



LAES TECHNICAL BULLETIN

1/92



INSECT PESTS OF COCOA IN PAPUA NEW GUINEA

IMPORTANCE AND CONTROL



J.E. MOXON

1992



PNGpa

633.74

MO

[illegible]

S & M SUPPLY CO

MOXON, J. E. PNGpa633.74
MO

Insect pests of cocoa in
PNG: importance & control

~~Insect pests of cocoa in PNG: importance & control~~

INSECT PESTS OF COCOA IN PAPUA NEW GUINEA - IMPORTANCE AND CONTROL

J. E. MOXON

Department of Agriculture and Livestock,
Lowlands Agricultural Experiment Station,
East New Britain Province, Papua New Guinea

DEPT. OF AGRIC. & LIVESTOCK
CENTRAL LIBRARY H/A

ABSTRACT

Cocoa is the major cash crop in the lowland regions of Papua New Guinea. Many insects feed on cocoa, attacking most parts of the tree in both the establishment and production phases. Crop losses may range from slight to serious, depending on insect type, density and distribution and the occurrence and duration of attack. A number of serious pests are absent from the North Solomons Province which can produce half of the country's cocoa. Cocoa pests are considered in this paper in four groups according to estimated economic importance. Their biology, distribution, importance, and control are discussed. The most important group of pests is composed of the wood-boring beetle larvae of the genera *Pantorhytes* and *Glenea* (longicorns), pod-damaging mirids, and leaf-eating caterpillars. The second group comprises Grey Weevils, which chew shoots of young trees; *Panosepta* moths, which feed on terminal branches of young and mature trees; and wood-eating termites. In the third group are *Rhyparida* leaf-eating beetles, pod-boring moths, Root Chafers, *Orymagis* beetle tip borers, *Amblypelta* bug pod-suckers, *Zeuzera* moth stem-borers, and mealybugs. The fourth category comprises pests of lesser importance.

A range of biological, cultural, and chemical control recommendations is available for most of the pests. Prophylactic, broad hectareage chemical spraying is discouraged and, because of a wide variety of pests and their natural enemy complexes, an integrated approach is preferred. Both large estate and smallholder sectors produce large amounts of cocoa. However, their farming methods are generally very different, the former having a much higher technical, financial, and management input than the latter. It is often necessary, therefore, to provide different pest control recommendations to suit the two farming sectors.

Many smallholder blocks either begin as - or eventually become - mixed gardens containing coconuts, areca palms, bananas, and other fruit, nuts, and food crops. Some pest associations between these crops and cocoa in the farming system and between shade trees and cocoa are considered, and the value of coconut as a shade for cocoa is highlighted.

INTRODUCTION

Cocoa is the most important cash crop in the lowland areas of Papua New Guinea. Large-scale redevelopment of senile cocoa and development in new regions, using high-yielding Trinitario x Upper Amazon hybrid material and clonal material derived from them, is expected to increase production significantly over the next few years. The major cocoa-growing provinces are North Solomons, East New Britain, Madang, New Ireland, and West New Britain; other areas are rapidly increasing production. While many factors such as climate, soils (Bleeker et al. 1981) and marketing favour cocoa production in the major cocoa-growing regions, pests, diseases, and poor management can impose serious constraints. *Pantorhytes* weevils, caterpillars, and vascular-streak dieback, for example, caused the collapse of the industry in several important regions in the 1960s and 1970s.

Many insects feed on cocoa. More than 300 species have been associated with the crop in Papua New Guinea (Szent-Ivany 1961, 1963). However, only about 10 pests regularly cause widespread, economic damage. The distribution of these pests is variable, and this has a marked influence on the ease, cost, and success of growing cocoa. For example, *Pantorhytes* weevil species, mirids, and some other pests are believed to be absent from North Solomons Province - an island that produces half of the country's cocoa. On the mainland, many primary pests are present and require high management and capital inputs for successful control. Pests can also be limited in distribution within regions. Flightless *Pantorhytes* and Grey Weevils may be abundant on one farm and absent from another just a few kilometres away. Climate, which influences both occurrence and density of pest populations, can be quite different within a region. In

DEPARTMENT
CENTRAL LIBRARY
BONEDCU
PAPUA - NEW GUINEA

PNG 633-74

MO

East New Britain Province, for example, rainfall varies from 2000mm to 4000mm per annum within 50 kilometres, and pests are consistently much worse in some areas than in others.

The economic importance of a cocoa pest is ultimately measured in terms of crop loss. This can be a direct result of feeding on pods or an indirect result of feeding damage on other parts of the tree which then affects pod production. The major pests in Papua New Guinea attack many parts of the tree, including pods, leaves, shoots, branches, trunks, and roots. Both young and mature cocoa trees are attacked, so pest control is often necessary throughout the life of the crop. Pest damage on young cocoa may stunt or kill the tree or cause a delay in production of the first pods and thus a crop loss. Pests which attack the wood of mature trees can cause premature senility or death, and so are particularly important. The insect type, density, distribution, occurrence, and duration of attack contributes to the overall importance of a pest. In the early 1950s, the major cocoa pests were *Pantorhytes*, Longicorns, mirids, and *Pansepta*; minor pests included *Rhyparida*, Grey Weevils, defoliating caterpillars, termites, *Zeuzera*, thrips, a collembolan, and the Giant African snail (Urquhart and Dywer 1951). Szent-Ivany (1961) lists *Pantorhytes*, mirids, longicorns, and *Amblypelta* as major pests, and more than 140 minor pests. An attempt has been made in this paper to identify the current status of cocoa pests in Papua New Guinea based on their estimated effect nationwide. A detailed account of important pests is given, with notes on minor pests. The major pests in recent times are considered, in four ranked categories according to estimated economic importance, in Table 1.

TABLE 1: INSECT PESTS OF COCOA IN PAPUA NEW GUINEA GROUPED IN ORDER OF ECONOMIC IMPORTANCE (NO RANKING WITHIN GROUPS)

Group	Insect Pest	Type of Damage
1.	Defoliating Caterpillars (Lepidoptera: Geometridae Limacodidae, Noctuidae)	Larvae eat both young and mature leaves.
	Longicorns (Coleoptera: Cerambycidae)	Larvae bore into wood of trunk and main branches
	Mirids (Hemiptera: Miridae)	Adults and nymphs suck sap from pods and shoots
	<i>Pantorhytes</i> (Coleoptera: Curculionidae)	Larvae bore into wood of trunk and main branches
2.	Grey Weevils (Coleoptera: Curculionidae)	Adults chew bark of young cocoa shoots
	<i>Pansepta</i> (Lepidoptera: Xylorictidae)	Larvae bore in branches of larger trees
	Termites (Isoptera: Kalotermitidae)	Adults and nymphs chew wood inside the tree
3.	<i>Amblypelta</i> (Hemiptera: Coreidae)	Adults and nymphs suck sap from pods
	Chafers (Coleoptera: Melolonthinae)	Larvae chew roots of young trees
	Mealybugs (Hemiptera: Pseudococcidae)	Adults and nymphs suck sap from shoots, pods and flowers.
	<i>Oxymagis</i> (Coleoptera: Cerambycidae)	Larvae bore into terminal branches
	Pod Borers: <i>Cryptophlebia</i> (Lepidoptera: Tortricidae) <i>Olethreutes</i> (Lepidoptera: Olethreutidae)	Larvae bore into husk of pods
	<i>Rhyparida</i> (Coleoptera: Chrysomelidae)	Adults eat leaves
	<i>Zeuzera</i> (Lepidoptera: Cossidae)	Larvae bore into wood of trunk and main branches
4.	Miscellaneous Pests	More than 300 species which eat leaves, pods and wood of the cocoa tree.

