in a similar way to garfish. It was found that, whereas occasionally fair catches of paradise fish and trevally were taken on artificial lures, the best results were obtained from garfish and belly strips. It is possible that fast-moving fish such as mackerel and tuna can smell the bait before striking and, if it is not attractive to them, will not strike.

Garfish and belly strips gave similar catch results when used as bait. The latter had the added advantage of being able to be used more than once, whereas the garfish was usually bitten in two and had to be replaced after each strike.

Use of Tagula *and Tenders*

The *Tagula* has a top speed of 8½ knots and during trolling operations best results have been obtained when cruising at this speed. The top speed of the two dories is about five knots and, although they are able to troll shallow reef waters, the low catches of dog-tooth tuna and other fast-moving species would indicate that a higher speed is required.

Echo Sounder

This instrument has proved invaluable for locating the Sunken Barrier Reef, which extends from Suau Island to Quessant Island, and shoal waters some distance from land. It has enabled the *Tagula* to follow this barrier closely except in very bad weather, and has resulted in some high catches. When trolling close to reefs, navigation is generally done by eye from the flying bridge so that the troll lines are kept in as shallow water as possible.

FISHING GROUNDS

Past Survey Findings

Prior to the survey by the M.V. *Fairwind* from 1948 to 1950, there was no available information on the distribution of pelagic species in Papuan waters, although both in pre- and postwar periods there were reports of Japanese tuna vessels operating with long-line gear near the off-shore New Guinea Islands. *Fairwind* daily troll catches in Papuan waters were only fair, the best results being obtained at Cannac Rock (Latitude 9 degrees 15 minutes, Longitude 153 degrees 30 minutes) (570 lb.) and Jomard Entrance (490 lb.). No further investigations were undertaken in Territorial waters until the inception of a Division of Fisheries in 1954. In 1955, a survey of the fishing potential of the Coral Sea and southern and eastern Papua was undertaken (Rapson, 1955). Once more, the shoal and reef waters east of Samarai yielded the best results—129 lb. per trolling hour having been taken at Kosmann Reef.

Present Survey Findings

Previous investigations were essentially surveys and time did not permit a concentrated study in any one region. With the *Tagula* in operation, intensified investigations of promising areas could be undertaken. The troll catches of the more important species over an 18-month period in each of the three areas are detailed in Appendix I and dissected in Appendix II. Examination of these indicates that the best trolling grounds are found east of Samarai. The catches, both when steaming from one locality to a different one and when trolling productive reefs, were far higher than for either of the other two areas. The catch per *Tagula* troll line hour and dory troll line hour on every voyage in Area 2 (Appendix III) exceeded the catch rates in Area 1 and Area 3.

Daily troll catches exceeding 500 lb. were recorded on 39 occasions (Appendix IV). On 11 days the total weight of fish taken was in excess of 1,000 lb. and with one exception these high catches were recorded in Area 2. Catches greater than 10 lb. per troll line hour were taken in this area only.

It is clear that the Sunken Barrier Reef and the reefs and shoal waters as far east as Duchateau Island, including Anchorage and Long Reefs, Bramble Haven and Jomard Entrance and

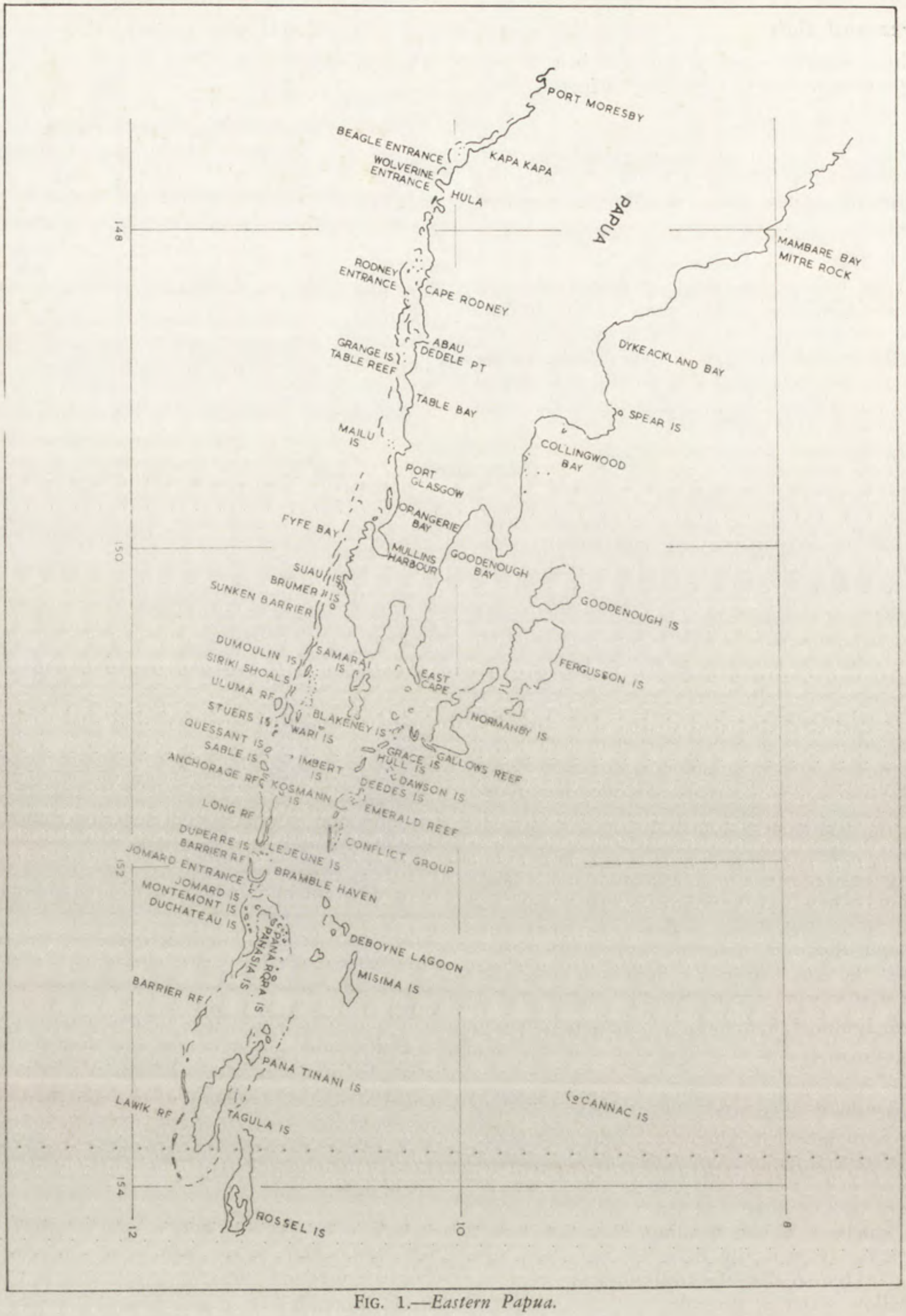


FIG. 1.—*Eastern Papua.*

Panasai and Pana Rora Islands are the most productive found to date in Papuan waters. This locality was fished periodically throughout 1958 and good catches were always recorded. These findings confirm the existence of productive trolling grounds in reef waters east of Samarai, as indicated by the surveys of 1948-50 and 1955. In addition, they show that in these waters good catches may be expected throughout the year. In contrast, fishing the fringing reefs of Tagula and Rossel Islands gave poor results.

The most productive reef in Area 1 was Table Reef, where the highest daily catch was 356 lb. The absence of off-shore reefs and shoal waters may account for the low catch figures in this area.

Fair results were obtained by trolling the Dawson, Boirama, Hull and Grace Island group (Area 3). The highest daily catch there was 1,008 lb. in May, 1958, but at other times catches were much lower. The daily catch for this area when trolling proven reefs averaged 380 lb. and the daily catch when steaming and trolling averaged 50 lb. Trolling the inshore reefs of Goodenough, Fergusson and Normanby Islands and the north-west coastline of Papua gave poor results. However, insufficient data are available to draw accurate conclusions of the trolling potential of seasonal species in this area.

