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CONTENTS

RESULTS OF THREE INSECTICIDE TRIALS AGAINST COCOA PODSUCKERS IN THE NORTHERN PROVINCE

E.S.C. Smith*

ABSTRACT

The results of three insecticide trials conducted against two insect species damaging cocoa pods are presented and discussed.

Under field conditions, the insects were controlled more effectively by gamma-HCH applied as a dust formulation than by the same insecticide applied in liquid formulation at the same rate.

In both the Kokoda area where the coreid Amblypelta theobromae *Brown is of major importance and in other areas of the Northern Province where* Helopeltis clavifer *(Walker) (Heteroptera : Miridae) is the more damaging species, results indicated that insecticide treatment if applied at the currently recommended rates of 154 g a.i. and 70 — 100 g a.i. gamma-HCH per ha respectively would be profitable at cocoa prices much lower than those presently being paid (K1400 per tonne — January 1981).*

INTRODUCTION

The cocoa podsucking bugs *Amblypelta theobromae* Brown (Heteroptera: Coreidae) and *Helopeltis clavifer* (Walker) (Heteroptera: Miridae) are serious pests of cocoa (*Theobroma cacao*) in several areas of the Papua New Guinea mainland, and especially in the Northern Province (Szent-Ivany 1961). Both are indigenous insects which have readily adapted to the plentiful food source and more favourable environment available in the cocoa monoculture.

Good control of these podsuckers can be attained by application of 150-200 g a.i. gamma-HCH (lindane) per hectare either as a dust or low volume spray at 2-3 week intervals until the damaging populations are brought under control. However, where control measures are neglected or not effectively applied, estimated crop losses of between 50 and 80% have been reported (Anon. 1969, 1971; DASF 1968).

Research on the control of these two pest species is reported in this paper. Experiments compared the relative efficacy of dust and spray formulations of gamma-HCH against these podsucking insects and the long term effects of spraying on crop yield and profit.

1. FORMULATION TRIAL

Prior to 1965, dusting with gamma-HCH was the established method of podsucker control in Papua New Guinea but since then spraying by motorised mistblower in cocoa blocks has been increasingly used. Dusting is faster and can utilize cheaper application techniques (Fernando and Manickavasagar 1956; Smee 1963), but chemical costs are higher than low volume liquid spraying. However, insecticide trials which have compared dusting and mist spraying

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against cocoa mirids have given variable results. Betram (1950) stated that dusting with rotenone was three to four times superior to spraying, but other workers using HCH have achieved greater success with insecticide spraying (Donald 1958; Hammond 1957; Situmorang 1971) or recorded inconclusive results (DASF 1963; Stapley and Hammond 1959). The study reported here compares the effectiveness of the two formulations of gamma-HCH under Papua New Guinean conditions.

MATERIALS AND METHODS

The trial was conducted between February and May 1972 on 14 year old cocoa trees planted on a 4 m (= 13 foot) triangle spacing at Serovi Plantation in the Northern Province. Two treatments and a control were replicated four times in a randomised block design over this four month period and were applied to plots of 300 — 400 trees (approx. 0.6 ha) in 15 lines of cocoa. The treatments were (i) dusting at the rate of 6.17 $kg \cdot ha^{-1}$ of Gammexane 20 (R) (= 2.6 percent $w \cdot w^{-1}$ gamma-HCH) and (ii) 983ml of 16 percent $w \cdot v^{-1}$ gamma-HCH liquid (Gamaphex 16 EC (R)) in 56 litres of water per hectare. These two treatments gave an insecticide application rate of 154 g a.i. ha^{-1}. The control plots which received no insecticide were sprayed with water at a rate of 56 $litres \cdot ha^{-1}$. All treatments were, when possible, applied to the plots well before the usual afternoon rain storms. Solo Port 423 misting machines were used.

A five line barrier around each plot was treated in the same manner as the trial plots to reduce insect migration between plots.

Pre and post-treatment counts of pod-suckers were recorded. Pre-treatment counts of both adult and immature *A. theobromae* and *H. clavifer* were scored by a recorder walking behind a team of plantation workers (walking line abreast, one to a cocoa line) who searched each tree individually for the insects. Post-treatment counts were recorded in a similar manner 24 hours after treatment.

The second counts were assessed as percentage mortality of the pre-treatment counts and an angular transformation was used for the analyses.

RESULTS AND DISCUSSION

In all except one situation, dusting was more effective in reducing the numbers of the two species of insects than was spraying (*Figure 1*). However, due to the large variation between treatments, significant differences between the two insecticide treatments could not be shown.

In some of the control plots, a slight net increase in numbers occurred, either through migration from neighbouring blocks or a natural growth increase (older nymphs being easier to detect than younger ones). The relatively low kill in replicate I was largely due to a tropical rainstorm shortly after insecticide application. Heavy mortality of insects in the control plots of replicates II and III stressed the need for extreme care to prevent insecticide drift, and for thorough cleaning of spray machines.

Raw (1959) stated that the observed reductions in West African cocoa mirid populations in the unsprayed plots of his trials were likely to have been caused by the powerful fumigant action of gamma-HCH sprayed in neighbouring plots, and many other workers (e.g. Hammond 1957; Stapley and Hammond 1959; Marchart 1968) have also commented on this property of gamma-HCH. The results suggest that either much wider barriers between plots or a systematic trial design, serially balanced for the effects of neighbouring plots, are desirable in experiments using insecticides which have

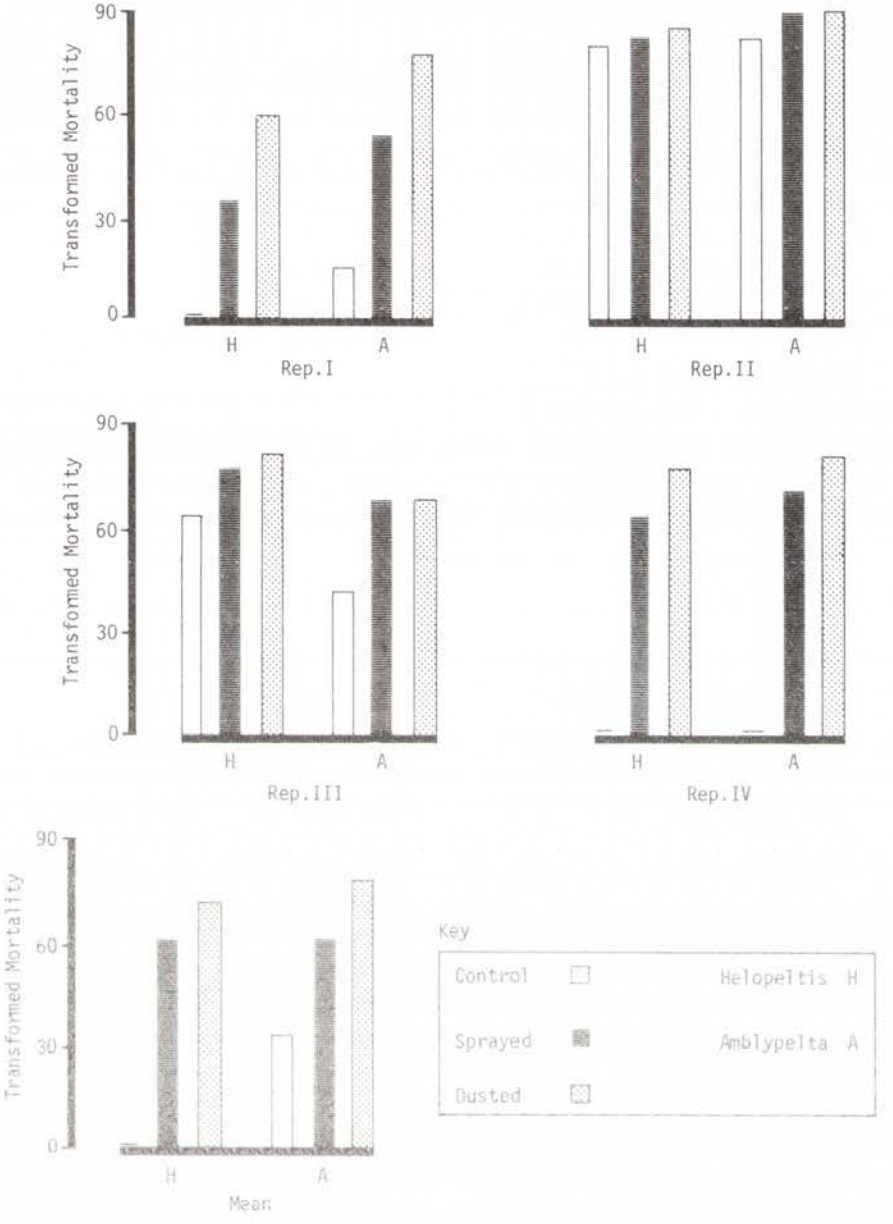

Figure 1.—Arcsin transformation of percent mortality of *H. clavifer* and *A. theobromae* in control plots or those sprayed or dusted with gamma-HCH

fumigant properties. Overall figures showed that gamma-HCH dust is very effective at killing both podsucker species when the insecticide is applied before the usual rainstorms. The ideal time of application was in the early morning, when the cocoa leaves were wet from overnight dew. At this time the dust particles adhered strongly to the leaves as they dried and were less likely to be washed off in light rain than were the dried liquid droplets.

In almost all cases both insecticide formulations were more effective at killing adult podsuckers than in destroying the immature stages. This effect is shown in *Figure 2*, where data from replicate IV are presented, but similar results were recorded in the other replicates of the trial.

2. CROP YIELD TRIAL — CONTROL OF *A. THEOBROMAE*

In the Northern Province, *A. theobromae* is only lightly scattered in cocoa plantations in the Popondetta/ Sangara area, but outside this, and especially in the Ilimo/Kokoda area, the insect is more abundant. Brown (1958) considered that *A. theobromae* was a potentially serious pest of cocoa, and more recently it has been estimated that the insect may cause 50-70 percent reduction in production where heavy infestations cause severe damage to young pods (Anon. 1969). Feeding on cocoa by this species causes necrotic lesions to appear on the pod surface, and these may be invaded by secondary fungi. Young pods may be severely distorted, or fail to develop when attacked by *A. theobromae*. Population densities of this insect are very low (rarely above one feeding insect per five mature trees) and they show a relatively even distribution throughout a cocoa block.

From December 1969 to August 1973, a spray trial was conducted in a cocoa block at Pirive village, Kokoda sub-province, to assess the effectiveness of monthly, two-monthly and three-monthly gamma-HCH sprays in controlling *A. theobromae* and to record any effect on crop yield. An unsprayed control plot was included in the trial. The incidence of *Helopeltis* in this block was very low and after 12 months of spraying, negligible in all four plots.

MATERIALS AND METHODS

The Pirive cocoa block was divided into four adjacent sub-plots of approximately 200 trees each (about 0.4 ha). Plots I, II and III were sprayed at monthly, two-monthly and three-monthly intervals respectively with gamma-HCH liquid formulation at an application rate of 154 g a.i. in 56 litres of water per ha. Plot IV was an unsprayed control. A barrier of three lines between plots III and IV was treated in the same way as plot III.

Pre-treatment counts of adult and immature *A. theobromae* and *H. clavifer* were made in all plots, and post-treatment counts of live insects in the treated plots were made the day after each spraying. In addition, the number of unscarred cherelles and large pods, the number of these fruit scarred by podsuckers and the number of pods either infected with black pod fungus (*Phytophthora palmivora* (Butler) Butler) or damaged by insects (other than podsuckers) were recorded. *Pantorhytes albopunctulatus* Heller (Coleoptera : Curculionidae) were causing little damage to cocoa trees in the block, but adults were hand collected and destroyed each month. All trees were fertilised with 100 g urea per tree at three monthly intervals from late 1971 to the termination of the trial.

Harvesting of mature pods was carried out in the intervals between spray applications and the plot yields recorded by the Department of Primary Industry (DPI)

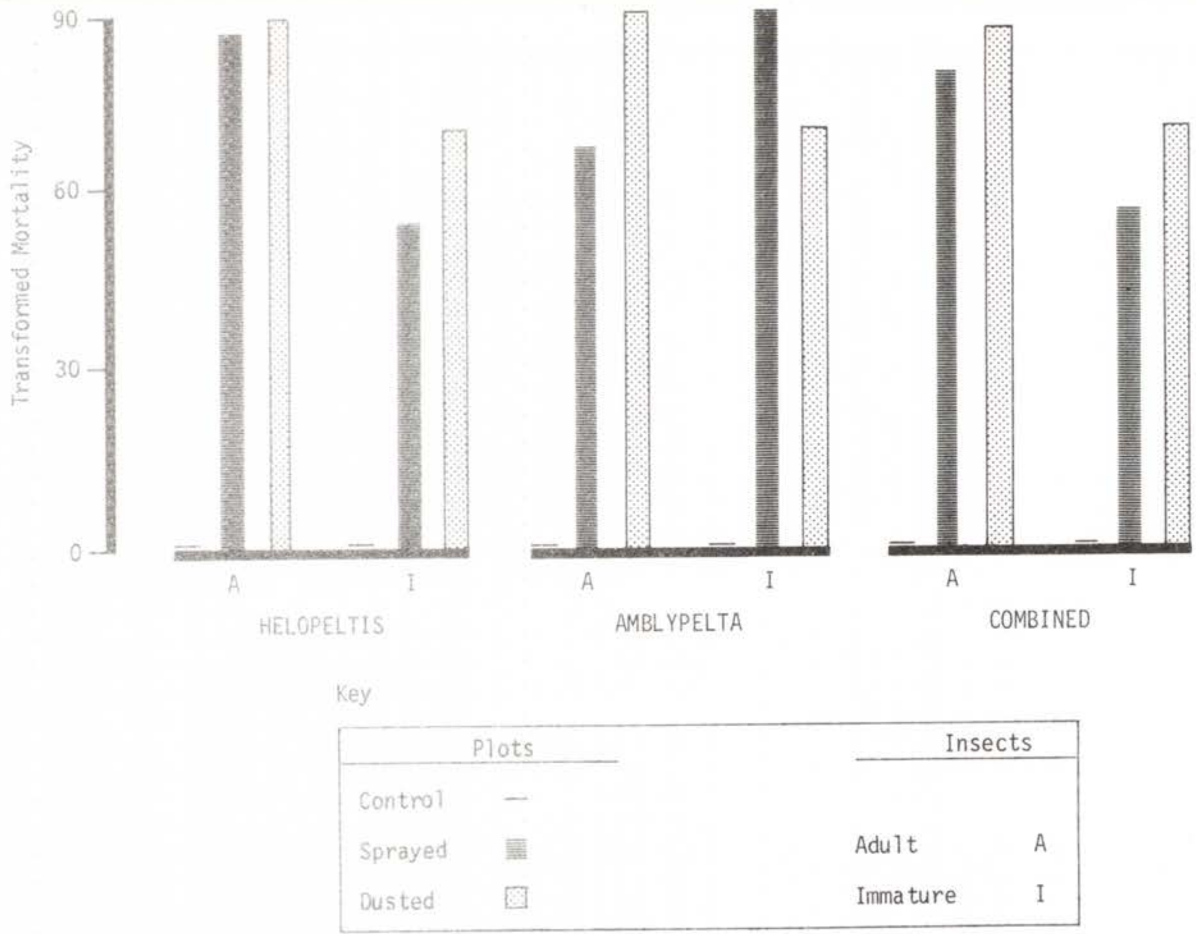

Figure 2. — Arcsin transformation of percent mortality of adult and immature podsuckers in control plots and those sprayed or dusted with gamma-HCH. Results of replicate IV only

extension staff at Kokoda. Unfortunately, yield data were recorded erratically after December 1971 and ceased after December 1972.

RESULTS AND DISCUSSION

INSECT POPULATIONS

Although pre-treatment numbers of *A. theobromae* were generally low, these population levels were sufficient to cause moderate economic damage. Post-treatment records indicated that 60-80% of *A. theobromae* present were killed by the gamma-HCH sprays applied to the plots. However, the rapid and large scale migration of these insects between plots and from neighbouring unsprayed blocks maintained a fairly evenly distributed population in the trial block. Spraying was more effective against *H. clavifer*, and reduced the population to very low levels after the first year of regular application. The densities of both species fluctuated seasonally, with peaks from October to January and low populations during the drier period of the year from May to August.

POD RECORDINGS

Pod numbers varied greatly during the year, with highest recordings from June to August each year, and lowest numbers from December to February. Trees sprayed at monthly intervals had the highest average number of pods per tree whilst the trees in the control plot had the lowest numbers. No difference in the incidence (as either % or number) of diseased or insect damaged pods was recorded between any of the sprayed plots and the control plot.

YIELD INCREASE DUE TO SPRAYING

The total yield recorded in each plot between May 1970 (six months after spraying began) and December 1971 in addition to yields during 1972 are presented in *Table 1*. Yields were increased in all plots receiving insecticide application and spraying for podsuckers at monthly intervals increased the yield by 69% over that of the unsprayed control plot.