PANTORHYTES

Pantorhytes species were noted as cocoa pests in 1938 (Frogatt 1938) and described in 1941 (Gressitt 1966). They have been recognised as possibly the worst pest of cocoa in Papua New Guinea since 1961 (Szent-Ivany 1961). *Pantorhytes* belong to the tribe Pachynryncini sub-family Brachyderinae, which is primarily Philippine and Papuan in distribution, although a few representatives occur in central Indonesia (Gressitt 1966). More than 70 species of *Pantorhytes* have been described, and their taxonomy is reviewed by Gressitt (1966) with later additions by Stibick (1978, 1979). *Pantorhytes* species occur in New Guinea, the Bismarck Archipelago, and the Solomon Islands, with certain species extending to Queensland in Australia. There are thought to be many undescribed species. Gressitt (1966) recognises 11 species as primary pests of cocoa, though about six of these are of particular importance and are distributed in all but one of the major cocoa regions (Stibick 1972; see also Table 2). It is interesting that in the North Solomons Province, *P. bipectatus* is scarce and never of economic importance while the same species in the neighbouring Solomon Islands can be the most damaging pest (Friend 1972).

Pantorhytes species are robust, heavily sclerotised, apterous weevils about 1cm-5cm long. The different species are of similar shape and size but can be identified by body markings. The sexes also look similar but can be distinguished by abdominal sclerites (Hassan 1973, 1975). The biology of a number of species has been studied (Frogatt 1938; Anon 1961, 1971; D.A.S.F. 1961; Szent-Ivany 1961; Baker 1970; Hassan 1971, 1973, 1975, 1976; Lamb and Scotter 1971; Dept. Ag. 1972; Baker et al. 1974; May 1978; Smith and Prior 1980). The eggs are white, ovoid and about 2mm long. They are laid singly in crevices on the trunk and main branches, particularly near the jorquette, intersections of main branches, and tree base. Eggs hatch after two to three weeks. The larva has a well-developed brown head and curved cream body with rows of fine hairs. The larva bores into the wood 1cm to 2cm deep and feeds on sapwood, making tunnels or channels parallel to the surface. The larva feeds for three to nine months through nine instars and then pupates beneath the bark for about 14 days. The newly-emerged adults feed for four to six weeks before mating, after which time the female lays about two eggs per day throughout her life span of one to two years.

TABLE 2: MAJOR PANTORHYTES PEST SPECIES IN PAPUA NEW GUINEA

Species	Location (Province)
<i>P. szentivanyi</i>	Oro
<i>P. plutus</i>	New Britain and New Ireland
<i>P. batesi</i>	Morobe
<i>P. proximus</i>	Central
<i>P. stanleyanus</i>	Milne Bay and Central
<i>P. pseudocarbonarius</i>	Sepik and Madang

Adults feed mainly on the semi-hardened bark of young cocoa shoots and occasionally on pod husks, leaves, and flowers, though this damage is rarely economic. Larval feeding, by contrast, is usually devastating. The larvae bore into the sapwood of trunk and main branches of trees over two-and-a-half years old. This causes structural weakness, tip dieback, and a general canopy degradation. Branches may be ring-barked and die, and trees may split at the jorquette. A severe drop in pod production follows and often a large proportion of trees in the plantation die. In Papua New Guinea tree losses of over 90% are common. Friend (1972, 1973) considers that more than three larvae per tree cause economic damage. The rapidity of population growth has been illustrated by Baker et al. (1974). Wounds in the bark, made by larvae, are an entry point for bark canker, *Phytophthora palmivora*, which also reduces yield and kills trees (Prior and Smith 1981). Termites may also enter the tree as secondary pests (Szent-Ivany 1956). Some species of *Pantorhytes* are more damaging than others. *Pantorhytes* is not present on all cocoa farms, and some areas are notoriously worse than others.

Much work has been done on biological, chemical, and cultural control of the pest, and is reviewed by Smith (1981a). The Department of Agriculture and Livestock (DAL) currently recommends five control methods (Smith 1980, revised by Moxon 1983a and 1992b).

1. Biological Control Using Crazy Ants

Although more than 30 parasites, predators, and pathogenic fungi have been recorded from *Pantorhytes* (Anon 1969, 1971a; Dept. Agric. 1972; Friend 1972, 1973; Bourke et al. 1973; Baker 1976a, 1978), none has shown promise as effective biocontrol agents (Szent-Ivany 1961; Baker 1976a) except the Crazy Ant, *Anoplolepis longipes* Jerd. (Baker 1972; Room and Smith 1975; Moxon 1983b, 1992b) and possibly the Kurakum ant, *Oecophylla smaragdina* (Friend 1972, 1973; Moxon unpublished). Dense Crazy Ant populations eliminate *Pantorhytes* from cocoa, but, as ant density decreases, *Pantorhytes* re-invade and increase (Moxon unpublished). A technique has been developed for collecting and introducing Crazy Ants to cocoa (Baker 1976b; Smith 1980; Moxon 1983b, 1992d). The Crazy Ant also controls some other cocoa pests. Crazy Ant populations are often transient.

2. Hand-Picking of Adults

Adults weevils are easily seen, collected, and destroyed by hand during the middle of the day when they descend through the canopy to cooler places below. This method is popular with smallholders who operate on a restricted budget. Some large estates also find the method cost effective - a "bounty payment" system is sometimes used.

3. Larval Channel Paints

Larvae are easily detected in the tree by the presence of frass expelled from the entrance hole of the larval channel. The frass is removed with a stiff brush, and the larvae are then easily killed by applying a solution (Channel Paint) of Dichlorvos, White Oil, Ridomil, (Metalaxyl) and water onto the bark around the entrance hole, using with a small brush. About 80% of larvae treated in this way die. Ridomil is added to the Channel Paint to control any *Phytophthora* that might be present. It is recommended that trees severely infested with *Pantorhytes* larvae be inspected and treated at least every two weeks.

4. Coconut Shade

Pantorhytes populations are often, but not always, low in cocoa grown beneath coconut shade (Hassan 1971; Room and Smith 1975; Smith 1981d), although the reason for this is unknown. One possible explanation is that coconuts often harbour *Oecophylla smaragdina* ants which are believed to kill *Pantorhytes* (Friend 1972, 1973; Moxon 1992b). By contrast, cocoa grown beneath other shade trees such as *Leucaena* and *Gliricidia* is often badly damaged by *Pantorhytes*. For this reason and other considerations, it is strongly recommended that coconuts be used as a shade for cocoa.

5. Insecticide Sprays for Adults

The first foliar insecticide sprays against *Pantorhytes* adults were used in 1938, and since then this method of control has continued to receive much attention. A list of chemicals tested against *Pantorhytes* adults and larvae is given by Smith (1981a). The present recommendation employs pyrethroids applied with either a knapsack pressure sprayer or mistblowing machine (Moxon 1992b), although this is expensive and is employed by few growers.

Because of the severity of the pest problem, growers are recommended to attempt control of both the larvae and adults simultaneously, using a combination of the above control methods. An integrated control scheme for cocoa pests and diseases in Papua New Guinea is described by Smith (1981b). Several alternate hosts of *Pantorhytes* are known (Moxon 1983a), and it is advisable to remove these in areas of newly-planted cocoa blocks. Vegetative barriers have been suggested as a means of restricting the spread of flightless pests, but the amount of land required for such barriers usually makes this impracticable unless the barrier is of additional value - for example, a pasture or cash cover crop.

LONGICORNS

A large number of cerambycid beetles, subfamily *Laminae* (longicorn beetles), feed on cocoa in Papua New Guinea (Szent-Ivany 1961). However, only two species are primary pests, *Glenea aluensis* Gahan, which occurs in the Islands Region and in the Solomon Islands, and *G.lefebueri* Guer, which is found on the mainland and in Irian Jaya (Snee 1963). A third species, *G. novemguttata* Cast, was a serious cocoa pest in Java (Dammernan 1929). The larvae of *Glenea* cause extensive damage throughout Papua New Guinea by boring into the trunk and, less frequently, main branches to feed on sap wood.

Adults lay their eggs singly in crevices on the tree trunk and, less frequently, on main branches. The larvae on hatching burrow into the tree and make tunnels while feeding on the sap wood. When fully mature, they are about 3cm long and 0.5cm wide, and have a sub-cylindrical, creamy-yellow body with prominent intersegmental constrictions. The larvae feed for one-and-a-half months before boring deeper into the tree to pupate. There is a larval dormancy period of a month, and pupation takes a further week (Schreurs 1965), giving a total life cycle duration of about three months.