Trolling proven reefs in Area 2, of the total catch (38,515 lb.) approximately one-tenth was taken by the dories. This low figure was due to their low operational trolling time, caused by inclement weather and, to a lesser extent, to their slower trolling speed, which resulted in very small catches of dog-tooth tuna. However, under optimum conditions, the catch per dory line hour greatly exceeded the catch per *Tagula* line hour. Additional dories with a higher trolling speed are therefore recommended.

CATCH STATISTICS AND FISHING SEASONS

In Appendix I the proportions of the more important troll species taken during the investigations are given. Listed in order of importance the species are Narrow-barred Spanish Mackerel, *Cybium commersoni* (Lacepede), 46.4 per cent.; Tuna, mainly dog-tooth, *Gymnosarda nuda* (Gunther), but including Yellow-fin Tuna, *Neothunnus macropterus* (Schlegal), Mackerel Tuna, *Euthynnus alletteratus* (Rafinesque), Striped Tuna, *Katsuwonus pelamis* (Linnaeus), and Big-eye Tuna, *Parathunnus mebachi* (Kishinouye), 17.4 per cent.; Trevally (*Caranx* sp.), 13.3 per cent.; Paradise Fish, *Aprion virescens* Valenciennes, 12.6 per cent.; Pike, *Sphyraena* sp., 9.9 per cent. ; Red Bass, *Lutjanus coatesi* Whitley, 0.4 per cent.

Small quantities of the following species were also taken :—

Coral Trout, *Variola louti* (Forskal).

Shark Mackerel, *Grammatorcynus bicarinatus* (Quoy and Gaimard).

Runner, *Elegatis bipinnulatus* (Quoy and Gaimard).

Reef Cod, various species of Epinephelidae, etc.

Wahoo, *Acanthocybium solandri* (Cuvier).

Leather-skin, *Chorinemus lysan* (Forskal).

Dolphin, *Coryphaena hippurus* Linnaeus.

Shark, various species.

The majority of the less-abundant species were taken when trolling reef and shoal waters. However, the yellow-fin tuna, wahoo and dolphin were also caught some distance from reefs, indicating that they do move out to deeper waters.

Comparison of the catch percentage of the more important individual troll species for each of the three areas (see Appendix II) shows that the highest proportion of mackerel, pike and trevally was taken in Area 1 and paradise fish and tuna in Area 2. Paradise fish were not taken in Area 1 and, compared with areas 2 and 3, catches of tuna were very poor.

The highest percentage (66.4) of Spanish mackerel was taken in May when this species was shoaling in the region of Boirama, Blakeney, Hull and Grace Islands (Appendix V). Trolling from Samarai to Bramble Haven in June yielded the highest percentage of pike (15.9). In November, 17.9 per cent. of the total catch was trevally, the troll catches for this month being the lowest recorded for the year. Dog-tooth tuna accounted for 33.3 per cent. of the total catch in the reef waters east of Samarai in March, with corresponding decrease in the relevant percentage of other species. This high figure was due to the discovery of a tuna spawning ground in March, 1958, when large catches of running ripe dog-tooth tuna were made on successive days. On no occasion were large catches of red bass taken. In July 21.6 per cent. of the total troll catch comprised paradise fish taken in Area 2 mainly along the Sunken Barrier.

The above figures indicate where the highest percentage of any one species may be expected in any one month. However, over the full period of investigations, the highest average catch and the highest catch rates for all species were always recorded in Area 2, the best months being December to March, and August to September.

ECONOMICS AND FUTURE DEVELOPMENT

The high average daily catch of 700 lb. taken over a 45-day period (Appendix VI) when trolling reef and shoal waters east of Samarai, for a period of 10 or more hours a day points to the possibility of establishing a commercial trolling enterprise based at Samarai. To fill a vessel with a freezer capacity of 20,000 lb. would require 30 days' trolling out of Samarai. Such a catch would consist of approximately 8,400 lb. mackerel, 3,800 lb. tuna, 3,000 lb. paradise fish, 2,800 lb. trevally, 2,000 lb. pike and 20 lb. red bass. Present Port Moresby fish prices of 2s. 6d. per lb. for mackerel, 2s. for paradise fish and 1s. 6d. for the remainder would return £2,000 net. However, it is unlikely that Port Moresby could absorb catches of this magnitude and the bulk would have to be sent to either Sydney or Brisbane for sale. Transportation under refrigeration would cost 3d. per lb. and there would be no market for trevally, tuna or red bass and only a restricted market for pike. The return from mackerel sold in Australia would approximately equal its return in Port Moresby.

Thus, briefly, for a vessel equipped with two motor tenders, 30 days' trolling could be expected to net no more than £2,000. An additional 10 days must be allowed for unloading of fish, repairs, maintenance, refuelling and inclement weather. The catch could be placed in a shore-based freezer erected at either Samarai or Sariba Island and shipped to either Port Moresby or Australia on the M.V. *Bulolo* which calls at Samarai every six weeks.

Commercial trolling in Area 2 would not involve any encroachment on native fishing rights, as there is no fishing by local indigenes in any of the reef and shoal waters where the best catches may be expected.

SUMMARY

Spanish mackerel is the most abundant troll species in Papuan waters. The catch during the period of investigations amounted to 46.4 per cent. of the total.

Dog-tooth tuna, which accounted for 17.4 per cent. of the total catch, schools and spawns in the vicinity of Bramble Haven waters in March, when they will readily take a fast-moving lure.

Belly strips of mackerel and tuna are the most satisfactory bait and the best trolling speed for fast-moving species appears to be in excess of five knots.

Troll catches between Port Moresby and Samarai were poor. Fair results were obtained in some reef waters north of Samarai and along the north-west New Guinea coastline, although insufficient investigations were carried out over a period to draw accurate conclusions. Very good results were generally obtained east of Samarai and along the Sunken Barrier where proven fishing reefs and shoals yielded consistently high catches. In this area, 150 miles of highly-productive trolling reefs extend from Suau Island along the Sunken Barrier Reef to Duchateau Island.

Off-shore reefs and shoal waters in each of the three areas always gave better results than fishing in-shore mainland reefs and reefs enclosing larger islands.

The results to date indicate that a profitable commercial trolling enterprise could be developed by fishing with a vessel of low overhead and running costs in waters east of Samarai, with headquarters based at Samarai or Sariba Island. Additional dories with a trolling speed in excess of five knots would result in greatly increased catches during favourable weather.

REFERENCE

RAPSON, A. M. (1955). Survey of fishing potentialities of the Coral Sea and southern and eastern Papua in 1955. Papua-New Guinea agric. J. 10 : 31-42.