ECONOMICS OF SPRAYING

Over the 19 months of spraying for which regular yields were available, monthly spraying gave an average of 725 kg of dry cocoa bean per hectare per year compared to 428 $kg \cdot ha^{-1} \cdot yr^{-1}$ in the control plot. This represents an increase in yield of 297 $kg \cdot ha^{-1} \cdot yr^{-1}$. Similarly, yields increased by 170 $kg \cdot ha^{-1} \cdot yr^{-1}$ and

Table 1. — **Yields (kg dry bean·ha^{-1}) and percentage yield increases in Pirive plots following regular insecticide treatment to control *A. theobromae* on cocoa**

Plot number	Spraying interval	Cumulative yield May 1970-Dec. 1971 ($kg \cdot ha^{-1}$ dry bean)	Ave. annual yield of dry bean ($kg \cdot ha^{-1}$)	% yield increase of sprayed plots over control plot IV	Cumulative yield Jan.-Dec. 1972 ($kg \cdot ha^{-1}$ dry bean)	% yield increase of sprayed plots over control plot IV
I	Monthly	1149	725.4	69.4	254	69.3
II	Two monthly	948	598.4	39.8	219	46.0
III	Three monthly	877	553.8	29.3	232	54.7
IV	Unsprayed	678	428.2	—	150	—

126 kg·ha^{-1}·yr^{-1} in blocks sprayed at two-monthly and three-monthly intervals respectively.

The costs which would currently be incurred in spraying blocks against podsuckers at the three time intervals are listed in *Table 2*. At the recommended rate of insecticide application, and which was used in this investigation, the total cost of spraying at monthly intervals would be about K80 ha^{-1}·yr^{-1}. The 'break even' point at which the costs of spraying would be covered by yield increases similar to those recorded in this study can be determined by referring to graphs such as those depicted in *Figure 3*. From this figure, it is evident that a yield increase of 200 kg per ha per annum would be required to cover spraying costs of K80 ha^{-1}·yr^{-1} if the net return (i.e. market price minus cost of production) was K400 per tonne dry cocoa. At net returns of K300, K250 and K200 per tonne, the annual yield increase necessary to cover costs of spraying at monthly intervals would be about 267, 320 and 400 kg per ha respectively.

In this trial, the annual yield increase was 297 kg per ha, which would require a net return of K267 per tonne dry cocoa to 'break even' and cover spraying costs. Similarly, the break even price for two-monthly sprays is K233 per tonne and at three-monthly spray intervals is K210 per tonne dry cocoa. Growers are currently (January 1981) receiving a net return of about K400 per tonne of dry cocoa, and at this return an annual increase of 99 kg per ha for two-monthly sprays or 66 kg per ha for three-monthly spray intervals would cover all costs incurred.

To enable growers to calculate the annual yield increases necessary to cover spray costs, the costs of spraying at frequencies ranging from 2 – 16 times per year are marked on *Figure 3*. As an example, if a grower sprays four times per year (at a cost of K25), his yield must increase by about 63 kg per ha at a net return of K400 per tonne dry cocoa for him to cover spray costs. Most growers find it necessary to spray two or four times a year against cocoa mirids in the Islands region.

YIELD INCREASE RESPONSE WITH TIME

Although yield records could only be used from the first 19 months of the trial

Table 2. – **Estimated costs of three frequencies of spraying for podsuckers**

Spraying interval (months)	Annual yield increase over control plot[1] (kg·ha^{-1})	No. sprays per year	Spraying costs (Kina·ha^{-1}·year^{-1}) Labour[2]	Insecticide[3]	Machine[4]	Petrol/Oil[5]	Total
1	297	13.0	15.60	41.60	6.50	15.60	79.30
2	170	6.5	7.80	20.80	3.25	7.80	39.65
3	126	4.3	5.20	13.87	2.17	5.20	26.44

1. From *Table 1*.
2. One man covers 2 ha·day^{-1} @ daily labour rate of K2.40.
3. At rate of 154 g a.i.·ha^{-1} gamma-HCH, 1 litre of 16% EC will be used per ha. Insecticide costs K3.20 per litre.
4. Assume machine is written off after 1 year (= 2400 hours or 300 days) or 600 ha. Purchase price is about K300, making machine depreciation about K0.50 per ha.
5. Assume consumption of 1 litre per hour, petrol-oil mix at 30 toea per litre = K1.20 per ha.

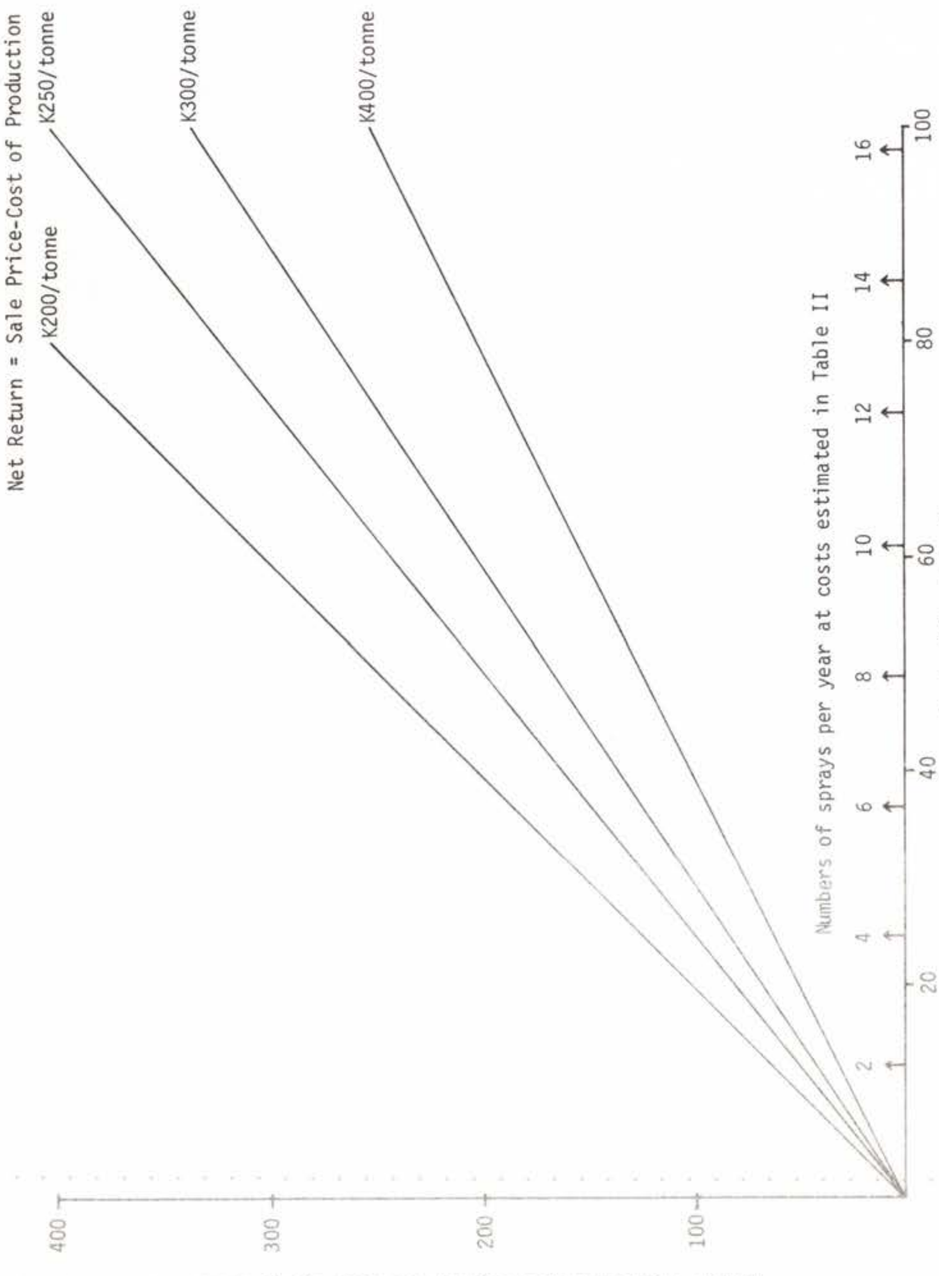

Figure 3. — **Yield increases required at various net returns per tonne of dry cocoa to cover spraying costs**

period, the number of pods per tree in each plot was recorded over the full 44 months. These records showed that the average number of pods per tree in the plot sprayed at monthly intervals was 78% higher than that in the control plot during the eight months May-December 1970 (when the pods were first fully protected by the sprays) but was 115% higher during the last eight month period from January-August 1973. The pod numbers indicated that an increase in spray response with time could be expected and that yield increase due to spraying would magnify in subsequent years of spraying.

Although only seven harvests were recorded during 1972, the data shown in *Table 1* also indicate that an equal or greater percentage yield increase occurred in all sprayed plots during that year of spraying than during the initial 19 month period.

Ali (1972) has reported that widespread gamma-HCH spraying for cocoa mirids in West Africa produced an increase in yield response with time, although the rate of response decreased over time. He pointed out however, that this effect may not all be attributable to insecticide treatment, since the increase may have been due to improved condition of the trees, weather conditions and/or unknown factors.

3. CROP YIELD TRIAL — CONTROL OF *H. CLAVIFER*

Helopeltis clavifer (Walker) was first reported attacking cocoa pods in the Central Province (Dun 1954), and since then, has become an important pest of the crop in mainland Papua New Guinea (Smith 1978).

In the Northern Province, *H. clavifer* is widespread in cocoa blocks especially in the Popondetta/Sangara area. No detailed data are available, but estimates of production loss through mirid damage range up to 80% (Anon. 1969). Distribution of this pest is highly contagious and numbers are small compared to most crop pests — rarely exceeding maxima of about 6,500 per hectare on cocoa in Papua New Guinea (Smith unpublished data).

H. clavifer primarily attack the pods of cocoa trees, but extensive tip dieback may be caused by mirids feeding on soft vegetative tissue and leaf petioles, especially on trees bearing few pods. When pods younger than two to three months are attacked by *H. clavifer*, they frequently fail to develop or become distorted. West African studies have also shown that mirid damage to larger pods can cause considerable reduction in the weight of the beans when mature (Akingbogungbe 1969), although a similar study in Papua New Guinea showed no effect (Smith unpublished data).

From December 1969 to March 1971, a spray trial was conducted in a cocoa block at Hanjiri village, Kokoda subprovince. This trial was designed to assess against an unsprayed control plot, the effectiveness of controlling *H. clavifer* populations with three-weekly gamma-HCH sprays, and to record any effect on crop yield resulting from this insect control. *H. clavifer* was much more abundant at Hanjiri than in the Pirive area, and was causing moderate to severe damage at the initiation of the trial. *A. theobromae* was also recorded in low numbers in the trial plots. An infestation of *Pantorhytes albopunctulatus* increased markedly after November 1970, so that by March 1971, the trees were in such poor condition that the trial was discontinued.

MATERIALS AND METHODS

A control plot of 217 trees (about 0.4 ha) was separated from the sprayed plot of 283 trees (about 0.5 ha) by a barrier of two lines of cocoa. Gamma-HCH liquid formulation at the rate of 154 g a.i. per ha in 56 litres of water per ha was applied to the treatment plot and to the barrier at about three weekly intervals.

Pre-treatment podsucker counts in both plots and post-treatment counts of live insects in the treated plot the day after spraying were recorded, in addition to the number of cherelles and other diseased or insect damaged pods.

Harvesting of mature pods was carried out in the intervals between treatments, and the weights recorded by the DPI extension staff at Kokoda.

RESULTS AND DISCUSSION

INSECT PEST DENSITY

Post-treatment records indicated that a high proportion (>85%) of *H. clavifer* were killed by the gamma-HCH spray and that migration of adult mirids from the control plot to the unpopulated spray area occurred on a large scale. *A. theobromae* populations were reduced by the spray treatment and these insects occurred in very low numbers compared to *H. clavifer*. Both insect populations varied seasonally, with peak numbers from October to February and lower numbers from May to August.

POD RECORDINGS

Pod numbers varied seasonally in a similar manner to those at Pirive, although the magnitude of the fluctuation was less. Trees receiving the spray treatment had, on the average, 25% more pods than the control trees.

No difference in the incidence of *Phytophthora* diseased pods was recorded between the sprayed and control plots despite the apparent association between *P. palmivora* and those cherelles which were deformed or damaged by the feeding of podsuckers or chewing insects such as *Pantorhytes*. This suggests that the disease is not transmitted by a podsucking vector. Prior (pers.comm.) has indicated that the fungus can only invade living tissue and since *H. clavifer* feeding results in almost immediate necrosis of the pod tissue (Smith 1978) *P. palmivora* cannot colonise mirid lesions.

YIELD INCREASE DUE TO SPRAYING

During the eight month (11 harvest records) period from May 1970 (six months after the trial began) until January 1971, the control plot produced the equivalent of 549.0 kg per ha of dry cocoa while the sprayed plot produced 664.5 kg per ha. This represents an increased production of 21% or an annual increase of at least 150 kg dry cocoa per ha due to spraying.

ECONOMICS OF SPRAYING

From the assumptions made for *Table 2*, the annual cost of spraying one ha of cocoa at three weekly intervals (17.3 times per yr) would be K106. The 'break-even' point at which these costs would be met by a yield increase of 150 kg is K707 per tonne net return, or at K400 per tonne, an annual yield increase of 265 kg per ha would be required (*Figure 3*). Although spraying at three-weekly intervals was not shown to be economic in the Hanjiri trial it is very likely that in other blocks less ravaged by *Pantorhytes*, much greater yield increases would result and that spraying costs would be more than covered by the increased production. The Pirive blocks for example (about 15 km away) recorded an annual yield increase of this order at less frequent spraying intervals than suggested here. Additionally, current planting of potentially high yielding clonal or hybrid cocoa material will, in future, magnify the yield increases which can be expected from the existing stands of cocoa trees.

If spraying is carried out over large areas, the migration from unsprayed areas would be greatly reduced and the number of treatments per year would be much less than the 17.3 discussed here. Other field trials (Smith unpub. results) have shown that good kills of *H. clavifer* are achieved when only alternate lines of cocoa are sprayed, since the very strong fumigant action of gamma-HCH, (discussed earlier in this paper) ensures effective control of mirids over the whole area. This method reduces the costs of application by half and is now recommended by DPI (Smith 1979). At the recommended rates, even spraying so frequently and for such a low yield response would be economic if cocoa prices were higher than K353 per tonne net return.

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A CHECKLIST OF MITE AND INSECT PESTS OF VEGETABLE, GRAIN AND FORAGE LEGUMES IN PAPUA NEW GUINEA

G.R. Young*

ABSTRACT

Over 100 species of both mites and insects have been recorded as feeding on vegetables, grain and forage legumes in Papua New Guinea. A checklist of these pests is presented, giving host plants and localities, and some assessment of the type of damage.

INTRODUCTION

Pests of legumes in Papua New Guinea have only recently received attention from entomologists. This has been as a result of interest in growing field crops such as soybean *Glycine max* (L) Merr. and mung bean *Vigna radiata* (L) Wilczek as well as subsistence crops such as snake bean *Vigna unguiculata* (L) Walp. and winged bean *Psophocarpus tetragonolobus* (L) DC.

Papers by Dun (1951, 1955), Froggatt (1940, 1941), Szent-Ivany (1956, 1959), Szent-Ivany and Catley (1960) and Szent-Ivany and Stevens (1966) make some reference to pests of legumes. Insect pest surveys (Anon. 1970, 1971; Bourke *et al*. 1973) have listed some mite and insect pests of vegetable, grain and forage legumes. Fenner (1974) reviewed mite and insect pests of grain and forage legumes in Papua New Guinea up to 1974, while Lamb (1976) reviewed mite and insect pests of winged bean in Papua New Guinea and elsewhere. This paper is an attempt to summarise information gathered by entomologists, past and present, working in Papua New Guinea. The systematic names of host plants have been used in preference to the common names wherever possible, and have been taken from Verdcourt (1979).

The systematic names of the host plants and their abbreviations are listed below.