The larval damage is similar to that caused by *Pantorhytes* but can be easily distinguished by the longer larval tunnels, which are made in a horizontal rather than a vertical direction. The frass, which is expelled from the entrance hole, is produced in greater quantities and has a more fibrous and foamy appearance than that of *Pantorhytes*. Larvae are often found in the base of trees surrounded by tall grass, and at the junction of branches with jourquettes where they can cause ringbarking. The biology and feeding behaviour of *G.lefebueri* larvae is described by Schreurs (1965). Larval damage causes a general reduction in canopy and resulting pod loss or death of the tree. *Glenea* longicorns prefer heavily-shaded conditions (Entwistle 1972) and are a particular problem in poorly managed cocoa and in plantings adjacent to forest.

Longicorn larvae are easily detected and controlled using a Channel Paint consisting of a systemic insecticide, Dichlorvos, mixed with White Oil, Ridomil and water in the same way as for *Pantorhytes* (Smith 1979a; Moxon 1992e). Inspection and treatment of trees is recommended at four-weekly intervals. Good hygiene, shade adjustment, and weed control help reduce infestations. Longicorn channels, like those of *Pantorhytes*, are a major source of entry for bark canker, *Phytophthora palmivora*, (Prior and Smith 1981) which also causes widespread crop loss and tree deaths. For this reason, Ridomil fungicide is added to the Channel Paint mixture.

MIRIDS

Mirids or capsids are the world's most widespread and important cocoa pest (Entwistle 1972). Four species of importance are present in Papua New Guinea: *Helopeltis clavifer*, *Pseudodoniella typica*, *P. laensis* and *P. pacifica*.

H. clavifer was described from Waigeo, Irian Jaya, in 1871. It was next collected as a pest on cocoa in 1954 (Dun 1954b). It is now a serious pest on cocoa throughout the mainland, and ranges from sea-level to 100m (Smith 1978). The species is also present on New Britain and New Ireland but does not attack cocoa there (Smith 1981c). *H. clavifer* is reported as a serious pest of cocoa in Sabah, Malaysia (Conway, 1971), and may also be present in Indonesia (Smith 1981c).

P. laensis is found on mainland Papua New Guinea and Irian Jaya (Schreurs et al. 1961). while *P. typica* and *P. pacifica* occur only in the Islands Region of Papua New Guinea. *P. pacifica* is further restricted to altitudes above 500m (Dun 1954b). No mirids have been recorded attacking cocoa in the major cocoa-producing province of North Solomons.

Pseudodoniella mirids were first seen attacking cocoa in 1949 (Dun 1954b). The three new species of *Pseudodoniella* were later described by China and Carvalho (1951) and Miller (1957). *Pseudodoniella* adults are similar in size and shape, being about 8mm long and 4mm wide. *P. laensis* and *P. pacifica* are orange with two brown spots on the thorax, while *P. typica* is dark brown. All three have a notable swelling on the dorsal surface of the thorax.

The robust bodies of *Pseudodoniella* are in strong contrast to the slender body of the well-known mosquito bug, *H. clavifer*. Information on the *Pseudodoniella* species is restricted to the few accounts of Dun (1951, 1954b), Szent-Ivany (1962), and Smea (1963), while a detailed study of the biology, ecology, and control of *H. clavifer* has been made by Smith (1972, 1973, 1977, 1978, 1979b, 1981, 1982).

The general biology and ecology of *Helopeltis* and *Pseudodoniella* are similar. Adults lay their eggs beneath the epicarp of the pod and, less frequently, on vegetative tissue such as young shoots. *Helopeltis* eggs hatch after about seven days, and nymphs undergo development through five nymphal stadia to adults in a further 10 to 13 days (Smith 1981c). By contrast, Dun (1954b) finds that the *P. typica* egg duration is about 14 days and nymphal duration 10 to 14 days. The maximum adult longevity in captivity is 46 days for *H. clavifer* and only 11 days for *P. typica*. *H. clavifer* is known to have a wide host range (Smith 1981c), while *Pseudodoniella* is known only on *Ficus* spp. and cocoa.

Both adults and nymphs attack cocoa, feeding preferentially on pods. The pests suck juices from the pods, causing physical damage. Feeding produces round lesions about 3mm in diameter, which at first have a brown, water-soaked appearance and after a few hours harden and turn black. Pod losses are caused by damage to pods less than 10cm long, while attack on larger pods may cause deformation and reduced bean size (Smith 1981c). Secondary infections by pathogenic fungi such as *Phytophthora palmivora* and *Gleosporium* spp. add to crop losses. Mirids also feed on young shoots and leaf petioles, which can cause considerable tip dieback, particularly damaging to young trees. Severe mirid damage in Papua New Guinea is both common and widespread in all areas except the North Solomons. Dun (1954b) reports 10% - 80% crop losses from *P. typica* in the Islands Regions. Smith (1981c), working with *H. clavifer* on the mainland, also reports a wide range of crop losses from 10% to 95%.

Few parasites of mirids are known in Papua New Guinea, but there is a large number of non-specific predators, including four ant species (Smith 1981c). *Wasmania auropunctata* is used to control cocoa mirids in Cameroon (Bruneau de Mire 1969), and *Oecophylla smaragdina* is also believed to be a good control agent (Szent-Ivany 1961; Friend 1973; Leston 1970; Smith 1981; Moxon 1992b). Research in Papua New Guinea has shown that the Crazy Ant, *Anoplolepis longipes*, can eliminate both *Helopeltis* and *Pseudodoniella* mirids from cocoa (Moxon 1992d). A number of insecticide trials have been conducted on mirids in Papua New Guinea (Smith 1982).

Chemical control of mirids is recommended by the Department of Agriculture and Livestock, using Lindane (BHC) at 100g ai per hectare or Karate (Lambda Cyhalothrin) at 8g ai per hectare (Moxon 1992c). The spray can be applied using either a mistblower or knapsack pressure sprayer. A Lindane recommendation is also available, using a thermal fogger and dusting machine. Control consists of two applications 14 days apart. It is only necessary to treat alternate cocoa rows with Lindane, because of the drift and fumigant effect. All trees are sprayed with Karate. Farmers usually find that two to three double applications of chemical per year are necessary on a "spot spraying" basis. Prophylactic spraying is strongly discouraged in order to enhance natural biological control agents. There have been no reports of poor control using Lindane, so presumably pest resistance is low. Not all large estates, and only a few smallholders, control mirids. National cocoa production could be increased substantially if mirid control were practised more widely in an integrated pest management system. The use of routine pest monitoring is becoming increasingly common on larger estates.

DEFOLIATING CATERPILLARS

While many caterpillars feeding on cocoa in Papua New Guinea are well-controlled by natural enemies, there is still a number of species that can cause serious widespread, and sometimes continuous, defoliation over successive generations. Defoliation can cause tip dieback, proliferation of side branches and physiological stress. In young trees it retards growth, and in mature trees causes loss of crop. Control of caterpillars on mature cocoa is difficult and expensive, and the effect of these pests nationwide is believed to be very large, placing them amongst the most important cocoa pests in the country.

The most important defoliating caterpillars are listed in Table 3. Chemical control recommendations are available (Moxon 1992f).

TABLE 3: MAJOR DEFOLIATING CATERpillARS OF COCOA IN PAPUA NEW GUINEA

Family	Species
Noctuidae	<i>Achaea janata</i> L. <i>Tiracola plagiata</i> Walk.
Geometridae	<i>Ectropis sabulosa</i> Warr. <i>Hyposidra talca</i> Walk.
Limacodidae	<i>Pinzulanza kukisch</i> Hering

Achaea janata

The Castor or Semi-Looper moth, which occurs from India to Australia, is found throughout the cocoa-growing areas of Papua New Guinea. The adult is a large greyish-brown moth with a wingspan of 6cm. The caterpillar is greyish-blue, black, or brown with black and white markings. Females lay large numbers of eggs (up to 600) at random on the surface of leaves and stems. The eggs hatch after three days and the caterpillar duration is from 11 to 17 days. Pupation occurs in a loose cocoon in the soil and in other sheltered places within the tree, and takes nine to 14 days. The adult moths live for about three weeks (Snee 1962a). The caterpillar has a very wide range of host plants (Entwistle 1972). The pest is usually slow to enter new cocoa plantings. It is particularly important in New Britain. In the Oro Province outbreaks lasting two years, followed by irregular epidemics, have been reported by Dun (1967). Egg parasitism of over 90% by *Telenomus* sp., *Trichogramma japonicus*, and *Eshthromorpha insidiator* has been recorded. Caterpillars are also parasitised by the tachinids *Exorista fallax* and *Winthemia diversa*.