APPENDIX I.—Proportions of Troll Fish taken by F.R.V. *Tagula* from 4th September, 1957, to 28th February, 1959

Fishing Voyage No.	Area	Duration	Weight (lb.)						
			Mackerel	Pike	Trevally	Tuna	Red Bass	Paradise	TOTAL
1	Port Moresby—Samarai	4.9.1957 to 20.9.1957	559	46	81	6	....	....	692
2	Port Moresby—Samarai	26.9.1957 to 8.10.1957	1,031	287	171	72	56	....	1,617
3	Port Moresby—Samarai	14.10.1957 to 26.10.1957	572	165	109	50	....	....	896
4	Port Moresby—Samarai	4.11.1957 to 14.11.1957	176	19	178	85	....	....	458
7	East of Samarai	29.12.1957 to 18.1.1958	1,804	480	539	517	....	406	3,746
12	East of Samarai	18.2.1958 to 3.3.1958	1,532	396	545	577	....	381	3,431
13	East of Samarai	14.3.1958 to 23.3.1958	1,180	176	484	1,128	52	363	3,383
14	N. and N.W. of Samarai	25.4.1958 to 15.5.1958	1,523	52	65	642	....	....	2,282
15	N. and N.W. of Samarai	29.5.1958 to 19.6.1958	1,223	343	158	160	....	258	2,142
16	Port Moresby—Samarai	1.7.1958 to 10.7.1958	181	26	6	33	....	....	246
17	Port Moresby—Samarai	17.7.1958 to 25.7.1958	376	....	267	32	....	28	703
17	East of Samarai	18.7.1958 to 31.7.1958	928	292	285	515	....	664	2,684
17	N. and N.W. of Samarai	3.8.1958 to 16.8.1958	473	97	38	99	....	....	707
18	N. and N.W. of Samarai	22.8.1958 to 25.8.1958	17	22	....	....	....	....	39
18	East of Samarai	26.8.1958 to 30.8.1958	1,590	204	750	440	....	792	3,776
18	N. and N.W. of Samarai	5.9.1958 to 6.9.1958	70	21	57	44	....	....	192
19	N. and N.W. of Samarai	10.9.1958 to 15.9.1958	92	35	8	28	....	6	169
19	East of Samarai	17.9.1958 to 22.9.1958	1,803	363	763	1,126	....	692	4,747
20	East of Samarai	26.9.1958 to 29.9.1958	1,108	219	339	219	....	323	2,208
21	East of Samarai	19.10.1958 to 24.10.1958	1,109	382	367	410	18	511	2,797
22	Port Moresby—Samarai	21.11.1958 to 22.11.1958	164	....	....	....	....	....	164
22	East of Samarai	26.11.1958 to 29.11.1958	192	83	13	128	....	32	448
23	East of Samarai	2.12.1958 to 21.12.1958	2,760	614	581	1,461	36	801	6,253
26	East of Samarai	5.2.1959 to 28.2.1959	1,471	250	483	404	19	591	3,218
		TOTAL	21,934	4,572	6,287	8,176	181	5,848	46,998
		Percentage	46.4	9.9	13.3	17.4	0.4	12.6	....

APPENDIX II.—Percentage Catch of Individual Troll Species in each area

AREA	LOCALITY	SPECIES (%)					
		Mackerel	Pike	Trevally	Tuna	Red Bass	Paradise
1	Port Moresby—Samarai	64.0	11.1	17.0	1.2	0.6	....
2	East of Samarai	42.3	9.6	14.0	18.9	0.1	15.1
3	North and north-west of Samarai	61.7	10.3	5.7	17.5	....	4.8

APPENDIX III.—Catch rates per fishing line hour on fishing voyages of F.R.V. *Tagula* September, 1957 to February, 1959

Fishing Voyage No.	Area	"Tagula" Catch/ Troll Line Hour (lb.)	Dory Catch/Troll Line Hour (lb.)
1	Port Moresby—Samarai	1.3	3.1
2	Port Moresby—Samarai	2.5	5.4
3	Port Moresby—Samarai	2.7	7.2
4	Port Moresby—Samarai	1.4	1.1
7	East of Samarai	4.8	....
12	East of Samarai	5.7	13.0
13	East of Samarai	14.9	7.4
14	North and north-west of Samarai	2.9	....
15	North and north-west of Samarai	1.9	....
16	Port Moresby—Samarai	0.6	....
17	Port Moresby—Samarai	0.6	1.0
17	East of Samarai	10.3	40.8
17	North and north-west of Samarai	2.7	....
18	East of Samarai	13.7	14.5
18	North and north-west of Samarai	1.1	....
19	East of Samarai	12.5	....
19	North and north-west of Samarai	1.1	....
20	East of Samarai	9.2	....
21	Port Moresby—Samarai	0.7	2.0
21	East of Samarai	8.0	12.5
22	East of Samarai	6.2	....
23	Port Moresby—Samarai	0.5	....
23	East of Samarai	11.6	....
26	East of Samarai	5.9	....

APPENDIX IV.—Daily Troll catches in excess of 500 lb. taken by the F.R.V. *Tagula* from 4th September, 1957 to 26th February, 1959

Fishing Voyage No.	Date	Locality	Catch (lb.)	Remarks
7	14.1.1958	Calvados Chain—Bramble Haven	730	Dories not trolling.
7	15.1.1958	Bramble Haven—Dumoulin Island	1,181	Dories not trolling.
12	24.2.1958	Quessant Island—Anchorage Reef	886	Dory catch 431 lb. *Tagula* catch 455 lb.
12	25.2.1958	Anchorage—Long Reef	1,330	Dory catch 516 lb. *Tagula* catch 814 lb.
12	26.2.1958	Bramble Haven—Sable Island	954	Dory catch 347 lb. *Tagula* catch 607 lb.
13	18.3.1958	Samarai—Jomard Entrance	626	Dory catch 129 lb. *Tagula* catch 497 lb.
13	19.3.1958	Jomard Entrance—Pana Rora Island	1,379	Including 320 lb. taken in 1½ hours by *Tagula*.

APPENDIX IV—*continued*

Fishing Voyage No.	Date	Locality	Catch (lb.)	Remarks
13	20.3.1958	Pana Rora Island—Panasai Island	1,481	Including 425 lb. taken in 1½ hours by *Tagula*.
14	10.5.1958	Blakeney Island—Dawson Island	710	Dories not trolling.
14	12.5.1958	Gallows Reef—Hull Island	1,008	Dories not trolling.
14	13.5.1958	Hull Island—Samarai	562	Dories not trolling. This catch taken between 0610-1145 hours.
15	15.6.1958	Long Reef	641	Dories not trolling.
16	17.6.1958	Long Reef—Sunken Barrier—Suau Island	626	Dories not trolling. Seas rough and most mackerel small and taken in deep water.
17	25.7.1958	Fyfe Bay—Sariba Island	637	Seas rough and dories not trolling.
17	28.7.1958	Long Reef—Pana Tinani Island	982	Seas rough and dories trolled for only 1½ hours each.
17	29.7.1958	Jomard Area	745	7 hours' trolling.
17	30.7.1958	Jomard—Anchorage Reef	562	Bright sun.
18	26.8.1958	Dumoulin Island—Quessant Island	1,245	Seas rough and dories not trolling. 1,000 lb. taken by *Tagula* in 5 hours.
18	27.8.1958	Quessant Island—Pana Tinani Island	822	Dory catch, 3 hours—75 lb.
18	28.8.1958	Pana Tinani Island—Sunken Barrier	1,209	Seas rough and dory trolling time limited.
18	29.8.1958	Pana Tinani Island—Quessant Island	554	Seas rough and dories not trolling.
18	30.8.1958	Quessant Island—Samarai	580	Dories not trolling, bright sun, seas glassy, calm.
19	17.9.1958	Samarai—Sunken Barrier—Quessant Island	1,138	Dories not trolling. 10 hours' trolling by *Tagula*.
19	18.9.1958	Quessant Island—Pana Rora Island	653	Dories not trolling.
19	19.9.1958	Pana Rora Island—Jomard Entrance	1,119	Including over 400 lb. in 1 hour by *Tagula*. Dory troll time small. Both booms broken.
19	20.9.1958	Duchateau Island—Jomard Entrance	642	Dories not trolling. Echo sounder broken down.
20	26.9.1958	Samarai—Sunken Barrier	731	Dories not trolling.
20	28.9.1958	Stuers Island—Sable Island	727	Dories not trolling.
21	20.10.1958	Long Reef—Pana Rora Island	572	Good trolling weather. Dory trolling time small.
21	21.10.1958	Pana Rora Island—Jomard Island	797	Dory catch 406 lb. *Tagula* catch 391 lb.
23	2.12.1958	Samarai—Long Reef	678	Dories not trolling. Unsuitable trolling weather.
23	5.12.1958	Long Reef—Pana Rora Island	687	Dories not trolling. Unsuitable trolling weather.
23	8.12.1958	Pana Rora—Jomard Island	895	Dories not trolling. Unsuitable trolling weather.
23	9.12.1958	Jomard Island—Stuers Island	652	Dories not trolling.
23	10.12.1958	Stuers Island—Suau Island	1,053	Dories not trolling. Good trolling weather.
23	11.12.1958	Suau Island—Sunken Barrier	1,032	Dories not trolling.
23	12.12.1958	Brummer Island—Samarai	629	Dories not trolling. Afternoon weather unsuitable.
26	20.12.1958	Stuers Island—Suau Island	823	Dories not trolling. Trolling Sunken Barrier.
26	21.2.1959	Suau Island—Samarai	560	Dories not trolling.