Arachis hypogaea Linnaeus	*A. hypogaea*
Cajanus cajan (Linnaeus) Millspaugh	*C. cajan*
Canavalia ensiformis (Linnaeus) A.P. de Candolle	*C. ensiformis*
Canavalia gladiata (N. Jacquin) A.P. de Candolle	*C. gladiata*
Centrosema pubescens Bentham	*C. pubescens*
Centrosema sp.	*Centrosema* sp.
Desmodium canum (J.F. Gmelin) Schinz & Theliung	*D. canum*
Desmodium intortum (P. Miller) Urban	*D. intortum*
Glycine max (Linnaeus) Merrill	*G. max*
Glycine wightii (Wight & Arnott) Verdcourt	*G. wightii*
Lablab purpureus (Linnaeus) Sweet	*L. purpureus*

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Lupinus sp.	*Lupinus* sp.
Macroptilium atropurpureum (A.P. de Candolle) Urban	*M. atropurpureum*
Macroptilium lathyroides (Linnaeus) Urban	*M. lathyroides*
Macrotyloma axillare (E. Meyer) Verdcourt	*M. axillare*
Medicago sativa Linnaeus	*M. sativa*
Mucuna pruriens (Linnaeus) A.P. de Candolle	*M. pruriens*
Pachyrhizus erosus (Linnaeus) Urban	*P. erosus*
Phaseolus coccineus Linnaeus	*P. coccineus*
Phaseolus vulgaris Linnaeus	*P. vulgaris*
Pisum sativum Linnaeus	*P. sativum*
Psophocarpus tetragonolobus (Linnaeus) A.P. de Candolle	*P. tetragonolobus*
Pueraria phaseoloides (Roxburgh) Bentham	*P. phaseoloides*
Pueraria sp.	*Pueraria* sp.
Vicia faba Linnaeus	*V. faba*
Vigna angularis (Willdenow) Ohwi & Ohashi	*V. angularis*
Vigna mungo (Linnaeus) Hepper	*V. mungo*
Vigna parkeri J.G. Baker	*V. parkeri*
Vigna radiata (Linnaeus) Wilczek	*V. radiata*
Vigna umbellata (Thunberg) Ohwi & Ohashi	*V. umbellata*
Vigna unguiculata (Linnaeus) Walpers	*V. unguiculata*
Vigna vexillata (Linnaeus) A. Richard	*V. vexillata*

Names of the provinces of Papua New Guinea have been abbreviated as follows: Central Province CP, Eastern Highlands Province EHP, East New Britain Province ENBP, East Sepik Province ESP, Enga Province EP, Gulf Province GP, Madang Province MdP, Manus Province MnP, Milne Bay Province MBP, Morobe Province MP, New Ireland Province NIP, North Solomons Province NSP, Northern Province NP, Simbu Province SP, Southern Highlands Province SHP, West New Britain Province WNBP, West Sepik Province WSP, Western Highlands Province WHP, Western Province WP.

The source of the data is acknowledged where possible in the column headed 'source'. The insect pest surveys are abbreviated as Anon. 1970, etc. and Konedobu records as K.

The names of the entomologists are abbreviated as follows:

Ardley, J.	J.A.
Catley, A.	A.C.
Dun, G.	G.D.
Fenner, T.L.	T.F.
Froggatt, J.L.	J.L.F.
Gagne, W.	W.G.
van S. Greve, J.E.	J.V.G.
Khan *et. al.*	T.K.
Lamb, K.P.	K.L.
Smith, E.S.C.	S.C.S.
Smith, S.L.	S.L.S.
Thistleton, B.M.	B.T.
Stevens, R.M.	R.M.S.
Szent-Ivany, J.J.H.	J.S.I.
Young, G.R.	G.Y.

Order Family	Genus and Species	Host Plant Species	Locality	Source	Damage
Acari					
Prostigmata					
Tetranychidae	*Tetranychus* spp.	*P. vulgaris*	Bubia MP	G.Y.	Leaves blotchy, webbing.
			Wau MP	W.G.	Leaf chlorosis.
			Sanga NP	Anon. 1970	Heavy damage.
		P. sativum	Wau MP	W.G.	Leaf chlorosis.
		P. tetragonolobus	Wapenamanda EP	B.T.	Leaves blotchy, much webbing.
			?	K.L.	?
			Bubia MP	G.Y.	Leaves blotchy, webbing.
Orthoptera					
Acrididae	*Valanga* sp.	*G. max*	Bubia MP	G.Y.	Nymphs feeding on leaves and flowers.
		P. vulgaris	" "	"	"
		V. radiata	" "	"	"
Gryllotalpidae	*Gryllotalpa africana* Palisot de Beauvois	*A. hypogaea*	Mt. Hagen WHP	B.T.	Adults feeding on shell and kernel.
Tettigoniidae	*Phaneroptera brevis* Audinet-Serville	*C. cajan*	Bubia MP	G.Y.	Feeding on leaves,
			Mutzing MP	"	damage slight.
		M. sativa	Wau MP	W.G.	Feeding on leaves.
		P. vulgaris	Sila NP	Anon. 1970	Feeding on foliage.
		P. tetragonolobus	Bubia MP	G.Y.	Feeding on leaves, damage slight.
Dermaptera					
Labiduridae	*Euborellia annulipes* (Lucas)	*A. hypogaea*	Marambung MP	G.Y.	Adults boring into shells and feeding on kernels.
Thysanoptera					
Indet.	Gen. et sp. indet.	*P. tetragonolobus*	Mt. Hagen WHP	B.T.	Unknown.
Indet.	Gen. et sp. indet.	*Lupinus* sp.	Tambul WHP	B.T.	Feeding on flowers.
Indet.	Gen. et sp. indet.	*P. tetragonolobus*	Unitech, Lae MP	K.L.	?

Order Family	Genus and Species	Host Plant Species	Locality	Source	Damage
Hemiptera-Homoptera					
Aleyrodidae	Gen. et sp. indet.	*P. tetragonolobus*	Mt. Hagen WHP	B.T. G.Y.	Feeding on leaves. " "
Aphididae	*Aphis craccivora* Koch	*A. hypogaea*	Keravat ENBP	J.S.I. 1959	?
		P. vulgaris	Wau MP	W.G.	Adults and nymphs sucking sap.
		P. tetragonolobus	?	K.L.	Feeding on buds and stems.
			UPNG, Port Moresby CP	T.K. 1974	Seldom damaging.
		V. radiata	Wau MP	W.G.	Adults and nymphs sucking sap.
		V. unguiculata	Bubia MP	G.Y.	A small proportion of
			Keravat ENBP	G.Y.	plants severely damaged.
			UPNG, Port Moresby CP	T.K. 1974	Seldom damaging.
		V. vexillata	Bubia MP	G.Y.	Flower buds and young shoots attacked.
	Gen. et sp. indet.	*V. unguiculata*	Kuk WHP	B.T.	Adults and nymphs sucking sap.
	Gen. et sp. indet.	*P. tetragonolobus*	Kuk WHP	B.T.	Adults and nymphs sucking sap.
	Gen. et sp. indet.	*Lupinus* sp.	Tambul WHP	B.T.	Adults and nymphs sucking sap.
	Gen. et sp. indet.	*Pueraria* sp.	Bubia MP	G.Y.	Adults and nymphs sucking sap.
Cicadellidae	? *Empoasca* sp.	*P. tetragonolobus*	Wau MP	W.G.	Adults and nymphs sucking sap.
	Eurythroneura sp.	*P. tetragonolobus*	Aiyura EHP Bena Bena EHP	G.Y.	Feeding on the under-sides of leaves, significant damage.

	? *Tartessus* sp.	*V. unguiculata*	Wau MP	W.G.	Adults and nymphs sucking sap.
	Zygina sp.	*P. tetragonolobus*	Bubia MP	G.Y.	Feeding on the undersides of leaves.
Pseudococcidae	*Ferrisia virgata* (Cockerell)	*C. cajan*	Wau MP	G.Y.	None.
	Planococcus ? citri (Risso)	*C. cajan*	Bubia MP	G.Y.	None.
			Wau MP	G.Y.	None.
		G. max	Bubia MP	G.Y.	Feeding on stems.
			Markham Valley MP	G.Y.	Populations were often high but no evidence
			Wau MP	G.Y.	of yield loss.
		P. erosus	Bubia MP	G.Y.	None.
			Ramu Valley MP	G.Y.	None.
Ricaniidae	*Euricania villica* Stal	*P. vulgaris*	Wau MP	W.G.	Adults and nymphs sucking sap.
	Ricania sp.	*V. unguiculata*	Wau MP	W.G.	Adults and nymphs sucking sap.
Hemiptera-Heteroptera					
Alydidae	*Melanacanthus margineguttatus* Distant	*C. cajan*	Mutzing MP	G.Y.	Adults and nymphs sucking pods.
		V. mungo	Mutzing MP	G.Y.	" "
		V. unguiculata	Mutzing MP	G.Y.	" "
	Riptortus annulicornis Boisduval	*C. cajan*	Laloki, CP	G.Y.	Adults and nymphs
			Bubia MP	"	sucking pods, damage
			4-Mile, Lae MP	"	often severe, up to
			Maralumi MP	"	90% of seeds damaged
			Mutzing MP	"	or destroyed.
			Wau MP	"	" "
		C. pubescens	Markham Valley MP	G.Y.	?
			Wampit MP	"	?

Order Family	Genus and Species	Host Plant Species	Locality	Source	Damage
Hemiptera-Heteroptera Alydidae	*Riptortus annulicornis* Boisduval	*G. max*	Bubia MP	G.Y.	Adults and nymphs sucking pods, damage often severe, up to 70% of seed shrivelled.
			Markham Valley MP	G.Y.	
			Wau MP	G.Y.	
		L. purpureus	Laloki CP	G.Y.	?
			Bubia MP	G.Y.	?
			Maralumi MP	G.Y.	?
			Mutzing MP	G.Y.	?
		M. lathyroides	Bubia MP	G.Y.	?
			Markham Valley MP	G.Y.	?
		P. vulgaris	Bubia MP	G.Y.	Adults and nymphs sucking pods.
			Wau MP	W.G.	Adults and nymphs suck pods, distort beans and allow pathogens to enter.
			Popondetta NP	Anon. 1971	Adults feeding on developing and ripe pods, damage severe.
		P. tetragonolobus	Bubia MP	G.Y.	Adults and nymphs sucking pods, damage not as severe as with other species of bean.
			Wau MP	W.G.	Adults and nymphs suck pods, distort beans and allow entry of pathogens.
		V. angularis	Bubia MP	G.Y.	Adults and nymphs sucking pods.

	V. mungo	Bubia MP	G.Y.	Adults and nymphs sucking pods.
		Markham Valley MP	G.Y.	" "
	V. radiata	Bubia MP	G.Y.	Adults and nymphs sucking pods.
	V. unguiculata	Laloki CP	G.Y.	?
		" "	K.	?
		Bubia MP	G.Y.	Adults and nymphs sucking pods, damage severe.
		Markham Valley MP		
		Wau MP	W.G.	Adults and nymphs sucking pods, distorting seeds and allowing pathogens to enter.
		Madang MdP	G.Y.	Adults and nymphs sucking pods.
		Hermit islands MnP	J.A.	?
		Maron island MnP	J.A.	?
Riptortus imperialis Kirkaldy	*G. max*	EP	K.	?
		Mt. Hagen WHP	B.T.	?
		Mt. Hagen WHP	G.Y.	Sucking pods.
	P. vulgaris	Imia EP	B.T.	Sucking pods.
		Imia EP	G.Y.	" "
	V. umbellata	Kuk WHP	B.T.	?
Riptortus obscuricornis Dallas	*G. max*	Aiyura EHP	S.C.S.	Sucking pods.

Order Family	Genus and Species	Host Plant Species	Locality	Source	Damage
Hemiptera-Heteroptera		*P. vulgaris*	Imia EP	B.T.	Sucking pods.
			Imia EP	G.Y.	" "
Alydidae	*Riptortus rubronotatus* Blöte	*V. unguiculata*	Keravat ENBP	K.	?
			Vudal ENBP	G.Y.	Adults and nymphs sucking pods.
			Aropa NSP	G.Y.	" "
			Rigu NSP	G.Y.	" "
	Riptortus sp. 1	*C. cajan*	Bubia MP	G.Y.	Adults and nymphs sucking pods.
			Mutzing MP	G.Y.	" "
			Wau MP	G.Y.	" "
		V. mungo	Bubia MP	G.Y.	" "
			Mutzing MP	G.Y.	" "
		V. unguiculata	Bubia MP	G.Y.	" "
			Mutzing MP	G.Y.	" "
			Wau MP	W.G.	" "
	Riptortus sp. 2	*V. unguiculata*	Vudal ENBP	G.Y.	Adults and nymphs sucking pods.
			Aropa NSP	G.Y.	" "
	Riptortus sp. 3	*V. unguiculata*	Vudal ENBP	G.Y.	" "
			Aropa NSP	G.Y.	" "
Coreidae	*Amblypelta* sp.	*P. tetragonolobus*	Wau MP	W.G.	Adults and nymphs attacking shoots and pods.
	Cletus sp.	*V. radiata*	Bubia MP	G.Y.	On pods, not known if insects were feeding.
	Clavigralloides acantharis (Fabricius)	*C. cajan*	Bubia MP	G.Y.	Adults sucking pods.
			Mutzing MP	G.Y.	Adults sucking pods.
	Leptoglossus australis Fabricius	*V. unguiculata*	Bubia MP	G.Y.	Sucking exudate from lesions on young shoots and pods.

	Mictis profana (Fabricius)	*C. cajan*	Bubia MP	G.Y.	Adults and nymphs feed on shoots causing shoots to wilt. Damage sometimes severe.
			Markham Valley MP	G.Y.	
Lygaeidae	*Nysius epiensis* China	*A. hypogaea*	Bubia MP	J.S.I. A.C. 1960	?
	Nysius sp.	*P. vulgaris*	Bubia MP	G.Y.	Yellow spotting on leaves.
			Mutzing MP	G.Y.	" "
			Sila NP	Anon. 1970	Caused yellow spotting on leaves.
	Pachybrachius nervosus Horvath	*P. vulgaris*	Sila NP	Anon. 1970	" "
Miridae	*Halticus tibialis* Reuter	*A. hypogaea*	Bubia MP	G.Y.	Yellow spotting on leaves.
			Keravat ENBP	J.S.I. 1956	?
		G. max	Bubia MP	G.Y.	Yellow spotting on leaves.
			Wau MP	W.G.	Adults and nymphs suck sap. Caused leaf chlorosis when populations were high.
		P. erosus	Bubia MP	G.Y.	Severe damage to leaves.
		P. vulgaris	Bubia MP	G.Y.	Severe damage to leaves at times.
				W.G.	Adults and nymphs suck sap. Caused leaf chlorosis when populations were high.
		V. umbellata	Keravat ENBP	J.S.I. 1956	?

Order Family	Genus and Species	Host Plant Species	Locality	Source	Damage
Hemiptera-Heteroptera Miridae	*Halticus tibialis* Reuter	*V. unguiculata*	Bubia MP	G.Y.	Severe damage to leaves at times.
			Aropa NSP	G.Y.	Severe damage to leaves.
			Rigu NSP	G.Y.	" "
	Halticus sp.		?	J.L.F. 1940	?
	Helopeltis clavifer Walker	*V. unguiculata*	Wau MP	W.G.	Adults and nymphs sucking sap of growing points.
	Creontiades pallidifer Walker	*V. angularis*	Mutzing MP	G.Y.	Feeding on flowers, damage unknown.
Pentatomidae	*Agapophyta similis* Blöte	*C. cajan*	Kar Kar Is. Mdp	J.S.I. & R.M.S. 1966	?
	Agapophyta sp.	*C. cajan*	Bubia MP Cleanwater MP Maralumi MP Mutzing MP Wau MP	G.Y. G.Y. G.Y. G.Y. G.Y.	Adults and nymphs sucking sap, attacking shoots and flower buds. Often causing severe damage and death of plants.
			Wau MP	W.G.	Sucking sap.
	? *Allocotus* sp.	*V. unguiculata*	Wau MP	W.G.	Adults and nymphs sucking sap.
	Nezara viridula (Linnaeus)	*C. cajan*	Asaro EHP	K.	?
		G. max	Aiyura EHP	S.C.S.	Slight damage.
			Bubia MP	G.Y.	Adults and nymphs sucking pods, up to 70% of seed shrivelled.
			Markham Valley MP	G.Y.	

	Wau MP	G.Y.	Sometimes feeding on flowers resulting in reduced fruit set.
L. purpureus	Laloki CP	G.Y.	Adults and nymphs sucking pods.
	Bubia MP	G.Y.	
	Markham Valley MP	G.Y.	" "
P. vulgaris	Tapini CP	K.	?
	Vudal ENBP	G.Y.	Sucking pods.
	Bubia MP	G.Y.	" "
	Markham Valley MP	G.Y.	" "
	Wau MP	G.Y.	" "
		W.G.	Adults and nymphs sucking pods.
	Rigu NSP	G.Y.	Sucking pods.
	Sila NP	Anon. 1970	Adults feeding on ripening pods.
P. tetragonolobus	Bubia MP	G.Y.	Sucking pods.
	Mt. Hagen WHP	G.Y.	" "
V. faba	Wau MP	W.G.	Nymphs and adults sucking pods.
V. angularis	Bubia MP	G.Y.	Sucking pods.
V. mungo	Bubia MP	G.Y.	Sucking pods.
V. radiata	Bubia MP	G.Y.	Sucking pods.
	Wau MP	W.G.	Adults and nymphs sucking pods.
	Aropa NSP	G.Y.	Adults and nymphs sucking pods.
	Rigu NSP	G.Y.	" "
V. umbellata	Bainyik ESP	K.	?