Tiracola plagiata

The Cocoa Army Worm extends from India to Australia but attacks cocoa only in Papua New Guinea. The pest is distributed throughout the country but is usually an economic problem only in certain areas of the mainland, where it appears regularly about every six weeks, causing defoliation and damage to terminal buds (Van Velsen 1967). The pest has been recorded in New Britain and North Solomon on four occasions but always in low numbers (Dun 1967).

The female lays large batches of eggs (200 or more) on the underside of leaves. Eggs take three to four days to hatch. The larva is dark grey with a yellow stripe running along each side of the abdomen. It feeds on young flush leaves for 15 to 17 days through six instars and then pupates in the ground for 10 to 15 days following a prepupal stage of about four days. The preoviposition period is 14 days (Snee 1963).

Tiracola larvae both feed and oviposit on *Leucaena*, and severe infestations on cocoa are usually associated with this shade tree. By contrast, cocoa grown beneath tall shade trees such as coconut and rubber are usually attacked less severely (Dun 1967). The biology and control of *T. plagiata* is given by Catley (1962a, 1962b, 1963, 1966). An extensive list of host plants is given by Entwistle (1972), but severe damage to these plants is rare, because of the pest's natural enemies. The pest has 12 known parasites but only two - *Ecthomorpha insidiator*, an ichneumonid wasp, and *Exorista fallax*, a tachinid fly - occur in cocoa areas. A *Trichogramma* species is suspected of being an egg parasite.

Ectropis and Hyposidra

These two Geometrid looper caterpillars are common defoliators of flush leaves in New Britain. They are also present on the mainland but are rarely a problem. The larvae of both species look similar. The body is yellow-brown, although *Hyposidra* is sometimes green. *Ectropis* larvae can be distinguished by a black spot on each side of the abdomen. Little is known of the life histories. Female moths of both species are believed to lay their eggs on *Leucaena* and probably also on cocoa. On hatching, the larvae descend on silk threads from the *Leucaena* to the cocoa, where they eat flush leaves. Pupation occurs in the ground. *Ectropis* is more common than *Hyposidra*. Several outbreaks may occur each year but usually do not last very long, probably because of natural enemies of the larvae such as the tachinids *Winthemia diversa* and *Calozenillia* species (Dun 1967). No egg parasites are known.

Pinzulenza kukisch

A number of species of Cup Moth or Nettle Caterpillar are serious pests of cocoa, particularly in the Madang, Kar Kar Island, and, more recently, Sepik regions of Papua New Guinea. They are different from previously discussed caterpillars in that they eat both new and old leaves. *P. kukisch* is the worst of these species and was responsible for complete defoliation of vast areas of cocoa in the 1950s before the pest declined to a position of unimportance. The Limacodias *Scopelodes* sp., *Parasa lepida*, and *Mambara inconspicua* are recorded by Froggatt (1940), Dun (1955), and Szent-Ivany (1961), respectively. Cup Moths became a problem again in the Madang region in 1987 and have since caused periodic, and sometimes complete, defoliation of both old and young cocoa leaves at roughly six-weekly intervals.

P. kukisch is thought to be a problem in lightly-shaded conditions (Szent-Ivany 1961) and it has been suggested that the pest also feeds on coconut fronds. The main parasite is a chalcidid, *Brachymeris salmonis*.

The Department of Agriculture and Livestock recommendations for the control of caterpillars are given by Moxon (1983d, 1992f). Control of defoliators on young trees is easily achieved by "spot spraying" any one of a wide range of chemicals with a knapsack pressure sprayer or mistblower. Control of caterpillars on mature trees, however, is difficult and expensive, particularly if the shade tree species is a host plant which must then also be sprayed. Consequently, spraying mature trees is advised only if the caterpillar species show persistent attack or causes repeated defoliation of both flush and mature leaves, as in the case of the Limacodids. In some areas, a change of the shade tree species may also be advisable.

GREY WEEVILS

Grey Weevils (tribe *Ceuleuthetini*) is the name given to a wide range of weevil genera, the adults of which chew the bark of young cocoa shoots, leaf petioles, and occasionally leaves. The distribution and host plants of some Grey Weevils in Irian Jaya is given by Thomas and Verloop (1962). The pests were first reported on cocoa by Urquhart et al. in 1951, and in recent years have emerged as major pests throughout most cocoa regions. Little was known of these pests until the recent studies on the biology, ecology, and control of *Hypotactus ruralis*, a major pest of cocoa in New Britain (Moxon 1992h).

The adult lays its eggs in the soil, and they hatch after six days. The larvae feed for two to three months on plant roots, predominantly those in the top six inches of the soil. Pupation occurs in the soil and takes 13 days. Adults have been kept alive in captivity for more than six months. Seasonality and density studies have shown that reproduction occurs throughout the year at a high level, with some population reduction in very wet or very dry weather. Larvae can live for at least 36 days without food, although 50% died within nine days in laboratory tests (DAL Ann. Rep. 1984-88). Both larvae and adults have a wide host range - all 30 plant species presented to them in tests were damaged to some extent.

Grey Weevils are now the most important pest of young cocoa in Papua New Guinea. Damage to the growing points of young shoots retards growth and can cause stunting or death. No economic damage occurs on trees older than about a year-and-a-half, because of tree vigour and a shade effect. Grey Weevil problems are particularly severe in lightly-shaded conditions, and are common where cocoa is established without adequate shade. Shade presumably affects the larval population feeding on weeds at ground level. Grey Weevil adults also feed readily on *Gliricidia sepium*, which is often used as a shade tree for cocoa. Dense pest populations can stunt *Gliricidia* and thus prevent establishment of both shade and cocoa. Pest infestation can also be severe under coconut shade.

Grey Weevils can be controlled using insecticides (Moxon 1983e, 1992h). Four to six pyrethroid sprays at two-weekly intervals are usually required to reduce populations to acceptable levels. Both cocoa and host shade trees, if present, must be treated. Systemic Furadan granules placed in the soil over the cocoa roots also give good control for six to eight weeks, and this is becoming a favoured control method. Some farmers use herbicides applied as a "blanket spray" to control weeds. This treatment also controls Grey Weevils by starving the larvae. Weed control also produces more vigorous cocoa tree growth which then helps the seedling "grow through" weevil attack.

PANSEPTA TELETURGA

The Cocoa Webworm is native to Papua New Guinea, occurring both on the mainland and the Islands Region with the exception of the North Solomons. It is also recorded in Irian Jaya. The larvae cause damage by boring into the main branches of young cocoa and terminal branches of mature cocoa.

The adult moth is shiny white and about 10mm long. The adult female lays eggs singly on cocoa branches and these eggs hatch after three to five days. The small larva then bores into a branch, often via a leaf scar. About 60% to 90% of the young larvae are believed killed by natural enemies before they enter the wood. The larva constructs a silk web, mixed with brown droppings or frass, over the feeding area for protection. Larvae feed on wood and bark for eight to 12 weeks. The pupal stage takes three to four weeks, and adults live for only a few days (Bailey 1978, 1979).

Pansepta larvae are most damaging on young trees when they bore into or ringbark the main branches. It is difficult to assess damage when terminal branches of mature trees are attacked, and Bailey (1978) considers that this may often be relatively unimportant. However, *Pansepta* has been particularly abundant in New Britain since about the beginning of 1987, and large areas of that province are suffering from severe tip dieback (including that of main branches), canopy degradation, and crop loss. The pest is easily controlled on young trees by removing the web and applying a systemic insecticide, Dimethoate, onto the bark with a brush or swab (Bailey 1978; Bailey and O'Sullivan 1978). *Pansepta* is controlled on mature trees by applying a 0.6% solution of Dimethoate with a knapsack pressure sprayer. (Moxon 1992l). *Pansepta* is usually only a problem on lightly shaded cocoa (Szent-Ivany 1961) and so is usually seen at the edge of cocoa plantings and along roadsides. Since 1987, the pest has also been reported throughout well shaded plantings. Szent-Ivany (1961) has recorded the braconid *Ipobracon* sp. from *P. teleturga*.