APPENDIX V.—Monthly total weights and percentages of the different troll species taken by F.R.V. *Tagula* from 4th September, 1957, to 28th February, 1959

Month	Mackerel Wt. (lb.)	%	Pike Wt. (lb.)	%	Trevally Wt. (lb.)	%	Tuna Wt. (lb.)	%	Red Bass Wt. (lb.)	%	Paradise Wt. (lb.)	%	Total Weight All Species
January	1,804	48.1	480	12.8	539	14.4	517	13.8	....	....	406	10.9	3,746
February	3,003	45.2	646	9.8	1,028	15.5	981	14.7	19	0.2	972	14.6	6,649
March	1,180	34.9	176	5.2	484	14.3	1,128	33.3	52	1.5	363	10.8	3,383
April	....	....	....	....	....	....	....	....	....	....	....	....	....
May	1,503	66.4	52	2.3	65	2.8	642	28.5	....	....	....	....	2,262
June	1,243	57.5	343	15.9	158	7.3	160	7.4	....	....	258	11.9	2,162
July	1,384	39.2	318	9.0	558	15.8	580	16.4	....	....	692	21.6	3,532
August	2,080	45.9	323	7.1	788	17.4	539	12.0	....	....	792	17.6	4,522
September	3,729	46.0	684	8.4	1,248	15.4	1,423	17.6	....	....	1,021	12.6	8,105
October	2,615	55.8	547	11.7	476	10.2	460	9.8	74	1.6	511	20.9	4,683
November	532	49.7	102	9.5	191	17.9	213	19.9	....	....	32	3.0	1,070
December	2,760	45.7	614	10.2	581	9.6	1,461	24.2	36	0.6	591	9.7	6,043
TOTAL	21,833	....	4,285	....	6,116	....	8,104	....	181	....	5,638	....	46,157

APPENDIX VI—Trolling catches to the east of Samarai

Fishing Voyage No.	Duration	Fishing Period (days)	Areas Trolled	Total Catch Trolled (lb.)
7	29.12.1957 to 18.1.1958	3	Samarai—Dumoulins—Conflicts—Deboyne—Pana—Tinani—Rossel—Tagula—Bramble Haven—Samarai	1,940
12	18.2.1958 to 3.3.1958	4	Samarai—Wari Island—Quessant Island—Anchorage Reef—Long Reef—Bramble Haven—Sable Island—Samarai	3,799
13	14.3.1958 to 23.3.1958	3	Samarai—Long Reef—Pana Rora—Panasai Island—Samarai	3,486
15	29.5.1958 to 19.6.1958	3	Samarai—Long Reef—Bramble Haven—Samarai	1,611
17	17.7.1958 to 16.8.1958	1	Samarai—Quessant Island—Bramble Haven—Anchorage Reef—Samarai	477
18	22.8.1958 to 6.9.1958	5	Dumoulins—Quessant Island—Bramble Haven—Anchorage Reef—Samarai	4,336
19	10.9.1958 to 22.9.1958	6	Samarai—Sunken Barrier—Wari Island—Long Reef—Bramble Haven—Duchateau Island—Samarai	5,071
20	26.9.1958 to 29.9.1958	4	Samarai—Suau—Stuers Island—Long Reef—Anchorage Reef—Stuers Island—Samarai	2,259
21	30.9.1958 to 4.11.1958	6	Samarai—Long Reef—Anchorage Reef—Jomard—Stuers Island—Samarai	3,646
22	17.11.1958 to 30.11.1958	2	Emerald Reef—Conflicts—Siriki Shoals—Samarai	395
23	2.12.1958 to 21.12.1958	7	Samarai—Sunken Barrier—Pana Rurawara Island—Jomard—Stuers Island—Suau—Samarai	5,626
26	5.2.1959 to 26.2.1959	5	Samarai—Dumoulins—Kosmann Island—Duchateau Island—Jomard—Long Reef—Stuers Island—Sunken Barrier—Samarai	2,406
	TOTAL	49	TOTAL	35,052

BLACK CROSS, CAUSED BY A NEW SPECIES OF PHYLLACHORA ON BANANA

By C. Booth * and Dorothy E. Shaw †

Phyllachora musicola sp. nov. is described—the cause of black cross on bananas in American Samoa, Bougainville, Fiji, Netherlands New Guinea, New Britain, New Guinea, New Hebrides and Papua. The disease has not been recorded on *Musa textilis*.

THIS disease has been known for the past four years and is widespread on bananas in New Guinea and the large islands of New Britain and Bougainville. It normally occurs as a sterile hypophyllous stroma which begins its development on the main lateral veins of the leaf and grows in the form of a cross. However, development along the lateral vein is more extensive than the growth at right angles which is parallel with the midrib of the leaf, and arms of the "cross" are therefore unequal, and sometimes double or multiple.

Mature ascospores were first found on a collection made in June, 1960 (2805a) in the Markham Valley, New Guinea. When this material was maintained in a humid atmosphere for 24 hours white masses of spore exudates occurred along the arms of the fungoid stroma. Considerable efforts were made to get both the exuded spores and those remaining in the perithecia into culture. Isolations were carried out in Papua and at the Commonwealth Mycological Institute, but without success. This is a common character of *Phyllachora*.

In November, 1960, Professor Bugnicourt sent to the C.M.I. a specimen of "black cross" which had been collected in Fiji. This was in excellent condition and it possessed mature ascospores, thus providing an interesting extension of the range of collections of this species. What is indeed surprising is that such a characteristic and conspicuous fungus has not been described before.

In June, 1961, Mr. A. Johnston sent to the C.M.I. five collections from American Samoa, Fiji and New Hebrides.

Stands of *Musa textilis* (Abaca, Manila hemp) growing near bananas at Bubia, New Guinea, and at Keravat, New Britain, have shown no sign of the disease.

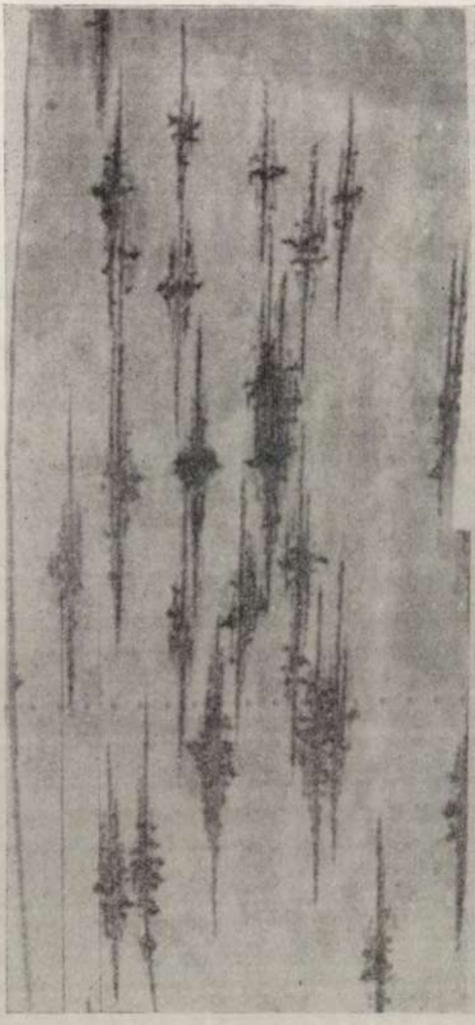


Plate 1.—Phyllachora musicola *sp. nov., causing black cross disease of banana.*

(Undersurface of leaf, natural size.)