Order Family	Genus and Species	Host Plant Species	Locality	Source	Damage
Hemiptera-Heteroptera Pentatomidae	*Nezara viridula* (Linnaeus)	*V. unguiculata*	Laloki CP	T.F.	?
			Bubia MP	G.Y.	Adults and nymphs sucking pods, causing severe damage.
			Markham Valley MP	G.Y.	Occasionally feeding on flower buds and reducing fruit set.
			Wau MP	G.Y.	Adults and nymphs
			" "	W.G.	sucking pods.
			Aropa NSP	G.Y.	Adults and nymphs sucking pods.
			Rigu NSP	G.Y.	" "
			Mt. Hagen WHP	B.T.	On cow pea.
			?	J.L.F. 1941	?
	Oncocoris sp. near *coelebs* (Fabricius)	*V. radiata*	Bubia MP	G.Y.	Adults and nymphs sucking pods, damage slight.
		V. unguiculata	Bubia MP	G.Y.	" "
	Philia femorata	*A. hypogaea*	Chambri ESP	J.S.I. & A.C. 1960	?
	Piezodorus sp. near *rubrofasciatus* (Fabricius)	*V. radiata*	Bubia MP	G.Y.	Adults and nymphs sucking pods, damage slight.
		V. unguiculata	Bubia MP	G.Y.	" "
	Plautia brunneipennis Stal	*P. vulgaris*	Bubia MP	G.Y.	Adults and nymphs sucking sap.
		V. radiata	Bubia MP	G.Y.	" "

		V. unguiculata	Bubia MP	G.Y.	" "
			Wau MP	G.Y.	" "
Plataspidae	*Brachyplatus papuus* Guérin-Méneville	*P. vulgaris*	Mageri CP	J.S.I. 1959	? Very dense populations.
	Brachyplatus sp.	*C. cajan*	Bubia MP	G.Y.	Sucking sap, damage unknown.
			Markham Valley MP	G.Y.	" "
			Wau MP	G.Y.	" "
		P. vulgaris	?	J.L.F. 1940	?
		M. pruriens	Wau MP	W.G.	Adults and nymphs sucking sap.
	Coptosoma pygmaeum Montandon	*C. cajan*	Bonahoi ESP	J.S.I. 1959	?
		P. phaseoloides	Kapsu Pltn. NIP	J.S.I. 1956	?
		Phaseolus sp.	" "	"	?
	Coptosoma sp.	*C. cajan*	Bubia MP	G.Y.	Sucking sap, damage unknown.
			Markham Valley MP	G.Y.	" "
Diptera					
Agromyzidae	*Ophyiomyia phaseoli* (Tryon)	*G. max*	Bubia MP	G.Y.	Damage slight.
			Mutzing MP	G.Y.	" "
			Wau MP	W.G.	Larvae mining stems of seedlings.
		M. lathyroides	Bubia MP	G.Y.	Larvae mining stems, heavily infested during dry periods.
			Markham Valley MP	G.Y.	Heavily infested.
		P. vulgaris	Laloki CP	G.Y.	?

Order Family	Genus and Species	Host Plant Species	Locality	Source	Damage
Diptera					
Agromyzidae	*Ophyiomyia phaseoli* (Tryon)	*P. vulgaris*	Rigo CP	T.F.	Serious stunting and distortion.
			Waigani CP	T.K. 1974	?
			Keravat ENBP	G.D. 1951	?
			Bubia MP	G.Y.	Larvae mining stems, up to 100% mortality of seedlings.
			Wau MP	W.G.	Larvae mining the stems of seedlings.
			Wau MP	J.S.I. & R.M.S. 1966	Severe damage to roots.
			Popondetta NP	Anon. 1971	Severe damage.
			Banz WHP	B.T.	Larvae feeding in stems of seedlings.
			Kuk WHP	B.T.	" "
		V. angularis	Bubia MP	G.Y.	Larvae mining stems of seedlings, up to 100% mortality.
		V. radiata	Bubia MP	G.Y.	Damage slight.
			Mutzing MP	G.Y.	Damage slight.
			Wau MP	W.G.	Larvae mining stems of seedlings.
		V. unguiculata	Bubia MP	G.Y.	Larvae mining stems and petioles.
			Mutzing MP	G.Y.	Sometimes severe damage during dry periods. Some varieties were more susceptible than others.

Coleoptera					
Anobiidae	*Lasioderma serricorne* (Fabricius)	*P. sativum*	Waigani CP	J.V.G.	Seed in storage.
		P. tetragonolobus	Waigani CP	J.V.G.	Seed in storage.
Anthribidae	*Araeocorynus* sp. nr. *cumingi* Jekel	*P. tetragonolobus*	Mt. Hagen WHP	J.V.G.	Seed in storage.
	Araeocorynus sp.	*P. tetragonolobus*	Mt. Hagen WHP	J.V.G.	Seed in storage.
	Araecerus fasciculatus Degeer	*P. tetragonolobus*	Mt. Hagen WHP	J.V.G.	Seed in storage.
Bruchidae	*Acanthoscelides obtectus* (Say)	*G. max*	Mt. Hagen WHP	J.V.G.	Seed in storage.
	Callosobruchus analis (Fabricius)	*V. radiata*	Port Moresby CP Quarantine detection	J.V.G.	Seed.
	Callosobruchus chinensis (Linnaeus)	*P. sativum* and other legume seeds	Keravat ENBP	G.D. 1955	Seed in storage.
	Callosobruchus maculatus (Fabricius)	*V. radiata*	Port Moresby CP	J.V.G.	Seed in storage.
Coleoptera					
Chrysomelidae	*Arsipoda tenimberensis* (Jacoby)	*G. max*	Wanepakosa EP	B.T.	Feeding on leaves.
			Wau MP	W.G.	" "
			Mendi SHP	B.T.	" "
			Dei WHP	B.T.	" "
			Kuk WHP	B.T.	" "
			Ogelbeng WHP	B.T.	" "
		P. vulgaris	Wanepakosa EP	B.T.	Feeding on leaves.
			Wau MP	W.G.	" "
			Mendi SHP	B.T.	" "
			Dei WHP	B.T.	" "
			Kuk WHP	B.T.	" "
			Ogelbeng WHP	B.T.	" "

Order Family	Genus and Species	Host Plant Species	Locality	Source	Damage
Coleoptera					
Chrysomelidae	*Aphthona bicolorata* Jacoby	*M. atropurpureum*	?	K.	Chewing holes in foliage.
	Aulacophora coffeae (Hornstedt)	*A. hypogaea*	Bubia MP	G.Y.	Feeding on leaves, damage slight.
		V. radiata	Bubia MP	G.Y.	" "
	Aulacophora femoralis Motschulsky	*M. sativa*	Wakepakosa EP	B.T.	Feeding on leaves.
			Wau MP	W.G.	" "
			Mendi SHP	B.T.	" "
			Dei WHP	B.T.	" "
			Kuk WHP	B.T.	" "
			Ogelbeng WHP	B.T.	" "
	Aulacophora pallidofasciata Jacoby	*G. max*	Popondetta NP	K.	?
		P. vulgaris	Sila NP	Anon. 1970	Adults collected from foliage.
	Aulacophora papuana Jacoby	*P. vulgaris*	Sila NP	Anon. 1970	Adults collected from foliage.
	Aulacophora similis Oliver	*V. faba*	Sila NP	Anon. 1970 K.	Feeding on leaves and petioles, complete defoliation.
	Aulacophora wallacei Baly	*V. radiata*	Aiyura EHP	S.C.S.	Feeding on leaves, damage slight.
	Cassena papuana (Jacoby)	*P. vulgaris*	Aiyura EHP	S.C.S.	Feeding on leaves.
			Bubia MP	G.Y.	" "
			Wau MP	W.G.	" "
		V. faba	Wau MP	W.G.	Feeding on leaves.
		V. radiata	Aiyura EHP	S.C.S.	Feeding on leaves.
			Bubia MP	G.Y.	Feeding on leaves,
			Mutzing MP	G.Y.	defoliation sometimes severe in the seedling stage.

		V. unguiculata	Bubia MP	G.Y.	Feeding on leaves.
			Mutzing MP	W.G.	" "
			Wau MP	W.G.	" "
	Monolepta nigroapicata Bryant	*G. max*	Bubia MP	G.Y.	Feeding on leaves.
		V. radiata	Bubia MP	G.Y.	" "
			Wau MP	G.Y.	" "
	Rhyparida coriacea Jacoby	*G. max*	Gusap MP	G.Y.	Feeding on shoots, damage severe.
		V. radiata	Gusap MP	G.Y.	" "
	Solenia intermedia Jacoby	*G. max*	Mendi SHP	B.T.	Shot hole damage to foliage.
		P. vulgaris	Wanepakosa EP	B.T.	Minor shot hole damage to foliage.
			Dei WHP	B.T.	" "
			Ogelbeng WHP	B.T.	" "
		P. tetragonolobus	Kuk WHP	B.T.	Minor shot hole damage to foliage.
Coleoptera Coccinellidae	*Henosepilachna signatipennis* (Boisduval)	*Centrosema* sp.	Rorona Plantation CP	K.	?
			Aiyura EHP	Anon. 1970	Adults and larvae feeding on leaves.
			Bubia MP	G.Y.	Adults and larvae feeding on leaves.
			Cleanwater, Markham Valley MP	G.Y.	" "
			Maralumi MP	K.	Feeding on foliage.
		M. lathyroides	Markham Valley MP	G.Y.	Adults feeding on leaves.

Order Family	Genus and Species	Host Plant Species	Locality	Source	Damage
Coleoptera Coccinellidae	*Henosepilachna signatipennis* (Boisduval)	*P. phaseoloides*	Kulili Pltn. Kar Kar Is. MdP	K.	?
			Bubia MP	G.Y.	Adults and larvae feeding on leaves.
		P. vulgaris	17 Mile Port Moresby CP	K.	?
			Awala NP	J.S.I. 1959	?
			Popondetta NP	Anon. 1971	Adults feeding on foliage.
			Sila NP	Anon. 1969	Adults feeding on foliage.
			Bubia MP	G.Y.	Adults and larvae feeding on leaves, shoots, flowers and immature fruit.
			Wau MP	W.G.	Adults and larvae feeding on leaves.
		P. tetragonolobus	Bubia MP	G.Y.	Adults and larvae feeding on leaves, shoots, flowers and immature fruit.
			Kuk WHP	B.T.	Adults and larvae feeding on foliage.
		V. angularis	Bubia MP	G.Y.	Adults and larvae feeding on leaves.
		V. radiata	Bubia MP	G.Y.	Adults feeding on leaves
			Marambung MP	G.Y.	" "
			Mutzing MP	G.Y.	" "
		V. umbellata	Oriomo, Agricultural Station WP	J.S.I.	Feeding on foliage.

		V. unguiculata	Brown River CP	J.S.I.	Feeding on foliage.
			Laloki CP	G.Y.	Adults and larvae feeding on leaves, shoots, flowers and immature fruit.
			Bubia MP	G.Y.	
			Markham Valley MP	G.Y.	
			Wau MP	G.Y.	Damage sometimes severe.
	Henosepilachna ? *28 punctata* (Fabricius)	*V. radiata*	Marambung MP	G.Y.	Feeding on leaves.
Coleoptera					
Alticidae	*Psylliodes brettinghami* Baly	*M. atropurpureum*	?	K.	Feeding on leaves.
Lagriidae	*Largria* sp.	*G. max*	Aiyura EHP	S.C.S.	Adults feeding on leaves, damage minor.
		V. radiata	Aiyura EHP	S.C.S.	" "
Nitidulidae	*Carpophilus* sp.	*A. hypogaea*	Atzera MP	J.V.G.	Shelled seed peanuts in storage.
Silvanidae	*Ahaversus advena* (Waltl)	*A. hypogaea*	Atzera MP	J.V.G.	Peanut kernels in storage.
Curculionidae	*Apirocalus cornutus* (Pascoe)	*V. radiata*	Wau MP	W.G.	Adults feeding on leaves.
	Oribius cinereus Marshall	*V. radiata*	Wau MP	W.G.	Adults feeding on leaves.
	Oribius cruciatus Faust	*V. unguiculata*	Wau MP	W.G.	" "
		P. phaseoloides	Brown River CP	J.S.I.1959	?
	Oribius ? *guttiger* Blanchard	*P. vulgaris*	Mul WHP	B.T.	Minor shot hole damage.
	Oribius inimicus Marshall	*G. max*	Mendi SHP	B.T.	Minor shot hole damage to foliage.
		P. vulgaris	Ogelbeng WHP	B.T.	" "
		P. tetragonolobus	Kuk WHP	B.T.	" "

Order Family	Genus and Species	Host Plant Species	Locality	Source	Damage
Coleoptera					
Silvanidae	*Oryzaephilus mercator* (Fauvel)	*A. hypogaea*	Atzera MP	J.V.G.	Peanut kernels in storage.
Tenebrionidae	*Caedius demeijerei* Gebien	?	?	K.	Damaging seedlings.
	Tribolium castaneum (Herbst)	*A. hypogaea*	Poligolo CP	J.V.G.	Peanuts in storage.
Trogossitidae	*Tenebroides mauritanicus* Linnaeus	*A. hypogaea*	Atzera MP	J.V.G.	Peanuts in storage.
Lepidoptera					
Gracillariidae	*Acrocercops caerulea* Meyrick	*P. coccineus*	Abanaka MP	G.Y.	Larvae mining leaves, damage slight.
		P. vulgaris	Bubia MP	G.Y.	" "
		V. umbellata	Bubia MP	G.Y.	" "
		V. unguiculata	Bubia MP	G.Y.	" "
			Mutzing MP	G.Y.	" "
	? *Acrocercops* sp.	*G. max*	Bubia MP	G.Y.	Larvae mining leaves, damage slight.
	? *Caloptila* sp.	*P. tetragonolobus*	Wau MP	W.G.	Larvae leaf rollers.
Geometridae	*Hyposidra talaca* (Walker)	*V. unguiculata*	Wau MP	W.G.	Feeding on leaves.
Lycaenidae	*Lampides boeticus* Linnaeus	*C. cajan*	Bubia MP	G.Y.	Larvae feeding on young pods.
			Kerema GP	J.S.I. 1959	Larvae in pods.
		Lupinus sp.	Daulo Pass EHP	B.T.	Larvae feeding on flowers.
		P. tetragonolobus	Bubia MP	G.Y.	Larvae boring pods, causing pods to become

			Wau MP	W.G.	Larvae boring pods.
			Kuk WHP	B.T.	Larvae feeding on flowers.
		V. unguiculata	Bubia MP	G.Y.	Larvae boring pods, common in subsistence gardens.
	Zizina otis (Fabricius)	*V. unguiculata*	Bubia MP	G.Y.	Larvae feeding on leaves, flowers and boring pods.
			Wau MP	W.G.	Larvae boring pods.
Lymantriidae	*Euproctis* sp.	*P. tetragonolobus*	Bubia MP	G.Y.	Larvae feeding on leaves, flowers and pods.
		V. unguiculata	Bubia MP	G.Y.	" "
			Lae MP	G.Y.	" "
Lyonetiidae	*Leucoptera* sp.	*P. tetragonolobus*	Aiyura EHP	G.Y.	Larvae mining leaves, damage severe.
			" "	S.C.S.	Larvae mining leaves.
			Bena Bena EHP	G.Y.	Larvae mining leaves, damage severe.
			UPNG, Waigani CP	K.L.	Larvae mining leaves.
			Bubia MP	G.Y.	" "
			Unitech, Lae MP	G.Y.	" "
			Wau MP	W.G.	" "
Noctuidae	*Agrotis* sp.	*Lupinus* sp.	Aiyura EHP	S.C.S.	Feeding on seedlings.
	Anticarsia irrorata (Fabricius)	*V. radiata*	Wau MP	W.G.	Feeding on leaves.
		V. unguiculata	Wau MP	W.G.	Feeding on leaves.
	Chrysodeixis eriosoma (Doubleday)	*V. radiata*	Bubia MP	G.Y.	Feeding on leaves.
			Markham Valley MP	G.Y.	" "
			Gabazung MP	G.Y.	Larvae feeding on leaves.
		V. unguiculata	Bubia MP	G.Y.	Feeding on leaves.
			Wau MP	W.G.	" "

Order Family	Genus and Species	Host Plant Species	Locality	Source	Damage
Lepidoptera					
Noctuidae	*Diachrysia orichalcea* Fabricius	*G. max*	Aiyura EHP	S.C.S.	Larvae feeding on leaves.
	Heliothis armiger Hübner	*C. cajan*	Bubia MP	G.Y.	Larvae feeding inside pods, damage was severe at times.
		P. vulgaris	Bubia MP	G.Y.	Larvae feeding inside pods.
			Ogelbeng WHP	B.T.	Larvae feeding on foliage.
		P. sativum	Wau MP	W.G.	Larvae feeding on pods.
			Kondepina WHP	B.T.	Larvae feeding inside pods.
		V. unguiculata	Bubia MP	G.Y.	Larvae feeding on flowers and pods.
			Kuk WHP	B.T.	Larvae feeding inside pods.
	Spodoptera litura	*P. sativum*	Wau MP	W.G.	Larvae feeding on leaves.
		P. tetragonolobus	Wapenamanda EP	B.T.	Larvae feeding on leaves.
		V. angularis	Bubia MP	G.Y.	Larvae feeding on leaves, damage was usually slight.
		V. radiata	Bubia MP	G.Y.	Larvae feeding on leaves, damage was usually slight.
		V. unguiculata	Bubia MP	G.Y.	" "
Pyralidae	*Ephestia cautella* (Walker)	*A. hypogaea*	Atzera MP	J.V.G.	Seed in storage.
		G. max	?	J.V.G.	Seed in storage.
		P. sativum	?	J.V.G.	Seed in storage.