TERMITES

Several species of termite attack cocoa in Papua New Guinea, but the most important is the giant termite, *Neotermes papuana*. It occurs throughout the Islands Region and is particularly damaging in New Britain (Smea 1962b). Termites enter the tree via dead branches and then feed on the living wood. The tree canopy is reduced, production falls, branches die, and eventually the tree is killed.

Termites are easily controlled by exposing the top part of the nest and pouring on a dilute solution of insecticide. Dieldrin and Chlordane were recommended at first (Smea 1962b), but these have now been replaced by pyrethroids which are both more effective and safer to use (Moxon 1992m). *N. papuana* does not construct covered runways on the tree, but the location of the nest is indicated by a dark, water-soaked stain on the bark. Some shade trees are also attacked by termites, so these must also be inspected regularly and treated. Termite infestations can be prevented to some extent by pruning dead branches from the tree.

AMBLYPELTA

The genus *Amblypelta* - represented in Indonesia, Papua New Guinea, Solomon Islands, Vanuatu, New Caledonia, and Australia - is revised by Brown (1958a). A number of species have been noted feeding on cocoa, but only *A. theobromae* and, to a much lesser extent, *A. cocophaga* are pests. *A. theobromae* was first recorded on cocoa in 1955 (Brown 1958b) and can cause large crop losses on mainland Papua New Guinea from Morobe to Milne Bay. Adults and nymphs suck the sap from pods and shoots, causing similar damage to mirids. The life cycle takes about six weeks. *A. cocophaga* occurs in the North Solomons and Solomon Islands, where it is an occasional pest of cocoa. The ant *Oecophylla smaragdina* is negatively associated with both species (Fenimore 1958; Szent-Ivany 1961). *Amblypelta* is controlled in the same way as mirids (Moxon 1983c, 1992c).

RHYPARIDA

Chrysomelid beetles of the genus *Rhyparida*, which feed on the flush leaves of cocoa, can build up rapidly and cause extensive defoliation (Urquhart and Dywer 1951). There are many species of *Rhyparida* and these are distributed throughout Papua New Guinea (Szent-Ivany 1961). Eggs are laid on the ground, and

the larvae feed on plant roots. Pupation also occurs in the ground, and the life cycle takes about six weeks. Defoliation can be prolonged and particularly damaging when associated with dry weather. It is often necessary, therefore, to control *Rhyparida* on cocoa trees up to two years old, using insecticides (Moxon 1983d, 1992g). Some Trinitario cocoa clones are partially resistant to *Rhyparida*. These clones include K24-102, K24-103, and K82. Interestingly, the first two of these also show good resistance to *Pantorhytes* pests. (DAL Ann. Rep. 1984-1988).

POD BORERS

Two pod boring moths, *Cryptophlebia encarpa* and *Olethreutes* sp., are minor pests of cocoa in Papua New Guinea. The larvae tunnel into the pod husks. *C. encarpa* is perhaps the most common and occurs both on the mainland and islands. Baker (1976c) also reports it from India and the Solomon Islands. *Olethreutes* sp. occurs in the Islands Region only (Szent-Ivany 1961). The biology, ecology, and importance of *C. encarpa* has been studied by Baker (1976c) and Moxon (1992k). Eggs are laid singly on the pod surface. The larvae hatch within 24 hours and burrow into the epicarp of the pod husk to feed. The larvae feed for 13 to 15 days. There is a pre-pupal period of three to four days, and pupation, which occurs near the pod surface, takes about eight days. Adults live for five to six days (Moxon 1992k).

Larvae attack cocoa pods of all ages, but are reported to have little effect on production, as they rarely enter the endocarp or seeds (Barker 1976c). However, secondary fungal infections (*Fusarium solani*, *F. decemcellulare* and *Gliocladium roseum*) can cause crop losses of over 50% when associated with Pod Borer damage. Pod Borers can be controlled by applying Karate (Lambda Cyhalothin) at 8g ai per hectare or Lindane at 100g ai per hectare with a mistblower or knapsack pressure sprayer, following the same method used for mirid control - a double application is also necessary for effective Pod Borer control (Moxon 1992k). Baker (1976c) records two non-specific predators, and two pupal parasites *Elasmus? hyblaeae* (Hymenoptera: Eulophidae) and *Anthopimpla flavolineata* (Hymenoptera: Anthophoridae) have recently been recorded in New Britain (Moxon 1992k).

ROOT CHAFERS

Larvae of the genus *Dermolepida* (Coleoptera: Melolonthinae) feed on cocoa roots in Papua New Guinea. Isolated outbreaks were reported in 1956 and 1959 from Northern, Madang, and Central Provinces (Szent-Ivany 1961). There were few other records until 1985, when outbreaks of several species were reported damaging cocoa in many areas on both the mainland and Island Region. Root chafers were also reported to be a limiting factor in cocoa establishment in Bioko, Africa (Entwistle 1972). The larvae or White Grubs feed on the roots of young and mature cocoa in Papua New Guinea. Second and third instar larvae chew and sever the tap root of seedlings. They can also ringbark the tap root and kill trees up to about two years old. Entire plantings can be destroyed by the pest, and replants will also be killed if the pest is not controlled. At present, damage is restricted to isolated areas. Feeding damage on mature trees has no observable effect on yield. The larvae also feed on sugar cane, sweet potato, taro, and bananas. Cocoa planted near food gardens is, therefore, particularly susceptible to attack (Moxon 1992j). Larvae of the genus *Dermolepida* are pests of sugar cane in Australia and have a life cycle of about six months. White Grubs are controlled on sugar cane and other crops by using BHC dust or Chlorpyrephos granules. These insecticides are also effective for controlling *Dermolepida* chafers on young cocoa. Suscon Blue (Chlorpyrephos) granules or Lindane (gamma BHC) granules are placed around the tap root at field planting (Moxon 1992j).

MEALYBUGS

Mealybugs, chiefly *Planococcus pacificus*, attack young shoots, flowers, and pods of cocoa in Papua New Guinea. They are not known to transmit serious diseases of cocoa as in other parts of the world, and are consequently a minor pest. Large numbers feeding on young seedlings can cause growth retardation and malformation. Occasionally, dense populations develop on pods, and these can cause significant crop loss. A cecidomyid, *Diadiplosis duni*, is the most important natural enemy (Moxon 1992o). Mealybug outbreaks on cocoa are often associated with ants. Mealybugs are easily controlled by spot spraying with Malathion and White Oil (Moxon 1983f, 1992o).

OXYMAGIS

Oxymagis vittocolis is a minor pest of cocoa in Papua New Guinea. The larvae bore into the outer branches of cocoa to feed on the sap and pith wood, causing tip dieback. *O. vittocolis* is recorded only from the North Solomons and Solomon Islands (Gressitt 1959; Szent-Ivany 1963a; Friend and Macfarlane 1978; Smith 1984). Feeding damage on mature trees is considered of no importance, but damage to the main branches of young trees merits control (Smith 1984). The pests are easily controlled by pruning out and burning infected branches (Moxon 1992n).

ZEUZERA COFFEA

The Coffee Stem Borer is reported attacking cocoa in Sri Lanka, Malaysia, Indonesia, and Papua New Guinea (Entwistle 1972). It usually occurs in low numbers in Papua New Guinea, presumably because of the effect of natural enemies. However, prolonged outbreaks do occur occasionally, as in the current situation in much of New Britain. The damage is typically severe on young trees where the wood-boring larvae can destroy both main branches and the trunk. There have been no detailed studies of this pest in Papua New Guinea other than on its control. The pest is controlled effectively by treating the infected branches with Nuvan (Dichlorvos), applied as a Channel Paint in a similar way to Longicorn control. Treatment rounds are required at two-weekly intervals until the infestation is diminished (Moxon 1992).