* Commonwealth Mycological Institute, Kew.

† Department of Agriculture, Stock and Fisheries, Port Moresby.

(Manuscript received 4th August, 1961.)

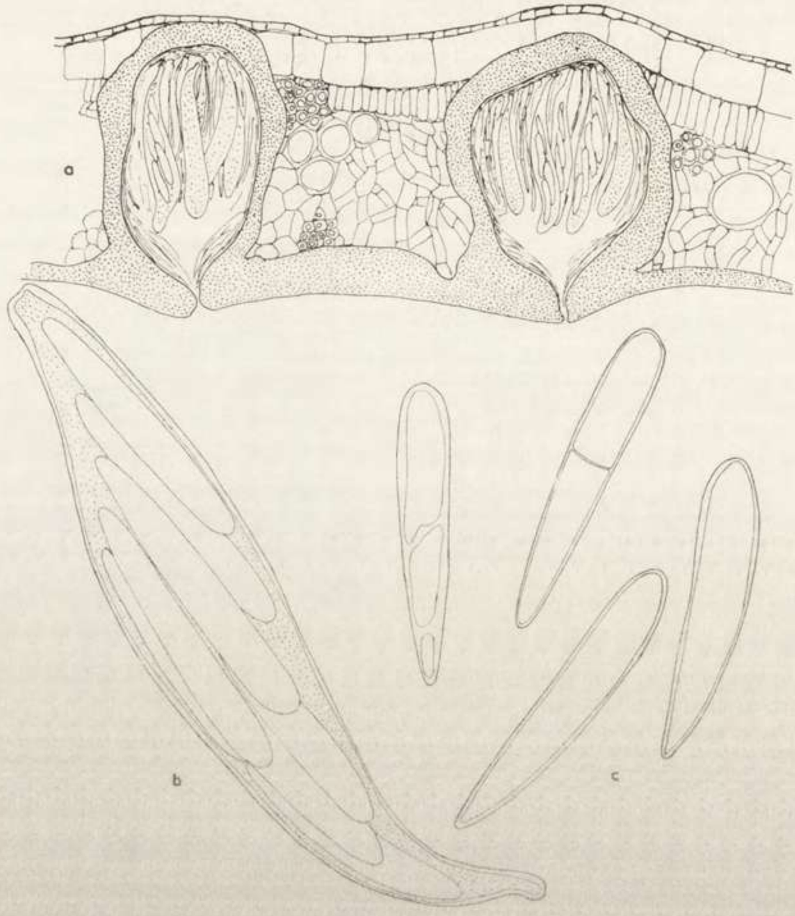


FIG. 1.—Phyllachora musicola *sp. nov. a—T.S. of banana leaf showing two perithecia* (x 125); *b—mature ascus* (x 1000); *c—four ascospores, one with pseudoseptum* (x 1000).

Phyllachora musicola sp. nov.

Stromata atra, hypophylla, elongata, secundum venas laterales cum cruce in medio crescentia, 3-6 cm. longa. *Perithecia* 10-40, in et sub stromatibus, subglobosa vel ovata, 200-240 micron dia. Paries perithecii 12-18 micron crassus, pallidus, brunneus, pseudoparenchymatous. *Asci* unitunicati, 8-spori, clavati, 115-140 x 16-20 micron. *Ascosporae* obliquae distichae, hyalinae, continuae, clavatae sed apice angustiore acuto, 35 x 6.5-8 micron. Paraphyses numerosae, fibrosae.

Habitat in foliis *Musae* species, Bubia, Markham Valley, New Guinea. Coll. D. Shaw, 2805a (I.M.I. 81614).

Description

The clypeus begins to develop on the main lateral veins on the abaxial side of the leaf. From its primary infection it spreads along the vein for about 3 cm. on either side. Simultaneously it grows out vertically and somewhat irregularly, parallel to the leaf midrib and about 0.5 cm. on either side of the lateral vein, thus producing the typical "black-cross" appearance of the mature stroma. On the upper or adaxial surface of the leaf the mature stroma appears as a series of black dots. The surrounding leaf tissues are at first discoloured and then become light-brown and occasionally whitish in the centre.

In sections the stroma or clypeus is well developed and occludes the cells of the ventral epidermis and sub-epidermal layers. Up to 40 perithecia develop beneath each clypeus ; these occupy the whole midrib and displace the palisade cells below the adaxial surface of the leaf. The base of each perithecium thus appears as a black dot below the dorsal epidermis.

In section they are oval to globose 200-240 micron dia. with a pseudoparenchymatic wall 12-18 micron wide. The apices of the perithecia are completely immersed in the clypeus and the ostiole is visible only as a minute aperture.

The asci develop from the base of the perithecium amongst the abundant paraphyses. They are unitunicate, somewhat clavate in shape but with the widest part near the centre of the ascus. They measure 115-140 x 16-20 micron and have eight obliquely distichous ascospores.

The ascospores are smooth, hyaline, aseptate and clavate but pointed at the narrow end ; they measure 35-50 x 6.5-8 micron and occasionally develop a central pseudoseptum. No pycnidia or conidial state was observed associated with the stroma.

The hosts are bananas, and once would have been given as *Musa sapientium*. We have now been advised that probably most if not all of the collections would be *M. acuminata* Colla cult. var. but flowers and fruit were usually not available for examination, and as other species of *Musa* occur in New Guinea and the adjacent islands, the collections are listed as *Musa* species.

Distribution

The following collections represent the known distribution of this species :—*American Samoa,* Tutuila June 61, A. Johnston, I.M.I. 87363, 87362. *Bougainville,* Kieta, Nov. 59, D. Shaw 2551. *Fiji,* Koronivia, Nov. 60, F. Bugnicourt ; Koronivia, June, 61, A. Johnston, I.M.I. 87361 87362. *Netherlands New Guinea,* Rendani and Wosi, May 60, D. Shaw and A. Johnston 96b and 83b ; Amban and Serui, May 61, D. Shaw and A. Johnston 129b and 155b. *New Britain,* Keravat, Nov. 60, D. Shaw 3040c. *New Guinea,* Bubia, Finschhafen, Kar Kar Is., Madang, Markham Valley, March-Nov. 60, D. Shaw, 3051, 2854a, 2708b, 2411, 2805a and 3052. *New Hebrides,* Vila and Mele, June 1961, A. Johnston, I.M.I. 87359 and 87360. *Papua,* Abam nr. Daru, Gehua, Kapogere, Laloki River, nr. Port Moresby, Oriomo River, July 57-Nov. 60, D. Shaw, 3050b, 1587a, 2173a, 2828a, 2924, 2898a.

Our thanks are due to Miss S. Daniels, Commonwealth Mycological Institute, Kew, for correcting the Latin diagnosis and to Mr. J. S. Womersley, Division of Botany, Department of Forests, Lae, New Guinea, for advice regarding the identification of species of *Musa.*

CHLOROTIC SPOT, A VIRUS DISEASE OF PASSIFLORA FOETIDA IN NEW GUINEA

By R. J. van Velsen *

SUMMARY

STUDIES on the symptomatology, identity and transmission of passion fruit chlorotic spot virus, a hitherto undescribed virus, are recorded. The virus can be mechanically transmitted to *Passiflora foetida, P. quadrangularis* L., *P. edulis* Sims. var. *flavicarpa, P. alba* Link and Otto., *Crotalaria anagyroides* H.B. et K., and *Nicotiana sylvestris* Spegazzini and Comes., but not to *Passiflora edulis* Sims., nor *P. suberosa* L.

The thermal inactivation point of the virus lies between 60 and 65 degrees C. for an exposure of 10 minutes ; the dilution end point lies between 10^{-6} and 10^{-7} and longevity in vitro is between 48 and 72 hours at a room temperature of 28 degrees C.