Crocidoloma binotalis Zeller	*P. tetragonolobus*	Kuk WHP	B.T.	Feeding on leaves.
Diaphania indica (Fabricius)	*A. hypogaea*	Bubia MP	G.Y.	Larvae tying leaves.
		Wau MP	W.G.	" " "
	G. max	Aiyura EHP	S.C.S.	Larvae tying leaves, serious damage.
		Bubia MP	G.Y.	Larvae tying leaves.
		Wau MP	W.G.	" " "
	M. sativum	Wau MP	W.G.	Larvae tying leaves.
	M. pruriens	Wau MP	W.G.	Larvae tying leaves.
	P. vulgaris	Bubia MP	G.Y.	Larvae tying leaves.
		Wau MP	W.G.	" " "
	P. sativum	Wau MP	W.G.	Larvae tying leaves.
	P. tetragonolobus	Bubia MP	G.Y.	Larvae tying leaves, occasionally serious damage.
		Kuk WHP	G.Y.	Larvae feeding on foliage.
	V. radiata	Bubia MP	G.Y.	Larvae tying leaves.
		Wau MP	W.G.	" " "
	V. unguiculata	Bubia MP	G.Y.	Larvae tying leaves.
		Wau MP	W.G.	" " "
Hedylepta diemenalis	*P. tetragonolobus*	Unitech, Lae MP	G.Y.	Larvae tying leaves.
	P. phaseoloides	Sowam ESP	S.L.S.	Severe damage.
		Saiho NP	Bourke et. al. 1973	Larvae defoliated localised patches.
		P.A.C. Popondetta NP	"	" "
	Pueraria sp.	Keravat ENBP	Anon. 1971	?
		Wewak ESP	K.	?

Order Family	Genus and Species	Host Plant Species	Locality	Source	Damage
Lepidoptera Pyralidae	*Maruca testulalis* (Geyer)	*C. cajan*	Bubia MP	G.Y.	Larvae feeding on flowers and pods, webbing pods together. Some varieties were more susceptible than others.
		C. ensiformis	4 Mile, Lae MP	G.Y.	Larvae boring pods, damage slight.
			Wau MP	W.G.	Larvae boring pods.
		M. pruriens	Wau MP	W.G.	Larvae boring pods, damage severe.
		P. vulgaris	Sogeri CP	Bourke et. al. 1973	Larvae boring pods.
			Bubia MP	G.Y.	" " "
			Wau MP	W.G.	" " "
			Popondetta NP	Bourke et. al. 1973	" " "
		P. tetragonolobus	Bubia MP	G.Y.	Larvae boring pods, damage has been severe on occasions.
			Kuk WHP	B.T.	Larvae feeding on flowers.
		Pueraria sp.	Keravat ENBP	Anon. 1971	?
		V. angularis	Bubia MP	G.Y.	Larvae feeding on flowers and pods, webbing pods together. Damage severe.

		V. radiata	Bubia MP	G.Y.	Larvae feeding on flowers and pods, sometimes boring pods.
		V. unguiculata	Bubia MP	G.Y.	Larvae feeding on flowers, boring and webbing pods. Damage was more severe during south-east season.
			Markham Valley MP	G.Y.	Larvae boring pods.
	? *Salebria*	*A. hypogaea*	Goroka EHP	K.	Feeding on leaves.
Tortricidae	*Adoxophyes* ? *aniara* (Diakonoff)	*P. tetragonolobus*	Kuk WHP	B.T.	Feeding on leaves.
	Adoxophyes sp. nr. *melichon* Low	*A. hypogaea*	?	J.L.F. 1940	On foliage.
	Adoxophyes ? *thoracica* Diakonoff	*G. max*	Wau MP	W.G.	Feeding on leaves.
	Archips sp.	*P. sativum*	Wau MP	W.G.	Feeding on leaves.
	Cryptophlebia	*A. hypogaea*	Wau MP	W.G.	Feeding on leaves.
	pallifimbriana Bradley	*C. gladiata*	Laloki CP	T.F. 1974	Feeding on pods.
	Homona coffearia Nietner	*A. hypogaea*	Wau MP	W.G.	Feeding on leaves.
		G. max	Wau MP	W.G.	Feeding on leaves.
		M. pruriens	Wau MP	W.G.	Feeding on leaves.
		V. radiata	Wau MP	W.G.	Feeding on leaves.
		V. unguiculata	Wau MP	W.G.	Feeding on leaves.

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CONTROL OF *PHYTOPHTHORA* SEEDLING BLIGHT OF COCOA

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ABSTRACT

Phytophthora palmivora *(Butler) Butler causes occasional serious losses of cocoa (*Theobroma cacao *Linnaeus) planting material in the nursery. Experiments were conducted to find an effective but inexpensive chemical control measure. Metalaxyl was found to be very effective both as a foliar spray and as a seed treatment and the prophylactic use of either method at the rate of about 10g a.i./1000 seedlings raised production costs by less than 0.5%.*

INTRODUCTION

Seedling blight of cocoa (*Theobroma cacao* Linnaeus), caused by *Phytophthora* species, has received little attention from research workers who have rightly concentrated on the more devastating pod and bark diseases caused by the same pathogens. Most work with cocoa seedlings has used them as convenient host material for fungicide testing (Newhall 1971; Daguenet 1980), pathogenicity testing (Firman and Vernon 1970) or resistance testing (Lawrence 1978). The fungus naturally attacks and kills unhardened 'flush' leaves and young green stem tissue. Under exceptional conditions it also infects mature leaves but this is not normally regarded as being serious (Manço 1966; Gregory 1969). Infection of flush leaves and stems can, however, lead to death of the growing point, or of the whole plant in the case of seedlings, and where the fungus spreads down a chupon (chupon wilt) bark cankers can form (Prior and Smith 1981).

Until recently little thought has been given to the control of seedling blight in Papua New Guinea (PNG), caused by *P. palmivora* (Butler) Butler as most plantings were done 'at stake', several seeds being sown and only the most vigorous healthy seedling left to grow to maturity. The development of high yielding Trinitario clones and Trinitario x Amazonian hybrids has led to the more frequent use of cocoa nurseries. The cost of hybrid seed and the inherent expense of running a nursery has prompted growers and nurserymen to request cheap and reliable measures for controlling disease outbreaks.

Seedling blight has a sporadic incidence but large losses of expensive seedlings or buddings can occur during periods of very wet weather, which are rather unpredictable in many cocoa growing areas of PNG. In Nigeria Chant and Hall (1959) found sprays of copper fungicide at 6 day intervals gave effective control of the disease. Although this is an expensive and time consuming routine, similar schedules at Keravat failed to prevent disease outbreaks. Virtually all outbreaks involved young plants, less than three weeks from emergence or bud growth, whose lowest leaves had not yet hardened off. It is likely that most infection came from the soil and the flush leaves were infected by rain splashed spores before being sprayed with fungicide. Although establishment of nurseries close to mature cocoa is strongly discouraged, they are still common in PNG and severe seedling blight occurs in such situations.

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The suggested source of soil for planting bags is from beneath virgin or secondary forest but this is not always available to cocoa plantations which frequently have to use soil from old cocoa blocks.

The seedling blight problem, being sporadic in nature but having the potential for causing serious and expensive losses, requires an inexpensive and reliable control measure which can either be incorporated into routine nursery procedures as prophylaxis or which can effectively stop disease outbreaks when they occur. The aim of this work was therefore to develop disease control recommendations which fulfilled the above requirements and would be acceptable to growers.

Cocoa seedlings grow very rapidly in the first few months after planting and in the first three weeks after emergence produce 4-6 leaves all of which are highly susceptible to *P. palmivora* attack as is the green stem tissue. Thus it was considered that the newly available systemic fungicides active against Oomycetes might prove more effective than surface protectants which have to be applied frequently to keep up with new leaf production. These systemic fungicides were tried both as spray and seed treatments in a series of experiments spanning three wet seasons at Keravat from November 1979 to February 1982.

MATERIALS AND METHODS

SITE AND NURSERY MATERIALS

Experiments were carried out beneath the shade of a large rain tree (*Samanea saman* Merrill) 60 m from the nearest cocoa. Black polyethylene planting bags (38 × 18 cm flat) filled with free draining, black volcanic ash topsoil were used for growing the cocoa seedlings. Soil was obtained from beneath secondary forest for each of the experiments except 5 and 6 which used bags from the previous experiment 4 from which the top 4 cm of soil had been removed and replaced with *Phytophthora* infested top soil from beneath old cocoa. Bags were arranged in plots of 100 (20 × 5 lines) each plot at least 1 m from its neighbours and separated from them by bare ground.

EXPERIMENTS

Experiments 1-3 were carried out from November 1979 to April 1980, experiments 1 and 2 concurrently, experiment 4 in December 1980 and experiments 5 and 6 from December 1981 to February 1982. Treatments are summarised in *Table 1*. Results were statistically analysed by Analysis of Variance.

Experiment 1. Fungicide spray comparison

Three systemic fungicides were tried, metalaxyl as Ridomil 25% w.p. (Ciba Geigy), aluminium tris (ethyl phosphonate) as Aliette 80% w.p. (May & Baker) and propamocarb as Previcur N 70% e.c. (Schering). Seedlings at the 2 – 4 leaf stage were used. A fine spray of each fungicide was applied by slide pump in 700 ml water per plot. Four mm of rain fell 4 h after spraying.

Inoculations were carried out during that rainfall (day 0) and again 1, 6, 16 and 26 days after spraying on one plot of each treatment and on the untreated control per inoculation date. Seedling blight in each plot was recorded 10 days after each inoculation.

Experiment 2. Fungicide seed treatment comparison

The three fungicides from experiment 1 were tried as seed treatments. One inoculation was performed on all plots 26 days after sowing (d.a.s.) at the four leaf stage. The number of seedling mortalities was recorded 14 days after inoculation.

Table 1. — **Fungicide treatments tested for effectiveness in controlling seedling blight of cocoa**

Experiment No.	Seed preparation	Method of fungicide application	Fungicide	Dose rate (% a.i.)	Treatment time (h)	No. replicate plots (100 seeds/plot)
1	pregerminated	spray	metalaxyl	0.13	—	5
			aluminium tris (ethyl phosphonate)	0.40	—	5
			propamocarb	0.35	—	5
			nil control	—	—	5
2	pregerminated	seed soak	metalaxyl	0.13	2	1
			aluminium tris (ethyl phosphonate)	0.40	2	1
			propamocarb	0.35	2	1
			water control	—	2	1
3	pregerminated	seed soak	metalaxyl	0.025	16	3
			"	0.050	16	3
			"	0.125	16	3
			"	0.250	16	3
			"	0.500	16	3
			"	1.250	16	3
			"	2.500	16	3
			water control	—	16	3
4	pregerminated	seed soak	metalaxyl	0.31	16	8
			"	0.63	16	8
			"	0.94	16	8
			"	1.25	16	8
			water control	—	16	8
5	ungerminated	seed soak	metalaxyl	0.25	16	10
			"	0.25	2	10
			"	0.25	dip	10
			nil control	—	—	10
6	ungerminated	seed soak	metalaxyl	0.13	dip	8
			"	0.25	dip	8
			"	0.38	dip	8
			"	0.50	dip	8
			nil control	—	—	8

Experiment 3. Metalaxyl seed treatment dose rate trial No. 1

Metalaxyl was found effective and systemic (see *Figure 1* and Results Section) so further experiments were conducted to determine the effectiveness of various doses of seed treatment. Percentage germination and emergence were recorded for each treatment overall. Three inoculations were performed 27 (4 leaf stage), 40 and 46 d.a.s. on one plot of each treatment. The number of seedlings with *P. palmivora* infection symptoms were recorded 10 days after each inoculation.

Experiment 4. Metalaxyl seed treatment dose rate trial No. 2

Percentage germination and emergence were recorded for each treatment. Inoculations were carried out 25 (4 leaf stage), 30 and 37 d.a.s. on one plot of each treatment and at 50 d.a.s. on the remaining five plots of each treatment. Blight symptoms were recorded 10 days after each inoculation.

Experiment 5. Metalaxyl seed treatment duration

In commercial practice mucilage re-

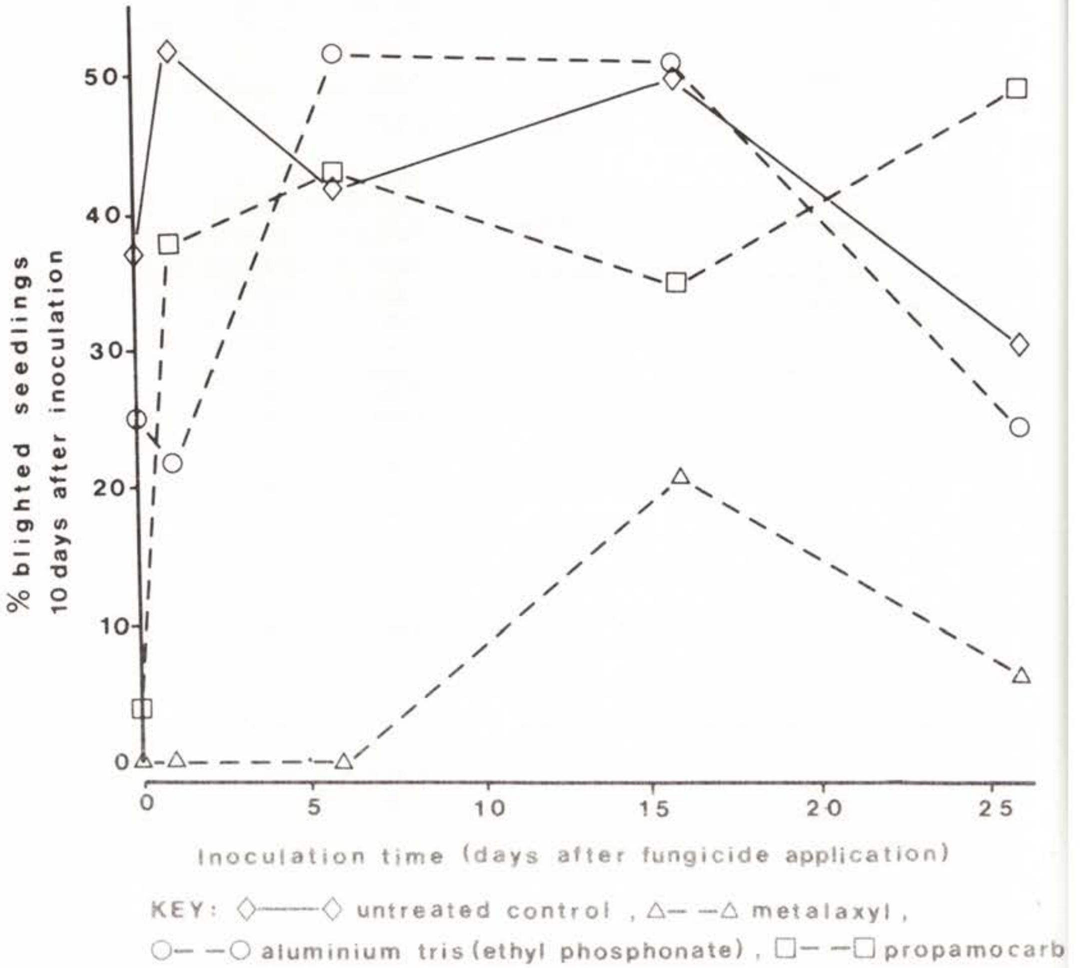


Figure 1. —Comparison of fungicide sprays for controlling seedling blight of cocoa (experiment 1).

moval and pregermination are seldom carried out. The retention of mucilage may affect fungicides' effectiveness so a replicated trial was performed with the aim of evaluating the effect of various treatment times on subsequent natural infection.

The 40 plots from experiment 4 were reused and the bags topped up with soil from a heavily black pod infected cocoa block. Percentage emergence was recorded for each plot and numbers of dead seedlings, as a proportion of emerged seeds, counted up to 50 d.a.s.

Experiment 6. Metalaxyl seed treatment dose rate trial No. 3

Merely dipping a batch of seed with mucilage intact and proceeding to sow the treated seed was found just as effective as an overnight soaking (see *Table 3* and Results Section). A final and replicated trial was therefore performed to re-evaluate the effectiveness of various rates of metalaxyl seed treatment under conditions of heavy natural infection. The 40 plots from experiments 4 and 5 were reused. The top 4 cm of soil from the bags was replaced with soil from a heavily black pod infected block. Percentage emergence was recorded for each plot and the numbers of dead seedlings, as a proportion of emerged seeds, recorded 40 d.a.s.