CONCLUDING REMARKS

The status of major and minor cocoa pests in Papua New Guinea reported over the past 30 years (Urquhart and Dwyer 1951; Szent-Ivany 1961; Smith 1979d) is much the same as it is today. Large-scale redevelopment was perhaps responsible for an increase, in the 1980s, in pests such as Grey Weevils, Root Chafers, and *Zeuzera* which feed on young cocoa. The combined effect of the large variety of minor pests and the damaging species of *Pantorhytes*, longicorns, mirids, and defoliating caterpillars is a substantial reduction in the country's potential cocoa production and in the economic life of cocoa trees. Much is known of the biology and ecology of most cocoa pests. Almost all major pests, with the possible exception of longicorns, and many minor pests are limited in their distribution within the country. The absence of *Pantorhytes*, mirids, *Pansepta*, and several harmful caterpillars from the North Solomons Province is undoubtedly a significant factor in the success of cocoa cultivation there. It is therefore important to reduce the risk of introducing new pests to areas by increasing awareness of potential problems amongst the farming community and by appropriate quarantine measures.

Natural enemies exert good control over many insects that feed on cocoa, and a variety of biological, cultural and chemical recommendations is available for those pests which become economically important. However, insecticides are required to some extent for most of the more troublesome pests, and there is an acknowledged need to ensure that they are used only when and where necessary to minimise the risk of killing beneficial insects. Prophylactic broad hectareage spraying is strongly discouraged. An increasing number of estates now operate a pest and disease monitoring system, and this reduces the amount of insecticide usage.

Cocoa production from the smallholder sector is about twice that of the plantation (estate) sector. A large proportion of estates, but few smallholders, practise chemical pest control. Surveys of farmers' knowledge, perceptions, and aspirations have shown that reasons for this include low technical awareness and financial and social constraints (Moxon 1983g; Moxon and Sitapai 1985). It is recognised, therefore, that appropriate, and sometimes different, recommendations are required for the high and low input systems of the two farming sectors. Biological control methods, wherever possible, are highly desirable. Biological and integrated control of cocoa pests are discussed by Smith (1981b) and Young (1982). Crazy Ants can control a number of serious cocoa pests, including the two most serious pests, *Pantorhytes* and Mirids. If Crazy Ant populations can be stabilised, they will be of tremendous value to both smallholders and estates. Another non-chemical pest reducing method, particularly useful for caterpillars and *Pantorhytes*, is the use of coconuts for shade. *Leucaena* shade has been associated with many pest problems on cocoa, while damage beneath coconut shade is often slight (Brown 1958; Catley 1962a; Smea 1963; Smith 1978; Szent-Ivany 1956; Szent-Ivany 1959). The relationship between shade types and cocoa pests is reviewed by Smith (1981d).

Smallholder cocoa farms are usually about a hectare in size. While the block of land may be fully planted to cocoa originally, tree deaths caused by pests and diseases release pockets of land in which a variety of foodcrops, fruit, and nuts is planted, thus forming a mixed garden. There is an increasing world interest in sustainable farming systems. Foodcrop research in Papua New Guinea has recently been reorganised into Farming System research, one object of which focuses on cocoa as the main crop. The wide alternate host range of several pests has been highlighted. Cocoa Root Chafers are a particular problem when cocoa is grown near food gardens: Longicorns can attack fruit and nut trees. Grey Weevils attack many plants, including both food and cash crops. The wide host ranges of *A. janta* and *H. clavifer* are well-known. In Papua New Guinea, where cocoa pests are of particular concern, their role in cocoa farming systems is most significant.

REFERENCES

- Anon. (1961). Pantorhytes control in cocoa plantations. Papua New Guinea Agricultural Journal 14 (1), 48-51.
- Anon. (1969). Insect pest survey for the year ending 30th June 1967. Papua New Guinea Agricultural Journal 21 (2), 49-75.
- Anon. (1971a). Insect pest survey for the year ending 30th June 1968. Papua New Guinea Agricultural Journal 22 (3), 179-201.
- Anon. (1971b). Control of Pantorhytes weevil in cocoa. Harvest 1 (1), 35-41.
- Ardley, J.H. (1960). Preliminary notes on new methods of cacao weevil control in New Guinea. XI international congress of entomology. 2, 1-3.
- Bailey, P. (1978). The biology of the cacao webworm *Pansepta telaturga* Meyr. (Lepidoptera: Xyloryctidae) in Papua New Guinea. Australian Journal of Zoology 26, 673-87.
- Bailey, P. (1979). Cocoa webworm; a pest of young cocoa trees. Harvest 5 (1), 59-63.
- Bailey, P. and O'Sullivan, D.F. (1978). Insecticides against larvae of the cocoa webworm. *Pansepta telaturga* Meyrick (Lepidoptera: Xylarictidae). Papua New Guinea Agricultural Journal 29 (1-4); 27-32.
- Baker, G.L. (1970). Some biotic factors influencing the population dynamics of the cocoa weevil borer *Pantorhytes szentivanyi* Marsh (Coleoptera: Curculionidae) and the effects of repeated monthly spraying with trichlophon on these biotic factors. Abstr. ANZAAE 42nd Congress, Port Moresby 1970. Sect. 11:7.
- Baker, G.L. (1972). The role of *Anopolepsis longipes* Jendon (Hymenoptera: Formicidae) in the entomology of cacao in the Northern District of Papua New Guinea. Abstr. 14th International Congress of Entomology, August 1972, Canberra, Australia, p. 207
- Baker, G.L. (1976a). The biology of *Pritocera rufa* Kieffer (Hymenoptera: Bathylidae), a parasite of *Pantorhytes szentivanyi* Marshall (Coleoptera: Curculionidae) in Papua New Guinea. Journal Australian Entomological Society 15: 153-160.
- Baker, G.L. (1976b). The seasonal life cycle of *Anopolepsis longipes* (Jerdon) (Hymenoptera: Formicidae) in a cacao plantation and under brushed rain forest in the Northern District of Papua New Guinea. Insectes Sociaux 23 (3), 253-261.
- Baker, G.L. (1976c). *Cryptophlebia encarpa* (Meyrick) (Lepidoptera: Tortricidae) as a pest of cacao pods in the Northern Province of Papua New Guinea. Papua New Guinea Agricultural Journal 27(1) & 2), 11-17.
- Baker, G.L., Arndt, F. and Loh, D.W. (1974). The development of a population of *Pantorhytes szentivanyi* Marshall (Coleoptera: Curculionidae) within a cacao planting in Papua New Guinea. Papua New Guinea Agricultural Journal 25 (1&2), 1-5.
- Bleeker, P. and Freyne, D.F. (1981). A preliminary inventory of areas suitable for cocoa production in Papua New Guinea. Cocoa Industry Board of Papua New Guinea. 47 pp.