The virus is transmitted in the laboratory by wingless adults of *Aphis gossypii* Glover in a non-persistent manner, and occurs naturally in the field on *Passiflora foetida, P. quadrangularis,* and *P. edulis* var. *flavicarpa.*

INTRODUCTION

Virus diseases of the passion vine have been recorded in Australia (Cobb, 1901), Kenya (McDonald, 1937), South Africa (Storey, 1940), England (Bewley, 1923), Sumatra (Palm, 1922) and New Zealand (Chamberlain, 1954).

Species of *Passiflora* occur throughout the Territory of Papua and New Guinea. *P. edulis* is mainly grown, sometimes commercially, in the Highlands at Goroka, Kainantu, and Wau. *P. quadrangularis, P. edulis* var. *flavicarpa* and *P. quadrangularis* var. *macrocarpa* are grown occasionally in backyard gardens at lower levels. *P. foetida* grows wild in many cleared areas throughout the Territory, but has not been found at Wau, Goroka or Kainantu where *P. edulis* is grown. Woodiness virus has not been recorded in the Territory of Papua and New Guinea to date, and the following investigations were carried out to determine the host range, identity and method of field transmission of the virus causing a chlorotic spotting on *P. foetida* growing wild at the Lowlands Agricultural Experiment Station at Keravat, New Britain.

Passiflora foetida, P. quadrangularis, and *P. edulis* var. *flavicarpa* are found naturally infected in the field with the chlorotic spot virus.

EXPERIMENTAL STUDIES

Throughout the investigations, *P. foetida* was used as the indicator plant unless otherwise stated, and field-infected plants were used as the source of inoculum. Infectious sap was obtained by grinding infected leaves of *P. foetida* in a mortar and straining through muslin. The test plants were inoculated when 21 days old, the filtrate being applied by a cotton pad with the aid of 500 grit carborundum. The plants were maintained in insect-proof cages for 28 days following inoculation, where the air temperature varied from 65 to 93 degrees F.

The test plants listed in Table 1 were inoculated with infectious sap at various ages as indicated. Twenty-eight days after inoculation, the leaves from the test plants above the point of inoculation were removed, ground up and the filtrate inoculated onto *P. foetida* seedlings. Of the plants tested, only *P. foetida, P. alba, P. quadrangularis, P. edulis* var. *flavicarpa, Crotalaria anagyroides*, and *Nicotiana sylvestris* are susceptible. It is important to note that *Passiflora edulis* was not infected in three separate tests.

* Plant Pathologist, Lowlands Agricultural Experiment Station, Keravat, New Britain.

(Manuscript received 26th September, 1960.)

TABLE 1.—THE HOST RANGE OF CHLOROTIC SPOT OF PASSION FRUIT

Test Plant.	Reaction.	Proportion of Plants Infected.*
† *Passiflora alba* (b)	Mottle	14/21
P. edulis (b)	Nil	0/60a
P. edulis var. *flavicarpa* (b)	Mottle	13/20
P. foetida (b)	Chlorotic spot	20/20
P. quadrangularis (b)	Mottle	15/20
† *P. suberosa* (b)	Nil	0/20
Cucumis sativus var. "palmetto" (b)	Nil	0/20
C. melo (b)	Nil	0/20
Cucurbita moschata (b)	Nil	0/20
C. pepo (b)	Nil	0/20
C. pepo var. *medullosa* (b)	Nil	0/20
C. melopepo (b)	Nil	0/20
Citrullus vulgaris (b)	Nil	0/20
Nicotiana tabacum var. "White Burley" (c)	Nil	0/20
N. glutinosa (c)	Nil	0/20
N. rustica (c)	Nil	0/20
N. sylvestris (c)	Vein clearing	4/20
Lycopersicon esculentum (d)	Nil	0/20
Petunia hybrida var. "Rosy Morn" (c)	Nil	0/20
Solanum melongena (c)	Nil	0/20
S. nigrum (c)	Nil	0/20
S. dulcamara (c)	Nil	0/20
Vigna sinensis var. "Cowpea" (d)	Nil	0/20
V. sinensis var. "Black Eye" (d)	Nil	0/20
Phaseolis vulgaris var. "Brown Beauty" (d)	Nil	0/20
P. vulgaris var. "Pinto bean" (d)	Nil	0/20
P. mungo (d)	Nil	0/20
Sesbania speciosa (e)	Nil	0/20
Crotalaria anagyroides (b)	Mosaic	10/20
Stizolobium deeringianum (d)	Nil	0/20
Centrosema pubescens (d)	Nil	0/20
Chenopodium amaranticolor (c)	Nil	0/20

* In all fractions, the numerator indicates the number of plants developing symptoms, and denominator indicates the number of plants inoculated.

† Seed kindly supplied by the Queensland Department of Agriculture, Brisbane.

a. results of three tests.

b. indicates test plants inoculated when cotyledons present.

c. inoculated when six leaves present.

d. inoculated when first true leaves present.

e. inoculated when seven days old.

Symptoms Induced by the Virus

Passiflora foetida

In the field, the first three terminal leaves of the vines show no symptoms. The fourth and subsequent leaves, however, bear numerous irregular-shaped yellow spots scattered over the leaf surface, giving the leaves a distinct spotted appearance (Plate A). The leaves are normal in shape and size and the plants are not stunted and flower and set seed normally.

In the laboratory, chlorotic leaf symptoms appear seven to 14 days after inoculation.

Passiflora quadrangularis

The young leaves at the tip of the tendrils on field-infected vines appear healthy, but the third and subsequent leaves show a distinct dark-green/light-green mottle (Plate B). The mature leaves, however, are dark-green and appear normal, although the virus has been isolated from them. The fruit is reduced in size and is slightly malformed.

Leaf symptoms, as described above, appear 14 to 21 days after inoculation in the laboratory.

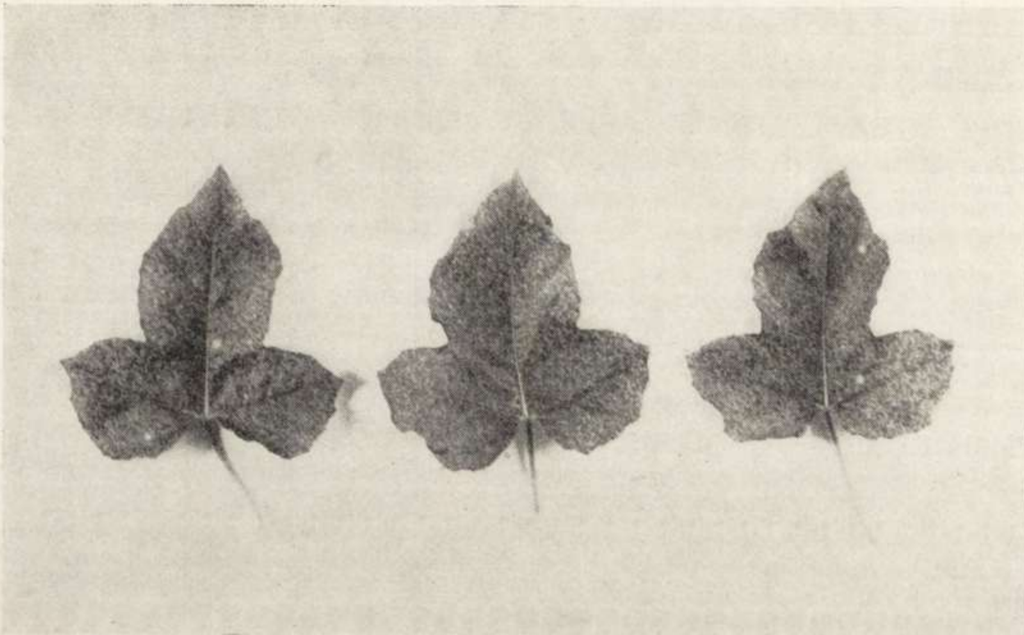


PLATE A.—*Leaves from field-infected* Passiflora foetida *L. showing chlorotic spotting.*