SEED SOURCE AND TREATMENT

For experiments 1,2,3 and 6 open pollinated seed from mixed Trinitario trees was used. To try to reduce variability in seedling growth rates seed from open pollinated pods of Trinitario clone KA2-101 was used for experiments 4 and 5. Pregermination of cocoa seeds produces an even stand of seedlings all bearing flush leaves for 2-3 weeks after emergence which was convenient for experimental purposes. Seeds were pregerminated by removing mucilage in sawdust and laying the seeds in damp hessian supported on a wire tray. Seeds were checked daily and planted as soon as the radicle was visible.

Seeds were soaked in fungicide suspension before pregermination or before sowing in the case of ungerminated seed which did not have mucilage removed.

INOCULUM PREPARATION AND SEEDLING INOCULATION

Zoospore suspensions were made by flooding 10 day old petri dish cultures of a local *P. palmivora* isolate on 5% V8 juice agar with 20 ml cold (*c.* 5°C) sterile distilled water. The plates were left in the dark for 40 min and the suspension decanted into a plastic bucket and diluted with rain water to a final concentration of about 5-8 $\times$ 10^3 spores/ml.

About 500 ml of the dilute zoospore suspension were sprinkled evenly over each plot of 100 seedlings using a plastic toy watering can during late afternoon or evening rainfall when the seedlings were expected to remain wet all night. Thus in all experiments inoculations were performed at irregular intervals when suitable weather conditions prevailed. This did not always coincide with leaf flushing particularly with older seedlings.

SYMPTOMS AND RECORDINGS

Germination was recorded as growth of the radicle beyond the testa. Emergence was defined as growth of the seedling above soil level to the stage of producing recognisable leaves within opened cotyledons.

Three symptoms of seedling blight were recognised; typical necrosis and withering of unhardened flush leaves (*Plate I* a, b & c), black 'V' shaped necrotic patches along margins or veins of 'hardened off' leaves (*Plate I* c & d) and dark brown necrotic patches on green stems or petioles. Infection of the stem at or just below the growing point, or infection spreading from flush leaves or petioles to that part of the stem produced the characteristic crook-neck appearance of dead seedlings (*Plate I* a & b). Infection of stems well below the growing point caused sudden death with the stem remaining erect bearing unwithered dead leaves. Any infection which killed the terminal bud rendered the seedling useless for transplanting or as rootstock but mature leaf infection alone was not damaging. In some cases infected flush leaves abcissed before infection reached the stem, particularly in dry weather, and where inoculations were performed between leaf flushes few seedling deaths resulted. Counts of mortality from successive inoculations were therefore not a reliable measure of the treatment effects. Consequently in experiments 1, 3 and 4 infection was recorded as any of the described symptoms. In experiments 2, 5 and 6, however, only one assessment was made and only death of the growing point was recorded as this is of greatest relevance to the grower.

RESULTS

Experiment 1. Fungicide spray comparison

The proportion of plants per plot with symptoms of *P. palmivora* infection is shown in *Figure 1* for the five successive inoculations. Metalaxyl gave complete control of the artificial inoculations up to 6 days after spraying and was better than the other treatments up to 26 days after spraying.

Some plants in three plots were infected before spraying. These were marked and their fate recorded. Of the 24 plants infected before treatment in a metalaxyl sprayed plot none subsequently died; the leaf and stem infections were completely arrested. Of the 34 plants infected before treatment in a propamocarb sprayed plot, 19 (55.9%) died of the infection and similarly in a control plot 26 of the initial 46 infected plants (56.5%) died of the infection. No pre-treatment infection occurred in the aluminium tris (ethyl phosphonate) sprayed plot. These results demonstrate a valuable curative effect of metalaxyl.

Experiment 2. Fungicide seed treatment comparison

The proportion of dead plants in each plot 14 days after inoculation was metalaxyl 0, aluminium tris (ethyl phosphonate) 22%, propamocarb 34% and water control 43%.

This supports the conclusion from experiment 1, that metalaxyl gives better control of seedling blight than the other treatments and demonstrates its systemic activity.

Experiment 3. Metalaxyl seed treatment dose rate trial No. 1

Percentage germination and emergence for the eight treatments are given in *Table 2*. The results of the successive inoculations are given in *Figure 2*. Germination and emergence appears to be increased by metalaxyl treatment except for the highest dose 2.5% which appeared to be phytotoxic. All metalaxyl treatments averaged over the three inoculation dates significantly reduced blight compared

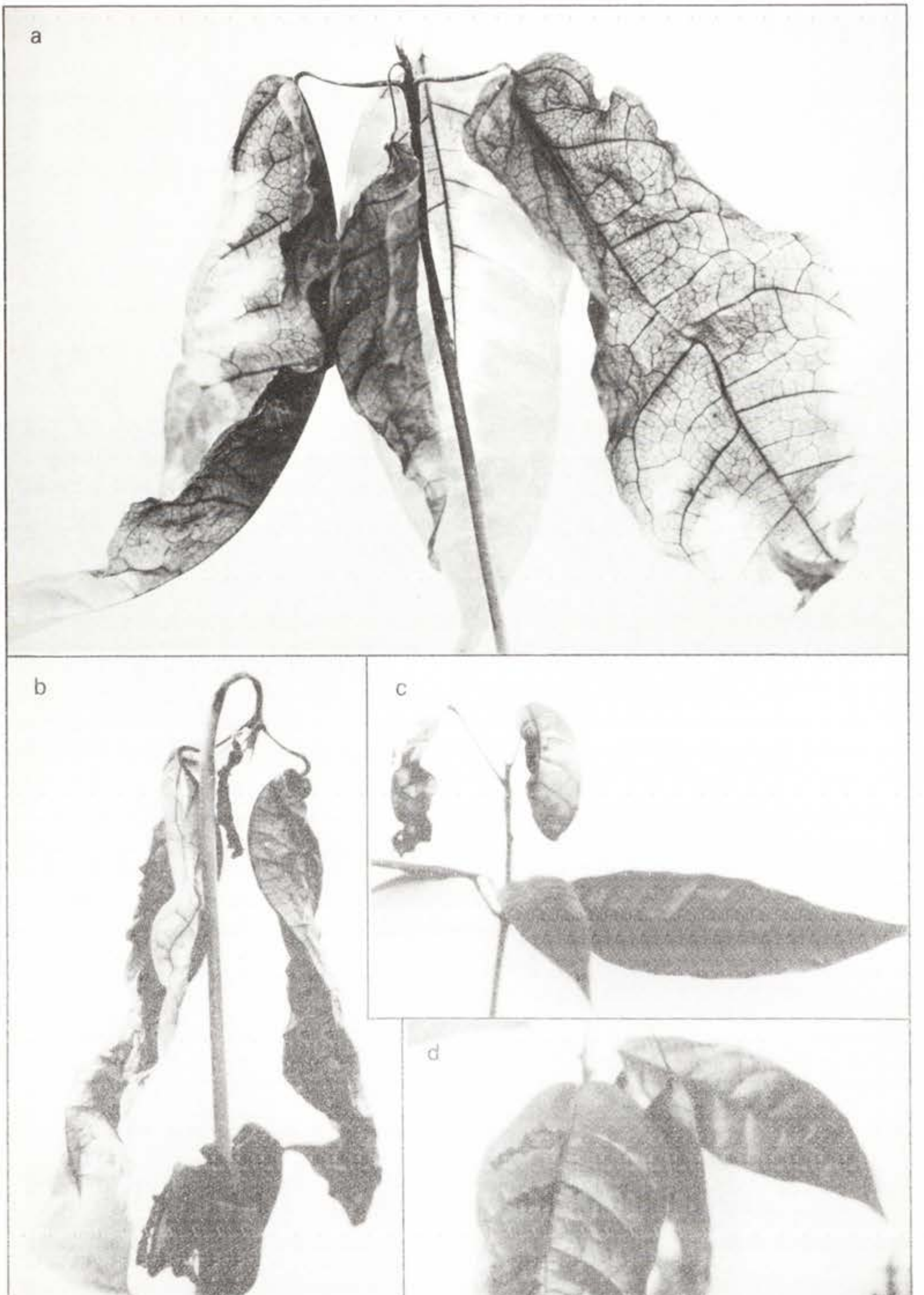
Plate I—Symptoms of cocoa seedling blight caused by *Phytophthora palmivora* (Butler) Butler.

a Early symptoms of flush leaves. Note the lesion spreading down the stem which is starting to bend.

b Crook-necked appearance of a seedling killed by progression of infection from flush leaves into the stem.

c Early symptoms on flush leaves and 'v' shaped lesions at the margin of a mature seedling leaf.

d 'V' shaped lesions along the veins of a mature seedling leaf.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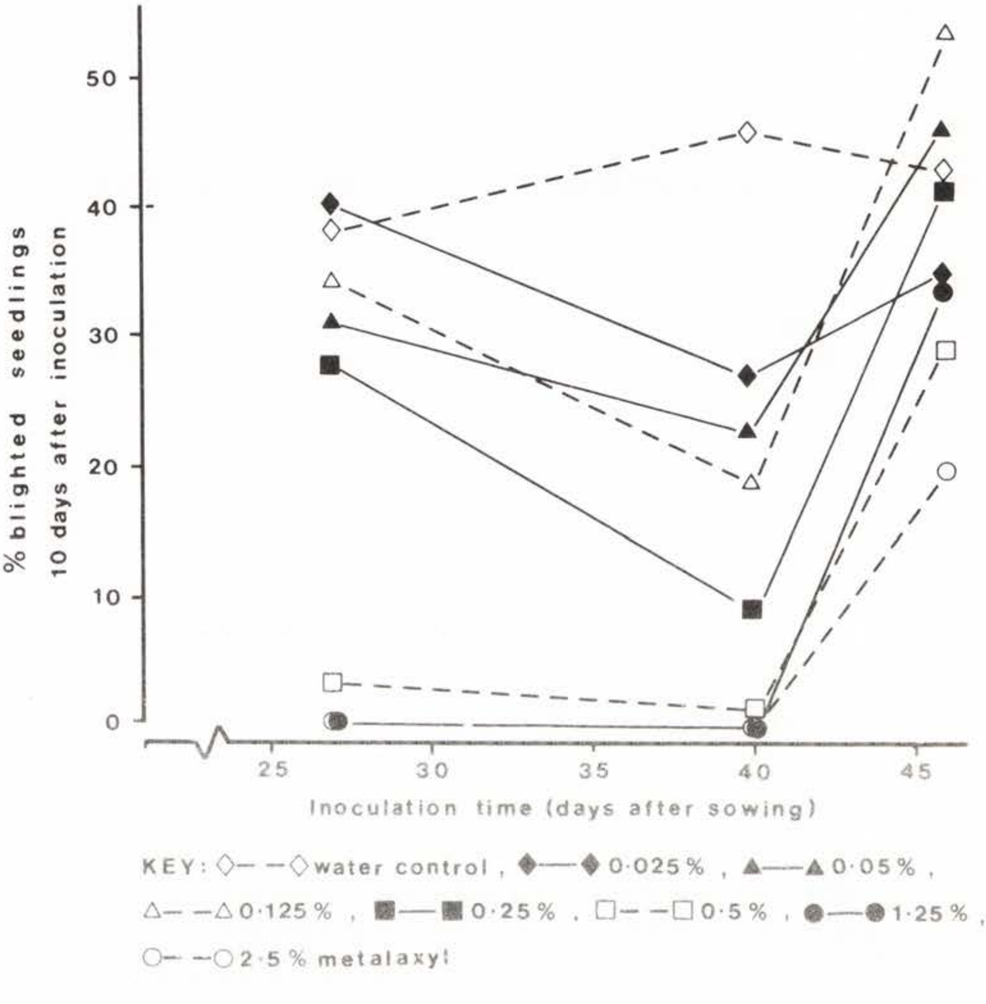

Figure 2.—Comparison of metalaxyl seed soaking dose rates for controlling seedling blight of cocoa: dose rate trial No. 1 (experiment 3).

Table 2.—**Effect of metalaxyl seed soaking treatment dose rates on germination and emergence of cocoa seeds (experiment 3)**

Treatment % metalaxyl	Germination %	Emergence %
0 (control)	86.52	61.46
0.025	89.84	97.87
0.050	89.22	96.94
0.125	89.75	97.83
0.250	90.90	100.00
0.500	88.20	98.98
1.250	86.31	98.94
2.500	81.73	82.29

with the untreated control ($P<0.01$). The three highest rates were, however, not significantly different and all gave significantly better control than all other treatments ($P<0.01$).

Experiment 4. Metalaxyl seed treatment dose rate trial No. 2

In contrast to experiment 3 the germination and emergence of untreated control seeds was over 94% and there was little difference between any metalaxyl treatment and the control. The results of the four successive inoculations are given in *Figure 3*. All metalaxyl treatments averaged over the first three inoculation dates significantly reduced blight compared with the untreated control ($P<0.001$). The two highest rates were not significantly different but were significantly better than the two lower rates ($P<0.001$). There was no significant difference between the control and any of the fungicide treatments 50 d.a.s.

Experiment 5. Metalaxyl seed treatment duration

Percentage emergence and percentage of seedlings infected for the four treatments are given in *Table 3*. All fungicide treatments gave significantly higher ($P<0.001$) emergence from heavily *P. palmivora* infected soil than the control and significantly lower ($P<0.001$) mortality but there was no significant difference between seed soaking times demonstrating that simply immersing a batch of seed in fungicide is adequate when mucilage is left intact.

Experiment 6. Metalaxyl seed treatment dose rate trial No. 3

The results of emergence and of natural mortality of seedlings grown in heavily *P. palmivora* infected soil are given in *Table 3*. All treatments were significantly better than the control ($P<0.001$) and the three higher doses gave significantly better control ($P<0.05$) than the lowest dose.

DISCUSSION

The results of the fungicide comparisons are in agreement with Daguenet (1980) and McGregor (1982) who also found metalaxyl more effective against *P. palmivora* than other systemic fungicides. The metalaxyl spray gave good control of artificially induced infection for three weeks after spraying and had a curative effect on established natural infection. Whilst this treatment cannot prevent early deaths of seedlings or damping off it is likely to be an effective control measure where disease outbreaks do occur.

In seed treatment experiments 5 and 6, where there was a large soil population of *P. palmivora* all doses of metalaxyl gave substantially increased emergence pre-

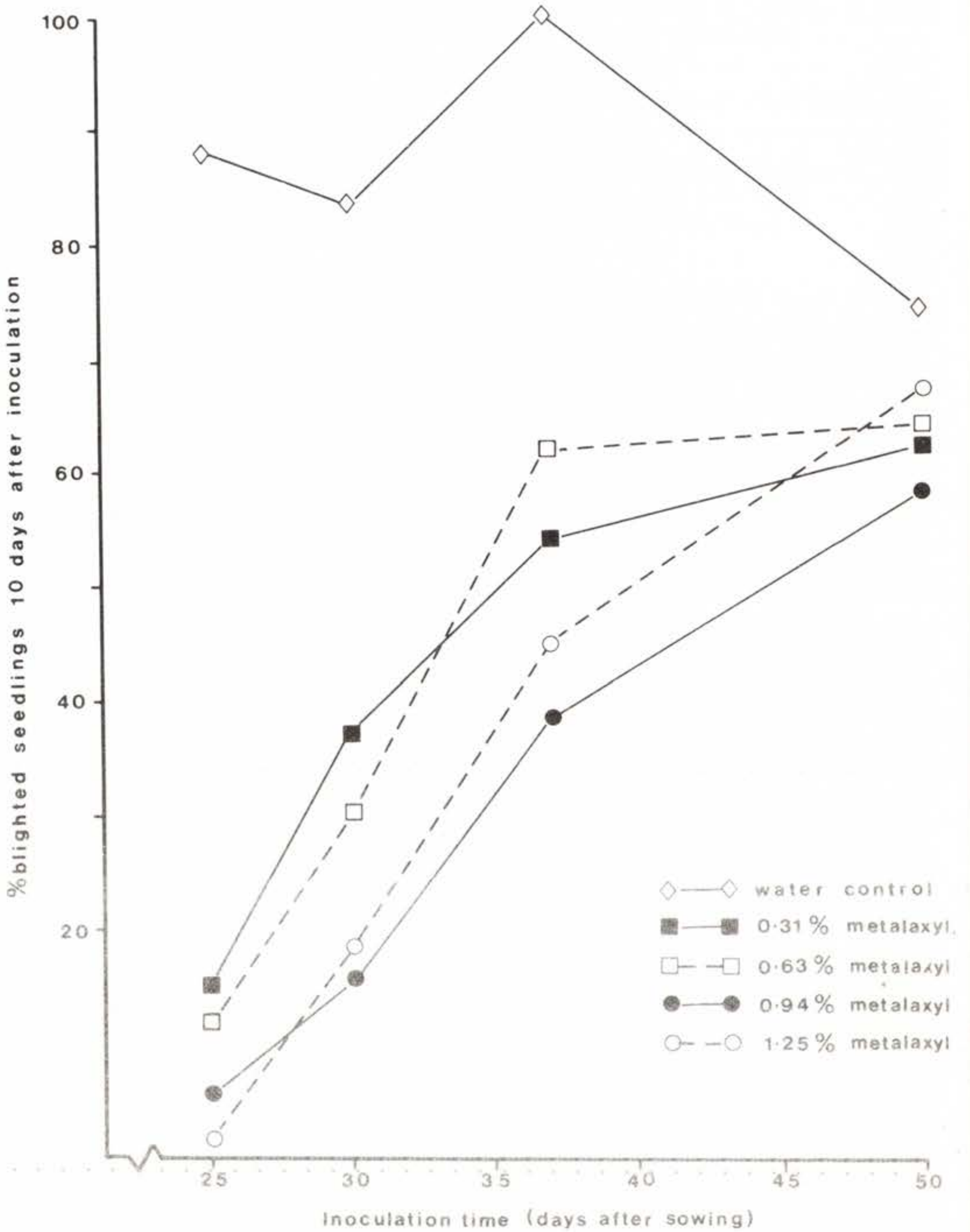

Figure 3. — **Comparison of metalaxyl seed soaking dose rates for controlling seedling blight of cocoa: dose rate trial No. 2 (experiment 4).**