- Bourke, T.V., Fenner, T.L., Stibick, J.N.L., Baker, G.L., Hassan, E., O'Sullivan, D.F., and Li, C.S. (1973). Insect pest survey for the year ending 30th June 1969. Department of Agriculture, Stock and Fisheries, Port Moresby. 57 pp.
- Brown, E.S. (1958a). Revision of the genus *Amblypelta* Stal. (Hemiptera: Coreidae). Bulletin of Entomological Research 49, 509-41.
- Brown, E.S. (1958b). Injury to cacao by *Amblypelta* Stal. (Hemiptera: Coreidae) with a summary of food-plants of species of this genus. Bulletin of Entomological Research 49, 543-54.
- Catley, A. (19862a). *Tiracola plagiata* Walk. (Lepidoptera, Noctuidae), a serious pest of cacao in Papua New Guinea. Papua New Guinea Agricultural Journal 15 (1&2), 15-22.
- Catley, A. (1962b). Armyworm caterpillars. Mageri Reporter 2 (1): 4-5. D.A.S.F., Territory of Papua and New Guinea.
- Catley, A. (1963). Observations of the biology and control of the armyworm *Tiracola plagiata* Walk. (Lepidoptera: Noctuidae). Papua New Guinea Agricultural Journal 5 (3&4), 105-109.
- Catley, A. (1966). Parasites and predators of some recorded insects from the Territory of Papua and New Guinea. Research Bulletin No. 2, D.A.S.F., Port Moresby, Papua and New Guinea, 18pp.
- China, W.E. and Carvalho, J.C.M. (1951). Four new species representing two new genera of *Bryocorinae* associated with cocoa in New Britain (Hemiptera: Miridae). Bulletin of Entomological Research 43, 465-471.
- Conway, G.R. (1971). Pests of cocoa in Sabah and their control with a list of the cocoa fauna. Bulletin of Department of Agriculture, Sabah.
- Dammerman, K.W. (1929). The Agricultural Zoology of the Malay Archipelago, Amsterdam.
- D.A.L. (1984-1988), Annual Report. Department of Agriculture and Livestock, Konedobu, Port Moresby, Papua New Guinea.
- D.A.L. (1989), Annual Report. Department of Agriculture and Livestock, Konedobu, Port Moresby, Papua New Guinea.
- D.A.S.F. (1968). Annual Report 1965-66. Department of Agriculture, Stock and Fisheries, Port Moresby, Territory of Papua and New Guinea. 164 pp.
- D.A.S.F. (1972). Annual Report 1967-69. Department of Agriculture, Stock and Fisheries, Port Moresby, Papua New Guinea. 250 pp.
- Dun, G.S. (1951). Pests of cocoa in the Territory of Papua - New Guinea In: Urguhart, D.G. and R.E.P. Dwyer. Report on the prospects of extending the growing of cacao in the Territory of Papua and New Guinea. Cadbury Bros., Bournville, U.K.: 32-35.
- Dun, G.S. (1954). Annual Report of the Senior Entomologist, Department of Agriculture Stock and Fisheries, 1952-1953. Papua New Guinea Agricultural Gazette 8 (3), 18-27.
- Dun, G.S. (1954b). Notes on cacao capsids in New Guinea. Papua New Guinea Agricultural 8(4), 7-11.
- Dun, G.S. (1955). Economic entomology in Papua New Guinea 1948-1954. Papua New Guinea Agricultural Journal 9 (3), 109-119.
- Dun, G.S. (1967). Cacao flush defoliating caterpillars in Papua and New Guinea. Papua New Guinea Agricultural Journal 19 (2), 67-71.
- Entwistle, P.F. (1972). Pests of Cocoa. Longman, London.
- Fenemore, M. (1958). Entomologist's Progress Report No. 6. British Solomon Islands.

- Fenner, T.L. (1967). Plantation pests in Papua and New Guinea. South Pacific Bulletin 17 (3), 27-30.
- Friend, P. (1972). Observations on *Pantorhytes biplagiatus* (Chevr.), a stem borer of cocoa in the British Solomon Islands Protectorate. In: Proc. IV International Cocoa Research Conference, St. Augustine, Trinidad, January 1972. pp. 590-596.
- Friend, D. (1973). Aspects of cocoa weevil borer *Pantorhytes biplagiatus* Guer. in the British Solomon Islands Protectorate. Papua New Guinea Agricultural Journal 24 (2), 61-69.
- Friend, D. and Macfalane, R. (1974). *Megaceresium horni* (Heller) a new longicorn stem borer of cocoa in the British Solomon Islands. PANS 20 (2), 203-207.
- Froggatt, J.L. (1938). Weevil pests of cacao. New Guinea Agricultural Gazette 4 (3), 6.
- Froggatt, J.L. (1940). Entomologist's report. In: Annual Report for the Department of Agriculture for the year ending 30 June 1939. New Guinea Agricultural Gazette 6 (2), 9-13.
- Gressitt, J.L. (1959). Longicorn beetles from New Guinea, I (Cerambycidae). Pacific Insects 1 (1), 59-171.
- Gressitt, J.L. (1966). The weevil genus *Pantorhytes* (Coleoptera) involving cacao pests and epizoid symbiosis with cryptogamic plants and microfauna. Pacific Insects 8 (4), 915-965.
- Grave, J.E. van S. and Ismay, J.W. (1983). Crop insect survey of Papua New Guinea Agricultural Journal 32 (1-4), 1-20.
- Hassan, von, Erol. (1969). Zur Biologie der *Pansepta teleturga* May. (Lep.) (in German) Sonderdruck aus Anzeiger für Schadlingskunde und pflanzenschutz XLII Jahrgang, Heft 9 (1969). Verlag Paul Parey, Berlin und Hamburg.
- Hassan, E. (1971). The behaviour and population dynamics of *Pantorhytes* weevil. Harvest 1 (3), 99-101.
- Hassan, E. (1973). The determination of sexes of the cacao weevil borer *Pantorhytes szentivanyi* Marshall (Coleoptera: Curculionidae); Papua New Guinea Agricultural Journal 14 (1), 45-48.
- Hassan, E. (1975). Sex characteristics and mating behaviour in *Pantorhytes szentivanyi* Mrsh. (Curculionidae). (In German) Geschlechtsmerkmale und Kopulations - Verhalten von *Pantorhytes szentivanyi*: Marshall (Col. - Curculionidae). Anz. Schadlingskde, Pflanzen - Umweltschutz 48, 25-27.
- Hassan, E. (1976). Egg-development and egg laying of the cacao borer *Pantorhytes szentivanyi* Marsh. (Coleopt.: Curcul.). Zeitschrift für angewandte Entomologie 80, 389-394.
- Ismay, J.W. and Dori, F.M. (1985). Crop insect survey of Papua New Guinea from 1979 to 1981, Department of Agriculture and Livestock, Port Moresby.
- Leston, D. (1970). Entomology of the cocoa farm. Annual Review of Entomology 15, 273-294.
- Lamb, K.P., Hassan, E. and Scotter, D.R. (1971). Dispersal of Scandium-46 - labelled *Pantorhytes* weevils in Papua cacao plantations. Ecology 5(1), 178-182.
- May, M. (1978). Immature stages of Curculionidae (Coleoptera): Some species in the genus *Pantorhytes* Faust (Pachyrhynchini) from the Papuan region and phylogenetic implication of certain characters. Journal of Australian Entomological Society 17 (4), 351-360.
- McGREGOR, A.J. and MOXON, J.E. (1985). Potential for biological control of tent building species of ants associated with *Phytophthora palmivora* pod rot of cocoa in Papua New Guinea. Ann. appl. Biol. 107, 271-277.
- Miller, N.C.E. (1957). Two new species of *Pseudodoniella* China and Carvalho (Hemiptera: Miridae). Bulletin of Entomological Research 48 (1), 57-58.

- Mire, P. Bruneau De** (1969). Une fourmi utilisee au Cameroun dans la lutte contre les mirides du cacaoyer *Luasmania auropunctata* Roger. *Cafe cacao* The 13, 209-12.
- Moxon, J.E.** (1983a). Pests of cocoa - *Pantorhytes*. Harvest 9, 169-170.
- Moxon, J.E.** (1983b). Pests of cocoa - The use of Crazy Ants for control of *Pantorhytes*. Harvest 9, 163-168.
- Moxon, J.E.** (1983c). Pests of cocoa - Mirids. Harvest 9, 171-174.
- Moxon, J.E.** (1983d). Pests of cocoa - Leaf eating insects. Harvest 9, 178-181.
- Moxon, J.E.** (1983e). Pests of cocoa - Grey Weevils. Harvest 9, 175-177.
- Moxon, J.E.** (1983f). Pests of cocoa - Mealybugs. Harvest 9, 183-184.
- Moxon, J.E.** (1983g). Review of the research requirements for cocoa in Papua New Guinea. Technical Report 83/7. Department of Primary Industry, P.O. Box 417, Konedobu, Papua New Guinea, pp. 109.
- Moxon, J.E.** (1992a). Chemical Mixtures For Cocoa Pests. L.A.E.S. Information Bulletin No.42.
- Moxon, J.E.** (1992b). Pantorhytes Pests of Cocoa. L.A.E.S. Information Bulletin No.43.
- Moxon, J.E.** (1992c). Mirid Pests of Cocoa. L.A.E.S. Information Bulletin No.44.
- Moxon, J.E.** (1992d). Use of Crazy Ants for Control of cocoa Pests. L.A.E.S. Information Bulletin No.45.
- Moxon, J.E.** (1992e). Longicorn Pests of Cocoa. L.A.E.S. Information Bulletin No.46.
- Moxon, J.E.** (1992f). Caterpillar Pests of Cocoa. L.A.E.S. Information Bulletin No.47.
- Moxon, J.E.** (1992g). Rhyparida Pests of Cocoa. L.A.E.S. Information Bulletin No.48.
- Moxon, J.E.** (1992h). Grey Weevil Pests of Cocoa. L.A.E.S. Information Bulletin No.49.
- Moxon, J.E.** (1992i). Coffee Stem Borer Pests of Cocoa. L.A.E.S. Information Bulletin No.50.
- Moxon, J.E.** (1992j). Root Chafer Pests of Cocoa. L.A.E.S. Information Bulletin No. 51.
- Moxon, J.E.** (1992k). Pod Borer Pests of Cocoa. L.A.E.S. Information Bulletin No.52.
- Moxon, J.E.** (1992l). Webworm Pests of Cocoa. L.A.E.S. Information Bulletin No.53.
- Moxon, J.E.** (1992m). Termite Pests of Cocoa. L.A.E.S. Information Bulletin No.54.
- Moxon, J.E.** (1992n). Longicorn Tip Borer Pests of Cocoa. L.A.E.S. Information Bulletin No.55.
- Moxon, J.E. and Sitapai, E.C.** (1985). Research Priorities for Cocoa in Papua New Guinea. Proceedings of the 9th International Cocoa Research Conference, Lome, Togo, 1984.
- Prior, C. and Smith, E.S.C.** (1981). Association of Phythophthora bark canker and insect damage in cocoa in Papua New Guinea. *Annals of Applied Biology* 97, 27-30.
- Room, P.M. and Smith, E.S.C.** (1975). Relative abundance and distribution of insect pests, ants and other components of the cocoa ecosystem in Papua New Guinea. *Journal of Applied Ecology*, 12, 31-46.
- Schreurs, J.** (1965). Investigations on the biology and control of *Glenea lefebueri*, a noxious longicorn beetle in West New Guinea. *Papua New Guinea Agricultural Journal* 17 (4), 129-35.