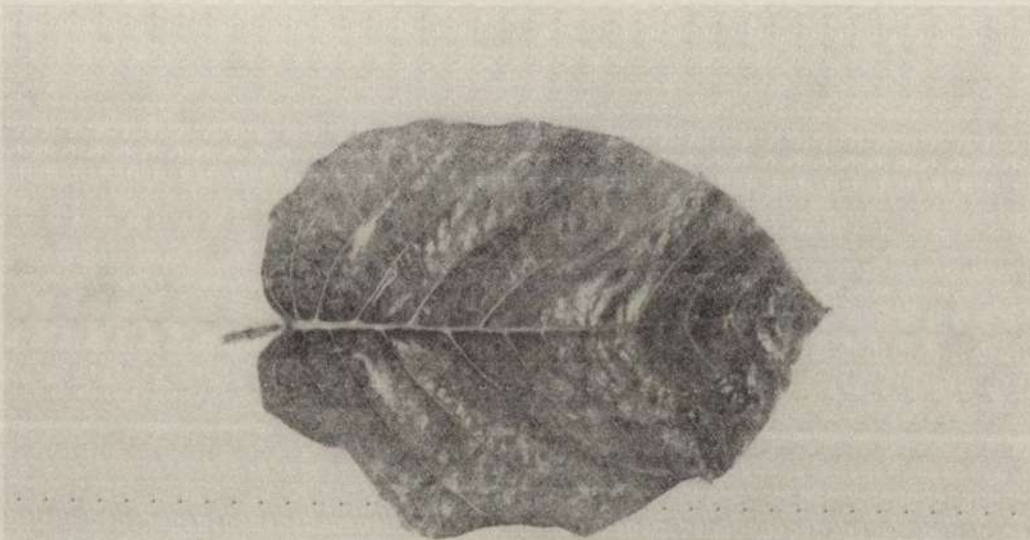


PLATE B.—*Leaf from diseased* Passiflora quadrangu'aris *L. showing mottle symptoms.*

P. edulis var. *flavicarpa*

The foliar symptoms are similar to those recorded on *P. quadrangularis*. However, infected vines bear normal edible fruits.

P. alba

This species of *Passiflora* has not been found on the Gazelle Peninsula, and thus no field symptoms are available. In laboratory tests, foliar symptoms were recorded seven to nine days following inoculation. The leaves emerging develop a distinct yellow-green mottle, which is not accompanied by vein clearing, wilting of the petioles or curling of the leaves as occurs with woodiness virus (McKnight, 1953). As the diseased leaves mature they become darker and the mottle is less distinct. The leaves are not stunted or malformed. When the plants are pruned heavily, the emerging leaves exhibit a distinct mosaic pattern and the leaves are severely stunted and malformed (Plate C).

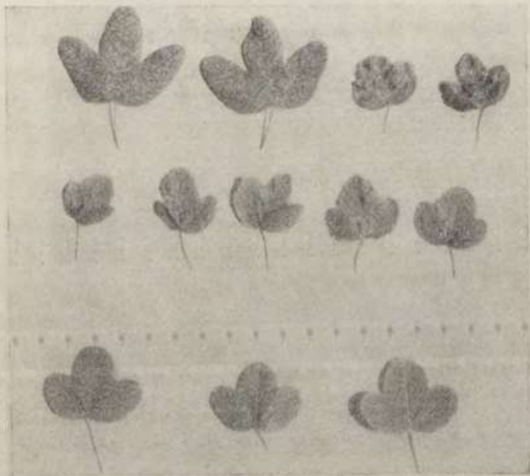


PLATE C.—*Leaves from* Passiflora alba *Link & Otto. Top two rows of leaves taken from plants inoculated with chlorotic spot virus, showing mottle and leaf distortion. Bottom row showing healthy leaves.*

Crotalaria anagyroides

C. anagyroides develops leaf symptoms seven to 14 days after inoculation. The first leaves emerging after inoculation bear no symptoms, but the following leaves show a light-green mosaic. The plants are slightly stunted, but flower and set seed normally.

Nicotiana sylvestris

A distinct vein clearing appears 40 to 50 days after inoculation. The leaves are reduced in size when compared with healthy leaves (Plate D).

PLATE D.—Nicotiana sylvestris *Spegazzini & Comes. Leaf on left from a healthy plant. Leaf on right showing vein clearing and reduction in leaf size following inoculation with passionfruit chlorotic spot virus.*

Physical Properties

The usual methods for the determination of the physical properties were used. *Passiflora foetida* was used throughout as the indicator plant. The dilution end point of the virus lies between 10^{-6} and 10^{-7} (Appendix 1), using distilled water as the diluent. The virus is inactivated in extracted sap following a 10-minute exposure at 65 degrees C., but not at 60 degrees C. (Appendix 2). The longevity in vitro of the virus lies between 48 and 72 hours when the solution is kept at room temperature of 28 degrees C. (Appendix 3).

Attempted Seed Transmission

From field observations carried out at Keravat, 45 to 100 per cent of the plants of *Passiflora foetida* showed chlorotic spot symptoms. The possibility of the virus being seed-transmitted was investigated. Seeds were collected from field-infected plants, washed to remove pulp, sorted, counted, and then planted out into sterilized forest soil. The seedlings were kept under observation for eight weeks. Seeds were also collected from disease-free plants grown in the laboratory. The results as recorded in Appendix 4 illustrate that the virus is not seed-transmitted.

Insect Transmission

A collection was made of insects found feeding on diseased *Passiflora foetida* in the field at Keravat and these were released in the laboratory onto healthy test plants of *P. foetida*. Specimens were kept and were forwarded to Dr. J. J. H. Szent-Ivany for identification. Of the insects tested (Appendix 5), only *Aphis gossypii* was found to transmit the virus.

Further transmission tests using *Aphis gossypii* as the vector were carried out to determine whether the virus is transmitted in a persistent manner or not. Aphids were collected from laboratory colonies maintained on *Cucurbita moschata* Duchesne, starved for two hours and then allowed an access feed of 10 minutes on diseased leaves of *Passiflora foetida*. The aphids were then removed and placed onto healthy plants of *Passiflora foetida* with the aid of a camel's-hair brush. Single apterous aphids were used. The aphids were then shifted to fresh plants every 24 hours or until they died. The results in Appendix 6 indicate that the virus is transmitted in a non-persistent manner. A further test was carried out in which the access-feeding time was less than 30 seconds. Of the 20 aphids tested, 11 were able to transmit the virus in a test-feeding period of two hours, preceded by an access-feeding period of 30 seconds. Thus, it is evident that the virus is transmitted in a non-persistent manner by *Aphids gossypii*.

DISCUSSION

The only other virus recorded on *Passiflora* spp. is passion fruit woodiness, which Magee (1948) states is a strain of cucumber mosaic virus. Passion fruit woodiness readily infects *P. edulis*. McKnight (1953) was unsuccessful in transmitting passion fruit woodiness to tomato, *Datura stramonium* L., cucumber, *Lupinus mutabilis* Sweet, and tobacco. The virus investigated at Keravat could not be transmitted to the above hosts or to *P. edulis*.