Table 3. — **Effect of metalaxyl seed soaking treatment time (expt. 5) and dose rate (expt. 6) on cocoa seed emergence and seedling mortality in soil heavily infested with *Phytophthora palmivora***

Treatment Time (h)	EXPERIMENT 5 Mean emergence[1]		Mean mortality[1]	
Untreated control	21.7a[2]	(16.9)	68.5 a[2]	(81.4)
Dip	76.2 b	(93.7)	17.0 b	(9.5)
2	73.5 b	(91.6)	17.6 b	(11.4)
16	74.5 b	(92.6)	16.7 b	(9.8)
s.e.d. (32 d.f.)	2.15		5.25	
Treatment % metalaxyl	**EXPERIMENT 6 Mean emergence[1]**		**Mean mortality[1]**	
Untreated control	40.3 a[2]	(42.0)	51.8 a[2]	(61.4)
0.13	68.7 b	(86.9)	17.1 b	(9.3)
0.25	72.3 b	(90.1)	6.5 c	(1.9)
0.38	69.0 b	(88.0)	7.8 c	(2.0)
0.50	71.6 b	(90.8)	2.2 c	(0.5)
s.e.d. (45 d.f.)	5.24		1.88	

Key: 1 Statistical analyses and significance tests performed on Arc Sin transformed data, with original per-cent values shown in brackets.
2 Within the same column treatments followed by different letters are significantly different ($P < 0.001$).

sumably by controlling damping off. A dip in fungicide suspension was found to be just as effective as an overnight soak in controlling natural infection. In experiment 3, 0.5% metalaxyl gave good disease control up to 40 days after sowing but in experiment 4 infection rates were exceptionally high due to the use of uniform and highly susceptible planting material and the frequent coincidence of suitable inoculation conditions with leaf flushing. Even under these conditions 0.94% metalaxyl gave excellent control of infection up to 25 days after sowing and some control up to 40 days after sowing. None of the metalaxyl treatments were effective 50 days after sowing but by this time seedling blight rarely occurs naturally. In experiment 6, using a natural inoculum source, 0.25% metalaxyl was not significantly different from the two higher doses.

It is clear that the optimum dose of fungicide varies with seedling susceptibility and inoculum pressure. The recommended dose should be that which is likely to give good and reliable control under normal field conditions and, as 0.5% metalaxyl gave good control in experiments 3 and 6, that would seem to be a suitable general recommendation. The lower dose of 0.25% is likely to give good control where nursery soil is obtained from primary or secondary bush with a low *P. palmivora* population, whilst 1% might be required where the nursery is established under mature cocoa.

The cost of the 0.5% metalaxyl treatment was K1.00/1000 seeds. The planting bags cost K15.00/1000, hybrid seed K100.00/1000 and other nursery running costs raise total production costs to about K200.00/1000 seedlings. Buddings are even more expensive to produce. Thus an effective fungicide seed treatment costs only 0.5% of total production costs. The cost of the single metalaxyl spray in experiment 1 was similar to the seed soaking treatment, K0.90/1000 seedlings or buddings.

Metalaxyl tolerance has been reported in other pathogens (Davidse *et al.* 1981; Urech *et al.* 1981) but only where the fungicide had been used intensively. It would therefore be wise to restrict the use of metalaxyl to once only on any plant in the nursery and to destroy subsequently blighted plants as a precaution against the possibility of transporting metalaxyl tolerant *P. palmivora* to the field.

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EFFECTS OF FOUR FUNGICIDES ON THE GROWTH OF *PHYTOPHTHORA COLOCASIAE*

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ABSTRACT

The efficiency of four fungicides in controlling Phytophthora colocasiae *Raciborski was investigated* in vitro *and* in vivo. *Du-ter and Ridomil were found to effect excellent control of fungal development but the phytotoxicity of Du-ter rendered it unsuitable for use on taro. Cuprox and Aliette were found to be less effective.*

INTRODUCTION

Phytophthora colocasiae Raciborski, the causal organism of Taro Blight affecting *Colocasia esculenta* (L.) Schott, is a common and frequently serious pathogen of this food crop plant throughout South-east Asia. The spread of the disease from its probable centre of origin in Java (Raciborski 1900) is described in detail by Trujillo (1967).

Infection by *P. colocasiae* results in the formation of small water-soaked lesions which subsequently enlarge and coalesce to cover much of the surface of the leaf. Severely infected plants suffer premature defoliation. Full accounts of the life cycle of the fungus are provided by Trujillo (1967), Sickey (1973) and Jackson (1977).

Control of Taro Blight is attempted traditionally by the use of cultural methods. These may include the removal and destruction of infected leaves and stems and the use of disease free planting material. The use of resistant taro varieties has been suggested as a possible means of disease control (Parris 1941; Deshmukh and Chhibber 1960; Hicks 1967; Plucknett *et al.* 1970), but so far success has been limited. Hicks (1967) concluded that only one of the clones he tested should be considered as moderately resistant. All other clones used in the trial were classed as weakly resistant. *P. colocasiae* can be controlled by the use of chemicals. In Hawaii yield increases of up to 50 per cent were recorded when young plants were treated with copper based fungicides (Trujillo and Aragaki 1964). Jackson (1977) also reported good control of the disease in the Solomon islands using copper oxychloride.

This paper describes a laboratory investigation in which the effectiveness of copper oxychloride in inhibiting *P. colocasiae* development was compared with that of three more recently developed fungicides.

METHODS

Fungicides used in the investigation were Aliette 80 WP (aluminium tris [ethylphosphonate]), Cuprox 50 WP (copper oxychloride), Du-ter Extra 47.5 WP (triphenyl-tin-hydroxide) and Ridomil 25 WP (metalaxyl).

Two experimental methods were employed during the course of the investigation:

1) Each fungicide was suspended in distilled water and incorporated into potato dextrose agar (P.D.A.), after sterilising, to provide concentrations of 100, 200, 500 and 1000 p. p. m. a.i.

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For each treatment 6 replicate plates were prepared and inoculated with a 5 mm plug of *P. colocasiae* mycelium taken from the margin of a colony growing on P.D.A. Control plates contained no fungicide. Inoculated plates were incubated at 23°C and colony radii measured after 3 and 7 days.

2) Leaf segments of taro (local variety) replicated five times, were sprayed to run-off with each of the fungicides suspended in distilled water to give concentrations of 100, 200, 500 and 1000 p. p. m. a.i. . Leaf segments to be used as controls were sprayed with distilled water. After spraying they were allowed to air-dry for 1 minute and then placed on moist filter paper in individual incubation chambers maintained at 23°C.

   Four drops of freshly prepared *P. colocasiae* zoospore suspension (1000 spores per ml) in distilled water were applied to each of the leaf segments. Lesion size was measured 7 days after incubation.

RESULTS AND DISCUSSION

The fungicidal effects on growth of *P. colocasiae* in both experiments are displayed in *Table 1*.

From these results it is apparent that the fungicides Du-ter and Ridomil gave excellent control of *P. colocasiae* on both agar and leaf. Mycelial growth was exhibited at only the lowest rate of application after 7 days on agar and the area of the colony was negligible in comparison with the control and less effective fungicides. However, Du-ter did exhibit extreme phytotoxicity. This was confirmed subsequently by spraying glasshouse grown taro plants, at the lowest rate of application (100 p. p. m. a.i.), . Over a period of seven days all treated plants developed symptoms of severe leaf necrosis and premature defoliation occurred.

Cuprox provided good control at rates of application in excess of 500 p. p. m. a.i. on both leaf and agar, whilst Aliette effected very poor control of *P. colocasiae* on agar and only partial control on

Table 1.—**Fungicidal effect of *Phytophthora colocasiae* Mean mycelial and lesion areas, cm²**

Treatment (p. p. m. a.i.)		Agar Mycelial area Day 3	Agar Mycelial area Day 7	Leaf Lesion area
Du-ter	100	0	0.08	0
	200	0	0	0
	500	0	0	0
	1000	0	0	0
Ridomil	100	0	0.58	0
	200	0	0	0
	500	0	0	0
	1000	0	0	0
Cuprox	100	1.10	9.91	6.61
	200	1.20	7.39	5.94
	500	0	0.49	0
	1000	0	0	0
Aliette	100	4.24	13.43	8.64
	200	5.05	14.96	6.91
	500	4.23	15.25	5.31
	1000	2.33	12.34	0
Control		5.0	33.34	42.67

the leaves relative to the other fungicides.

It is suggested, in view of the above results and the possible development of resistance by *P. colocasiae* to Ridomil, that where chemical control is necessary, Ridomil and Cuprox be used alternately throughout the period of susceptibility. In an attempt to overcome this problem of resistance recent formulations of Ridomil have been modified by the inclusion of a copper component although these are not available locally.

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DEEP-SEA BOTTOM HANDLINE FISHING IN PAPUA NEW GUINEA: A PILOT STUDY

Per Sundberg* **and Andrew Richards†**

ABSTRACT

Bottom handlining was performed in three areas: Port Moresby, Milne Bay and Manus. It was shown that the catch rates are not Poisson distributed, i.e. they are not random, but no differences in catch rates could be found between the three areas, the time of the day or between different depths in the range fished, 70-270 m. It is concluded that the clumped distribution of the catch rates is probably due to different bait or by fishing at different sites, or both.

Differences in mean weight of fish were found for different depths, with a general trend for fish weight to increase with depth. The mean weight at 200-210 m is significantly higher than at depths 140-150 m and mean weight at 220-270 m is significantly higher than at depths 80-110 and 140-190 m.

Depth distributions are given for the 15 most common species encountered: Gnathodentex mossambicus, Lutjanus argentimaculatus, L. malabaricus, Pristipomoides multidens, P. flavipinnis, Etelis carbunculus, E. coruscans, E. radiosus, Tropidinus zonatus, T. argyrogrammicus, Tangia *sp.*, Epinephelus compressus, E. magniscuttis, E. morrhua *and* Epinephelus *sp. The depth associations between these species are described by cluster analysis based on a similarity matrix.*

INTRODUCTION

Interest in the deep water resources of the South Pacific is increasing for three reasons: first, stocks of demersal fish (fish living on, or close to, the seabed) are limited because of the almost complete absence of continental shelf, second, the overfishing of demersal stocks in those areas where they exist, and third, the problem of ciguatera poisoning does not exist with the deep water fish.

The South Pacific Commission (SPC) has been involved in deep water projects since 1974 (Crossland and Grandperrin 1980), and has endeavoured to both teach and encourage handline bottom fishing.

In early 1982, SPC staff visited Papua New Guinea to carry out a training programme in deep water handlining. Information on catch rates and catch composition was collected during this training programme and was analysed to describe the differences in catch rates between the three areas fished (Port Moresby, Milne Bay and Manus), the distribution of catch rates with respect to depth and time of day, and the depth distribution for the most common species. The depth and abundance associations between these species were also analysed.

This paper deals only with teleost (bony) fish. In some areas however, a substantial part of the catch consists of elasmobranchs (sharks).

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MATERIALS AND METHODS

Fishing

Three areas were fished: Port Moresby (seven trips, 41 hours fishing), Milne Bay (four trips, 65 hours fishing) and Manus (four trips, 61 hours fishing) (*Figure 1*). Fishing trips lasted from two hours to three days and depths ranged from 70 to 270 m. Small launches (6-8 m) were used on all trips except one where fishing was undertaken from a 10 m research vessel.

Fishing in Milne Bay and Manus was carried out on the slopes of the fringing reefs, i.e. where there is a shelf of coral growth, while in Port Moresby the outer slope of a barrier reef, i.e. a reef parallel to, but at some distance from the shore, was fished. All fishing was done from anchored positions; the anchor was dropped in shallow water and the rope paid out until a suitable depth was reached. Depths were determined with a Japan Marina Co., model 707 A/B, echo-sounder.

Fish were hauled by hand-reels of the Samoan type, equipped with over 300 m of monofilament line (125 kg test) and a wire terminal rig with three Mustad hooks, sizes 5, 6 and 7. A detailed description of the fishing gear is given by Fusimalohi and Crossland (1980).

The bait varied according to availability. The main baits used were skipjack tuna (*Katsuwonus pelamis*), dogtooth tuna (*Gymnosarda nuda*) and different mackerel species. It was either used fresh or toughened with salt.

Analyses

If there is a random temporal and spatial dispersion of catch rates, they will follow a Poisson distribution. A property of this distribution is that the variance is equal to the mean, a property that can be used as a test of randomness. If the catch rates are distributed randomly the ratio variance/mean value should equal one (Sokal and Rohlf 1981) and to test this the ratio A is used (Elliot 1971).

$A = \{ s^2 (n-1) \} \cdot \bar{x}^{-1}$

where:

s^2 = the variance of the catch rates

$\bar{x}$ = the mean value

n = the sample size.

This ratio is approximately χ^2 distributed with $n-1$ degrees of freedom (d.f.).

Catch rates are in kg of ungutted fish caught per line and hour. Differences in the catch rates between areas, time of day and depths, together with differences in average weight of fish for different depths, were analysed by the non-parametric Kruskal-Wallis one-way analysis of variance (ANOVA) (Daniel 1978). When significant differences were found, an *a posteriori* comparison was made by the procedure proposed by Dunn (1964), and described in Daniel (1978). An experimentwise error rate (Daniel 1978; Sokal and Rohlf 1981) of 0.15 was used in this comparison.

Ecological associations with respect to depth distribution and abundance were analysed using the two cluster analysis techniques: unweighted pair-group method using arithmetic averages (UPGMA) (Sokal and Michener 1958; Sneath and Sokal 1973), and single linkage clustering (Sneath 1957; Sneath and Sokal 1973). The cluster analyses were based on the similarity coefficient S.

$S = .5 \{ A \cdot (A+B+C)^{-1} + 2W \cdot T^{-1} \}$

where:

A = the number of depths where species i and j occur together

B = the number of depths where i, but not j, is present

C = the number of depths where j, but not i, is present

W = the sum of the lesser number of specimens for the species common to both depths

T = the total number of specimens for i and j.

This coefficient is a combination of the Jaccard (1908) and Bray-Curtis (in Southwood 1978) coefficients. The reason for

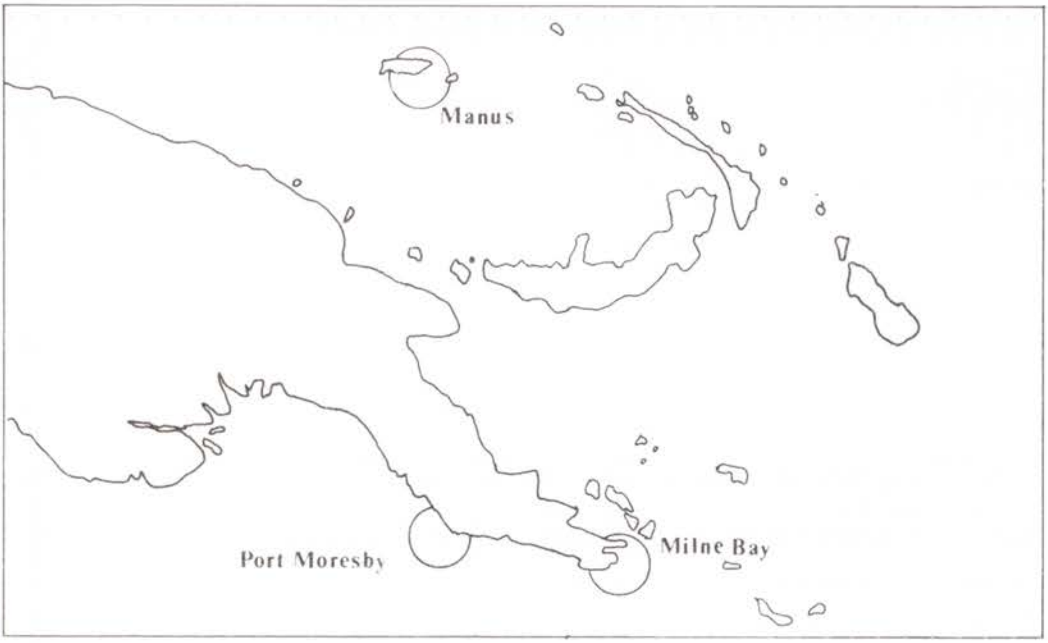

Figure 1. — **A map of Papua New Guinea, showing the three fishing areas used in this study; Port Moresby, Milne Bay and Manus**

combining them is that the former does not take into account abundance and will give high similarity even if some of the species are rare, whilst the Bray-Curtis coefficient underestimates the ecologically important fact that two species do occur together, even though their abundances are low.