- Schreurs, J. and Simon Thomas, R.T. (1961). Cocoa pests in Netherlands New Guinea. Bulletin of Economic Affairs, Netherlands New Guinea (Agric. Ser. 1961, No. 2) 1-16. 16 pp.
- Smee, L. (1962a) *Achaea janata* L. A noctuid defoliating the flush of *Theobroma cacao*. Papua New Guinea Agricultural Journal 14 (4), 163-165.
- Smee, L. (1962b). Control of the giant cacao termites (*Neotermes* sp.). Papua New Guinea Agricultural Journal 14 (4), 193-194.
- Smee, L. (1963). Insect pests of *Theobroma cacao* in the Territory of Papua and New Guinea, their habits and control. Papua New Guinea Agricultural Journal 16 (1), 1-19.
- Smith, E.S.C. (1972). Population fluctuations of the cacao mirid in the Northern District of Papua New Guinea. Abstr. 14th International Congress of Entomology, August 1972, Canberra, Australia, p. 330.
- Smith, E.S.C. (1973). A laboratory rearing method for the cacao mirid *Helopeltis clavifer* Walker (Hemiptera: Miridae). Papua New Guinea Agricultural Journal 24 (2), 52-53.
- Smith, E.S.C. (1977). Presence of sex attractant pheromone in *Helopeltis clavifer* (Walker) (Heteroptera: Miridae). Journal of Australian Entomological Society 16 (2), 113-116.
- Smith, E.S.C. (1978). Hosts and distribution records of *Helopeltis clavifer* Wlk. (Heteroptera: Miridae) in Papua New Guinea. Papua New Guinea Agricultural Journal 29 (1-4), 1-4.
- Smith, E.S.C. (1979a). Entomology Bulletins: No. 3. Control of trunk longicorns in cocoa. Harvest 5 (3), 200-202.
- Smith, E.S.C. (1979b). Descriptions of the immature and adult stages of the cocoa mirid *Helopeltis clavifer* (Heteroptera: Miridae). Pacific Insects 20 (4), 354-361.
- Smith, E.S.C. (1979c). Entomology Bulletins: No. 2. Control of termites in cocoa. Harvest 5 (3), 197-199.
- Smith, E.S.C. (1979d). Cocoa pests and their control. Harvest 5 (3), 186-196.
- Smith, E.S.C. (1980). Entomology bulletins: No. 5. Recommendations for the control of *Pantorhytes* in cocoa. Harvest 6 (1), 41-42.
- Smith, E.S.C. (1981a). Review of control measures for *Pantorhytes* (Coleoptera: Curculionidae) in cocoa. Protection Ecology 3, 279-297.
- Smith, E.S.C. (1981b). An integrated control scheme for cocoa pests and diseases in Papua New Guinea. Tropical Pest Management 27(3), 351-359.
- Smith, E.S.C. (1981c). The biology, ecology and control of *Helopeltis clavifer* (Walker) (Heteroptera: Miridae), a major cocoa pest in Papua New Guinea. M.Sc. Thesis submitted to University of Papua New Guinea. 363 pp.
- Smith, E.S.C. (1981d). The interrelationships between shade types and cocoa pest and disease problems in Papua New Guinea. Proc. 7th International Cocoa Research Conference, Douala, Cameroons, (1979), 37-43.
- Smith, E.S.C. (1982). Results of three insecticide trials against cocoa pod suckers in the Northern Province. Papua New Guinea Agricultural Journal 33 (1-2), 1-11.
- Smith, E.S.C. (1984). An outbreak of the longicorn *Oxymagis horni* (Heller) (coleoptera: cerambycidae) on cocoa in the North Solomons Province of Papua New Guinea. Proc. 9th International Cocoa Research Conference, Lome, Togo, (1984), 603-608.
- Smith, E.S.C. and Prior, C. (1980). Preliminary note on the use of the entomophagous fungus *Beauveria bassiana* against *Pantorhytes* pests of cocoa. South Pacific Commission 3rd Regional Meeting on Plant Protection, Port Moresby, Papua New Guinea, 22 April 1-2 May 1980. Mimeo 10 pp.

- Stibick, J.N.L. (1972). Evolution and biogeography of the economic cacao weevils, *Pantorhytes*. Division A. Abstr. 14th International Congress of Entomology, August 1972, Canberra Australia, p. 94.
- Stibick, J.N.L. (1978). The genus *Pantorhytes* (Coleoptera: Curculionidae). I. Additions and changes to the common and major cocoa species. *Pacific Insects* 18, 115-136.
- Stibick, J.N.L. (1979). The genus *Pantorhytes* (Coleoptera: Curculionidae). 11. Additions to the four-spotted species of studded weevils of New Guinea. *Pacific Insects* 20(1), 101-131.
- Szent-Ivany, J.J.H. (1956). Two new stem borers of cocoa in New Guinea. F.A.O. Plant Protection Bulletin 4 (12), 177-178.
- Szent-Ivany, J.J.H. (1959). Insect pests of Theobroma cacao in the Territory of Papua and New Guinea. Proc. 1st FAO Technical Cacao Meeting, Accra, Ghana Feb, 1959. 82 pp.
- Szent-Ivany, J.J.H. (1961). Insect pests of Theobroma cacao in the Territory of Papua and New Guinea. Papua New Guinea Agricultural Journal 13(4), 127-47.
- Szent-Ivany, J.J.H. (1962). Entomology in the Territory of Papua and New Guinea. Australian Territories 2 (3), 4-10.
- Szent-Ivany, J.J.H. (1963). Further records of insect pests of Theobroma cacao in Papua New Guinea. Papua New Guinea Agricultural Journal 16 (1), 37-43.
- Szent-Ivany, J.J.H. and Dun, G.S. (1964). Insect pests of Theobromae cacao L. in the Territory of Papua and New Guinea. Proceedings of Conference of Mirids and other Pests of Cocoa, Nigeria 1964.
- Thomas, R.T.C. and Verloop, J. (1962). Host plants and distribution of some grey weevil species of the tribe Celeuthetini in Netherlands New Guinea. Papua New Guinea Agricultural Journal 15, 1-2.
- Urquhart, D.H. and Dwyer, R.E.P. (1951). Prospects of extending the growing of cocoa in Papua and New Guinea. Cadbury Bros., Bournville, U.K., 39pp.
- Van Velsen, R.J. (1967). A nuclear polyhedral virus disease affecting the larvae of Tiricola plagiata Walk.. Papua New Guinea Agricultural Journal 18 (4), 134-138.
- Young, G.R. (1982). Recent work on biological control in Papua New Guinea and some suggestions for the future. Tropical Pest Management 28 (2), 107-114.