Since no serological tests could be carried out at Keravat, the host range and symptom pattern are used as the critical criteria in identifying the virus. The symptom patterns of the virus on *Passiflora foetida, P. alba, and P. edulis* var. *flavicarpa* are distinct from those recorded by McKnight induced by passion fruit woodiness. In Appendix 7, a comparison is made between cucumber mosaic (Smith, 1957), passion fruit woodiness (McKnight, 1953) and passion fruit chlorotic spot. From this comparison it is evident that the host range of passion fruit woodiness (McKnight, 1953) is similar to that of passion fruit chlorotic spot where results are available, but it must be noted that the virus is not transmitted to *P. edulis* or *P. suberosa*. It is essential to note that passion fruit chlorotic spot differs from cucumber mosaic virus in its host range. Thus, it is not valid to term passion fruit chlorotic spot a strain of cucumber mosaic virus. The mean maximum temperature at which the tests were carried out was 92 degrees F. The author is of the opinion that the virus investigated is distinct from cucumber mosaic and passion fruit woodiness virus and is a new virus hitherto undescribed. It is termed chlorotic spot virus of passion fruit.

ACKNOWLEDGEMENTS

The author wishes to acknowledge that the insect identifications were carried out by Dr. J. J. H. Szent-Ivany and the photographs are the work of Mr. A. E. Charles.

REFERENCES

BEWLEY, W. F. (1923). Mycological Report. 8th Annu. Rep. Cheshunt expt. Sta. pp. 34,35.

CHAMBERLAIN, E. E. (1954). Plant Virus Diseases In New Zealand. N.Z. D.S.I.R., Bull. 108.

COBB, N. A. (1901). Woodiness of the passion fruit. Agric. Gaz. N.S.W. 12 : 407-18.

MAGEE, C. J. (1948). Woodiness or mosaic disease of passion fruit. Agric. Gaz. N.S.W. 59 : 199-202.

McDONALD, J. (1937). Report of Senior Plant Pathologist. Rep. Dep. Agric. Kenya. 1936.

McKNIGHT, T. (1953). The woodiness virus of the passion vine (*Passiflora edulis* Sims.). Qd. J. agric. Sci. 10 : 1-32.

PALM, B. T. (1922). Verslag van het Deli Proefstation over 1 Juli 1920 - 30 Juni 1921. Meded. Deli Proefstat. te Medan-Sumatra. 1 Ser. II 21 : 72 pp. (Rev. appl. Mycol. 11, 35).

SMITH, K. M. (1957). A text book of Plant Virus Disease, 2nd. Ed. pp. 225-227. London, Churchill.

STOREY, H. H. (1940). Annual Report of the Plant Pathologist. Annu. Rep. E. Afr. Res. Sta. Amani, 1939 : 8-11.

APPENDIX 1.—The dilution end point of chlorotic spot of passion fruit, using *Passiflora foetida* as the test plant.

Dilution.	Proportion of Plants Infected.
Undiluted	20/20
1 : 10	20/20
1 : 100	20/20
1 : 1,000	20/20
1 : 10,000	20/20
1 : 100,000	12/20
1 : 1,000,000	3/20
1 : 10,000,000	0/20
1 : 100,000,000	0/20

APPENDIX 3.—The longevity in vitro of chlorotic spot of passion fruit, at a room temperature of 28 degrees Centigrade, using *Passiflora foetida* as the test plant.

Time of Exposure in Hours.	Proportion of Plants Infected.
0	20/20
24	16/20
48	2/20
72	0/20
96	0/20
120	0/20
144	0/20

APPENDIX 5.—Transmission of chlorotic spot of passion fruit by insects found infesting *Passiflora foetida* in the field.

Insect Species	No. Insect per plant.	Proportion of Plants Infected.
Aphis gossypii (a)	20	6/20
Red Spider	20	0/20
Euricania splendida F. (b)	20	0/20
Nisia atrovenosa Leth. (c)	20	0/20

a. Identified by Dr. V. F. Eastop.

b. Identified by Dr. J. J. H. Szent-Ivany.

c. Identified by Mr. R. G. Fennah.

APPENDIX 2.—The thermal inactivation point of chlorotic spot of passion fruit, at an exposure of 10 minutes, using *Passiflora foetida* as the test plant.

Temperature in Degrees Centigrade.	Proportion of Plants Infected.
28	20/20
35	20/20
40	16/20
45	11/20
50	9/10
55	6/20
60	2/20
65	0/20
70	0/20

APPENDIX 4.—The percentage of seed transmission of chlorotic spot virus in *Passiflora foetida*.

Plant.	No. Seeds Planted.	No. Plants.	Per Cent. Germination.	Per Cent. Diseased.
Healthy	2,000	1,973	98.7	Nil
Diseased	2,000	1968	98.4	Nil

APPENDIX 6.—Persistency test of chlorotic spot virus using *Aphis gossypii* as the vector.

Aphid Number	Time after access feed in days. 1	2	3	4	5	6	7	8	9	10	11
1	+	—	—	—	D						
2	+	—	—	—	—	D					
3	+	—	—	—	—	—	—	—	—	D	
4	+	—	—	—	—	D					
5	—	—	—	—	—	—	—	—	D		
6	—	—	—	—	—	—	—	—	—	—	—
7	+	—	—	—	—	—	—	—	—	—	—
8	—	—	—	—	—	D					
9	+	—	—	D							
10	—	—	—	—	—	—	—	D			
11	—	—	—	—	—	—	—	—	—	—	D
12	—	—	—	—	—	—	—	—	—	—	—

D death of aphid.

\+ infection.

— non-infective.

APPENDIX 7.—Comparison of cucumber mosaic virus (Smith, 1957), passion fruit woodiness (McKnight, 1953) and chlorotic spot virus (van Velsen).

Property.	Cucumber Mosaic.	Passion Fruit Woodiness.	Chlorotic Spot
Host range—			
Passiflora alba	N.R.	+	+
P. edulis	+	+	—
P. edulis var. *flavicarpa*	N.R.	+	+
P. quadrangularis	N.R.	N.R.	+
P. suberosa	N.R.	+	—
P. foetida	N.R.	+	+
Cucumis sativus	+	—	—
Tobacco	+	—	—
Tomato	+	—	—
Nicotiana glutinosa	+	—	—
Petunia hybrida	+	—	—
Dilution end point	1 : 10,000	N.R.	10^{-7}
Thermal In. Pt.	60-70	N.R.	65 degrees C.
Longevity	3-4 days	N.R.	3 days
Insect vectors	*Aphis gossypii*	*A. gossypii*	*A. gossypii*
	Myzus persicae	*M. persicae*	N.R.
	Macrosiphum euphorbiae	*Macrosiphum gei*	N.R.
	Aulacorthum solani	N.R.	N.R.
Persistency	*Non-persistent*	N.R.	*Non-persistent*

+ susceptible.

— not susceptible.

N.R. No results given.

Port Moresby: W. S. Nicholas, Government Printer.—5731/8.61.

Notice to Authors of Papers

All articles submitted for publication in the *Journal should* be typed with double spacing. Carbon copies should not be sent.

Authors are requested to avoid the use of abbreviations and not to underline either words or phrases.

References to articles and books should be carefully checked. In a reference the following information should be given : initials of author, surname of author, full title of article, name of journal, volume, ful date, number of the first page of article. If a reference is made to an abstract of a paper, the name of the original journal, together with that of the journal in which the abstract has appeared, should be given with full date in each instance.

Authors who are not accustomed to preparing drawings or photographic prints for reproduction are invited to seek the advice of the Editor.

Communications

All communications should be addressed to the Editor, *The Papua and New Guinea Agricultural Journal*, Department of Agriculture, Stock and Fisheries, Port Moresby.

Subscription Rates

Commencing with Volume 9, No. 1, *The Papua and New Guinea Agricultural Journal* will be the title for the former publication *Papua and New Guinea Agricultural Gazette*. The publication will still follow the form of the pre-war *New Guinea Agricultural Gazette* and will deal with recent advancement in tropical agriculture and act as an extension medium for the dissemination of agricultural information to the Territory planting and farming community.

The Annual Subscription payable in advance will be 1s. 6d. postage paid for each issue or 6s. per annum for four issues.

Advertising Rates

Applications for advertising space in this *Journal* should be addressed to—

The Editor, *The Papua and New Guinea Agricultural Journal*,

Department of Agriculture, Stock and Fisheries, Port Moresby.