RESULTS AND DISCUSSION

Catch rates and species composition

The mean catch rates are given in *Table 1* and the species encountered are listed in *Table 2*, which also lists where the species have been caught elsewhere in the South Pacific. The most common species are *Etelis carbunculus, Epinephelus morrhua, Tropidinus zonatus*, and *Lutjanus bohar*.

The differences between the rates are not statistically significant for the three areas (ANOVA, $P < 0.05$). For comparison, some other catch rates obtained by the same method of fishing in the South Pacific region are listed in *Table 3*.

The mean catch rate in this study, is about the average for the region and is at a level which could probably support an artisanal, i.e. small-scale, fishery. Although it was not possible to demonstrate in this study, it is our impression that the bait used has a significant influence on catch rates, a finding supported by Fusimalohi (pers. comm.). It is likely that oily fish with red flesh, such as skipjack tuna, produce higher catch rates. It should be pointed out that most of the fishing was undertaken by inexperienced trainees and catch rates can be expected to increase with experience of the crew.

Catch rates, depth and time of the day

Since this study was carried out in conjunction with a training programme, not all depths and times of the day could be fished in all areas. Hence for the analyses in this section, and the test of differences

Table 1. — **Mean catch rates for the three areas fished**

Area	Mean catch rate (kg/hr x No. of lines)	95% confidence interval	Sample size (hours of fishing)
Port Moresby	3.99	2.07	41
Milne Bay	2.50	0.74	65
Manus Island	4.55	1.74	61
Pooled	3.68	0.85	167

Table 2. — **List of the species encountered in Papua New Guinea and elsewhere in the South Pacific**

Species	No. of fish	% per weight	Mean weight	Source[4] A	B	C	D	E	F
Etelis carbunculus	111	47.2	4.9	X	X	X	X	X	X
Pristipomoides multidens	44	8.22	2.1	X	X				X
Etelis coruscans[1]	15	5.76	4.4	X	X	X			X
Epinephelus magniscuttis	13	5.58	4.9		X			X	X
Lutjanus malabaricus	11	1.30	1.4						X
Gnathodentex mossambicus	10	1.73	2.0						X
Epinephelus morrhua	9	1.61	2.0	X	X[3]	X	X	X[3]	X
Tropidinus zonatus	9	1.01	1.3	X		X	X	X	X
Pristipomoides flavipinnis	8	0.45	0.6	X	X[3]	X		X[3]	X
Epinephelus compressus	5	12.1	27.6	X					
Lutjanus argentimaculatus	5	2.25	5.1			X		X	X
Etelis radiosus[2]	5	2.18	5.0						
Epinephelus sp.	5	0.31	0.7		X[3]			X[3]	
Tangia sp.	4	1.34	3.8						
Pristipomoides filamentosus	4	1.13	3.2	X	X[3]			X[3]	X
Tropidinus argyrogrammicus	4	0.16	0.5	X					X
Epinephelus chlorostigma	3	0.45	1.7		X[3]	X		X[3]	X
Lutjanus bohar	2	1.06	6.1	X		X	X	X	X
Lethrinella miniata	2	0.87	5.0	X		X		X	X
Seriola dumerilii	2	0.48	2.8						
Variola louti	2	0.07	0.4	X		X	X		X
Pristipomoides auricilla	2	0.07	0.4		X[3]	X		X[3]	
Leptocephalidae	1	0.93	10.6						
Epinephelus tauvina	1	0.91	10.4		X[3]	X		X[3]	
Seriola purpurescens	1	0.49	5.6					X	X
Caranx lugubris	1	0.44	5.0				X	X	
Gymnosarda nuda	1	0.40	4.6						
Caranx sp.	1	0.39	4.4			X		X	X
Lutjanus erythropterus	1	0.37	4.2						
Lettrinus kallopterus	1	0.27	3.1						
Paracaesio sp.	1	0.26	3.0						
Branchiostegus wardi	1	0.13	1.5						
Cephalopholis sp.	1	0.02	0.02						

[1] *Etelis coruscans* is identified from Anderson (1981).
[2] *Etelis radiosus* is a recently described species (Anderson 1981).
[3] The source only reports the genus, not the species
[4] A. Fusimalohi and Grandperrin 1979
B. Fusimalohi 1979
C. Taumaia and Crossland 1980
D. Mead 1980a
E. Mead and Crossland 1980
F. Mead 1980b

Table 3. —**Mean catch rates (kg/h x No. of lines) of bony fish, obtained by the South Pacific Comission deep sea fisheries development project in different places around the South Pacific area**

Place	Average Catch	Source
New Caledonia	7.1	Fusimalohi and Grandperrin 1979
Niue (1979)	7.0	Mead 1980a
Palau	3.0	Taumaia and Crossland 1980
Tanna	2.8	Fusimalohi 1979
West New Britain	4.3	Fusimalohi and Crossland 1980
Yap Island	4.6	Mead and Crossland 1980
Fiji	9.2	Mead 1980b

in average weights, data from the three areas have been pooled.

The calculated value of the ratio variance/mean value is significantly higher than one (χ^2-test, $P<0.001$, d.f. = 166) and hence the catch rates are clumped in their distribution, with one group of low catch rates and a second with high. However, the test for differences in catch rates for different times of the day, and differences in catch rates at different depths shows that no differences could be found (ANOVA, $P<0.005$, d.f. = 22 and 8 respectively) and hence fishing at different depths or at different times of the day is not the cause of this clumping of catch rates.

Rather we hold the view that the uneven distribution of catch rates was caused by a combination of bait effectiveness and whether or not fishing was undertaken in a good place. By bait effectiveness we then mean, as mentioned above, that certain bait seems to give higher catch rates. From our experience it is also apparent, even if we have not been able to show it statistically due to the sampling programme, that certain places within an area yielded high catch rates, whilst others, irrespective of depths and time of day, did not.

Depth association among the 15 most common species

The results of the two cluster analyses are illustrated in *Figure 2*. Two different independent clustering methods are used to assess the stability of the groupings. Since both methods produce similar results, this suggests that they reflect the true association between the species.

From a practical point of view, a knowledge of species associations is of interest since it gives information on species expected to be caught together. This could in turn be useful in the planning, and the assessment, of a fishery. *Figure 2* indicates for instance that *Etelis coruscans, Epinephelus compressus, E. magniscuttis, E. morrhua* and *Gnathodentex mossambicus* will be caught together. Similarly, other associations can be discerned by examining *Figure 2*, and higher similarity values can be interpreted as higher probabilities of being encountered together.

Species composition, mean weights and depth

The depth distribution for the 15 most commonly encountered species are depicted in *Figure 3*.

The average weight of fish, irrespective of species, (*Table 4*) is significantly higher at certain depths (ANOVA, $P<0.001$, d.f. = 9) with a general trend for fish weight to increase with depth. The average weight at 200-210 m is significantly higher than at depths 140-150 m and the average weight at 220-270 m is higher than the average weights at 80-110 and

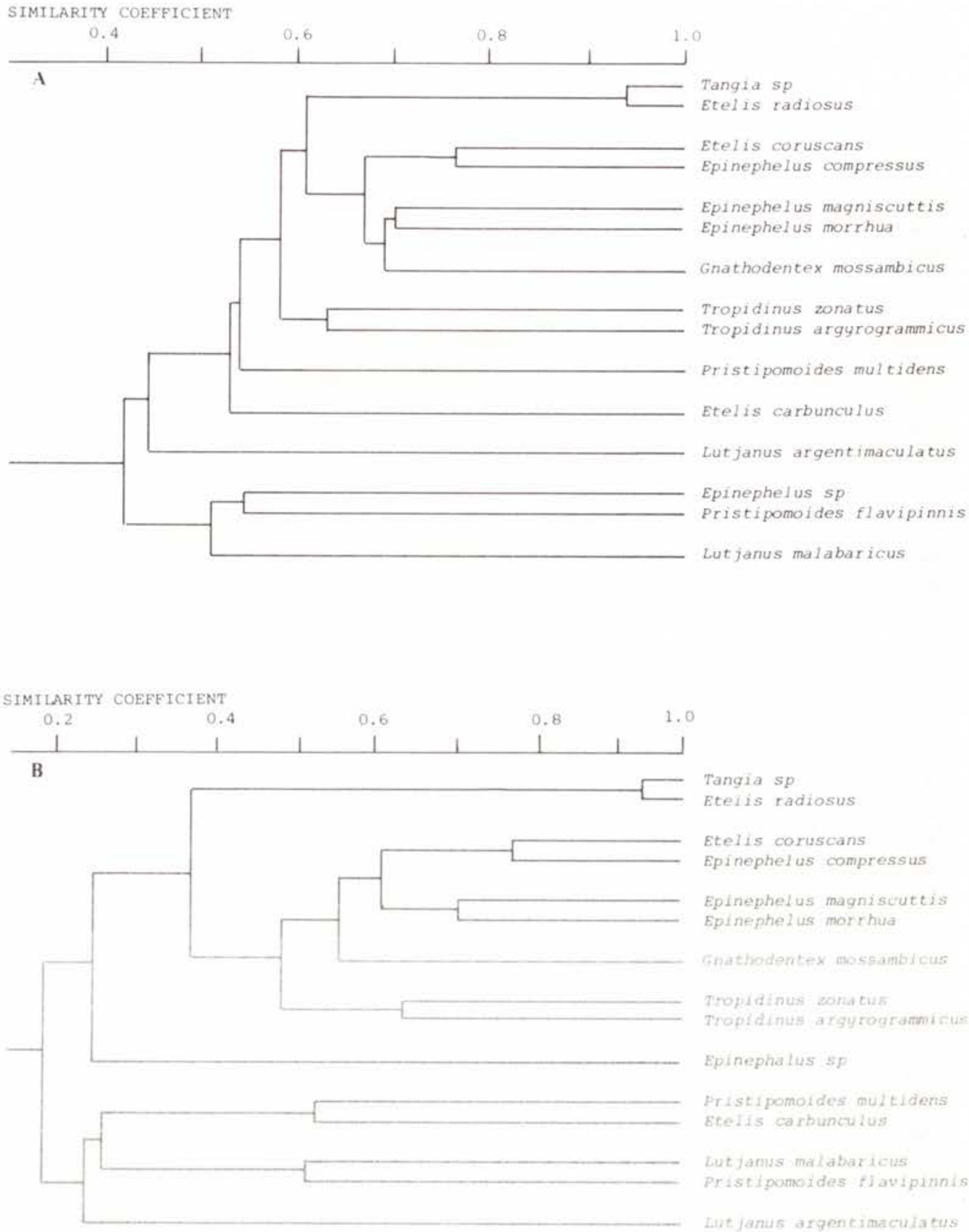

Figure 2.—**Cluster analysis of the depth associations between the 15 most common species. Based on a combination of the similarity coefficients proposed by Jaccard (1908) and Bray-Curtis (in Southwood, 1978). 2A. Single linkage clustering 2B. Unweighted pair-group method using arithmetic averages (UPGMA)**

Table 4. — **Mean weight of fish for different depth intervals**

Depth (m)	Mean weight (kg)	95% confidence interval	Sample size
80 – 90	1.6	1.1	8
100 – 110	2.2	1.0	15
120 – 130	3.3	1.5	15
140 – 150	1.3	0.9	12
160 – 170	2.3	0.5	21
180 – 190	3.1	1.1	40
200 – 210	4.3	1.3	47
220 – 230	4.9	0.7	20
240 – 250	5.8	2.9	51
260 – 270	4.8	1.2	56

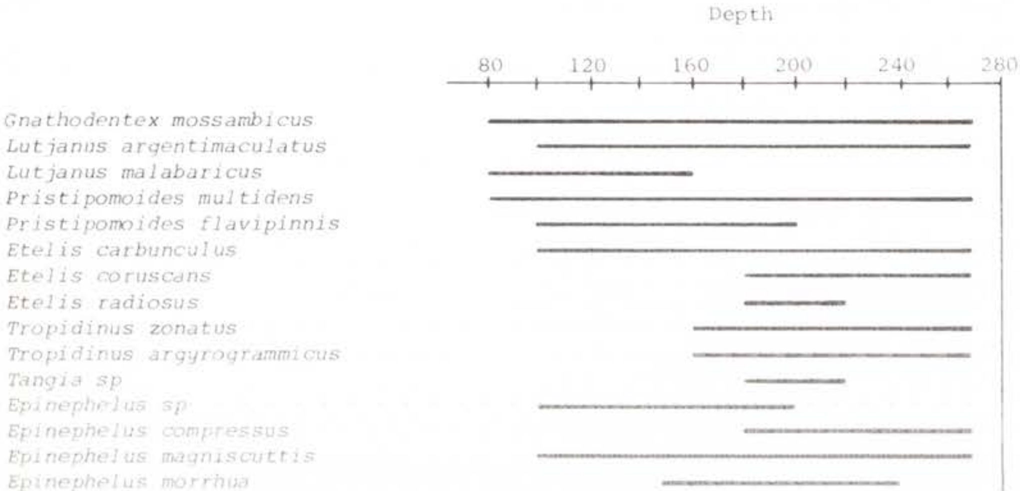

Figure 3. — **Depth distribution of the 15 most common species**

140-190 m. The depth range is divided into 20 m intervals, because even though the echosounder will give a precise reading, it is not possible to know exactly where the hooks are.

Since there is no significant variation in catch rate with depth, fishing at greater depths yields bigger but fewer fish. Unless certain species, or large fish are sought, it could therefore be more beneficial to fish in shallower water.

CONCLUSIONS

Based on the limited data from 41-65 hours of fishing in each locality, no significant difference in average catch rate between the three areas, Port Moresby, Milne Bay and Manus, could be found. The mean catch rate is 3.7 ±0.85 (±95% confidence interval).

The available data do not indicate any differences in catch rates between different times of the day, or between different depths. The distribution of the catch rates is however contagious which indicates that there are factors influencing the catch rate.

There is a significant difference in average weight at different depths, so that the average weight is higher at 200-210 m than at 140-150 m, and the average weight is higher at 220-270 m than at 80-110 and 140-190 m.

Certain of the 15 most common species are more likely to be encountered together. The most likely combinations are: *Tangia* sp. and *Etelis radiosus; Etelis coruscans* and *Epinephelus compressus; Epinephelus magniscuttis* and *E. morrhua* (similarity of 0.7, using a combination of the Jaccard and Bray-Curtis coefficients, chosen as an arbitrary limit for grouping).

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MUSCIDAE (DIPTERA) ASSOCIATED WITH CATTLE IN PAPUA NEW GUINEA

K.R. Norris* and I.L. Owen†

ABSTRACT

Flies (Muscidae; Diptera) were netted from above the backs of groups of cattle in Papua New Guinea, chiefly from the Eastern Highlands. The most frequently taken species was Musca conducens, *followed by* Morellia hortensia. *Also occurring in the samples were* Musca inferior, M. domestica, M. vetustissima, M. ventrosa, Stomoxys calcitrans *and* Haematobia irritans exigua.

The importance of these flies in relation to cattle, and the significance of their possible further dispersal from country to country are discussed.

INTRODUCTION

Undoubtedly the most serious dipterous pest of cattle in Papua New Guinea is the screw-worm fly, *Chrysomya bezziana* (Calliphoridae) (e.g., Norris and Murray 1964), but a number of muscoid flies of lesser importance also occur on cattle, worrying and injuring them to varying degrees, and in some cases transmitting diseases. Some Papua New Guinea flies of this type were discussed by Norris and Ferrar (1974). Other notes were given by Pont (1973) and Ferrar (1974). The survey reported in the present paper extends the above information on cattle-frequenting muscid flies in Papua New Guinea.

METHODS

Insects associating with cattle were monitored at irregular intervals in Papua New Guinea between 1976 and 1980 in the course of a continuous survey to check on the distribution and spread of the buffalo fly, *Haematobia irritans exigua* (de Meijere), from the lowlands to the central highlands of the country. In the Eastern Highlands Province, where most of the samples were taken, the monitoring was carried out between the Kassam Pass and the Daulo Pass within the Goroka, Henganofi and Kainantu districts, an area of about 6,200 sq. km (see inset, *Figure 1*). Sampling was confined largely to the region that straddles the main highway through the province, at an altitude of 1500-1600 m. The time and frequency of sampling was dependent on the requirements of the buffalo fly control and eradication programme. The cattle sampled, a mixture of British breeds and Brahmans and their crossbreds, were those considered at risk of buffalo fly infestation through their proximity to roads over which cattle were transported. A few other areas were sampled as opportunity offered.

Samples were collected by sweeping an entomological net several times over the heads and backs of groups of cattle held in yards or a crush. The groups usually comprised a few animals only, but in some cases there were several hundred animals. All insects caught were preserved for later examination.

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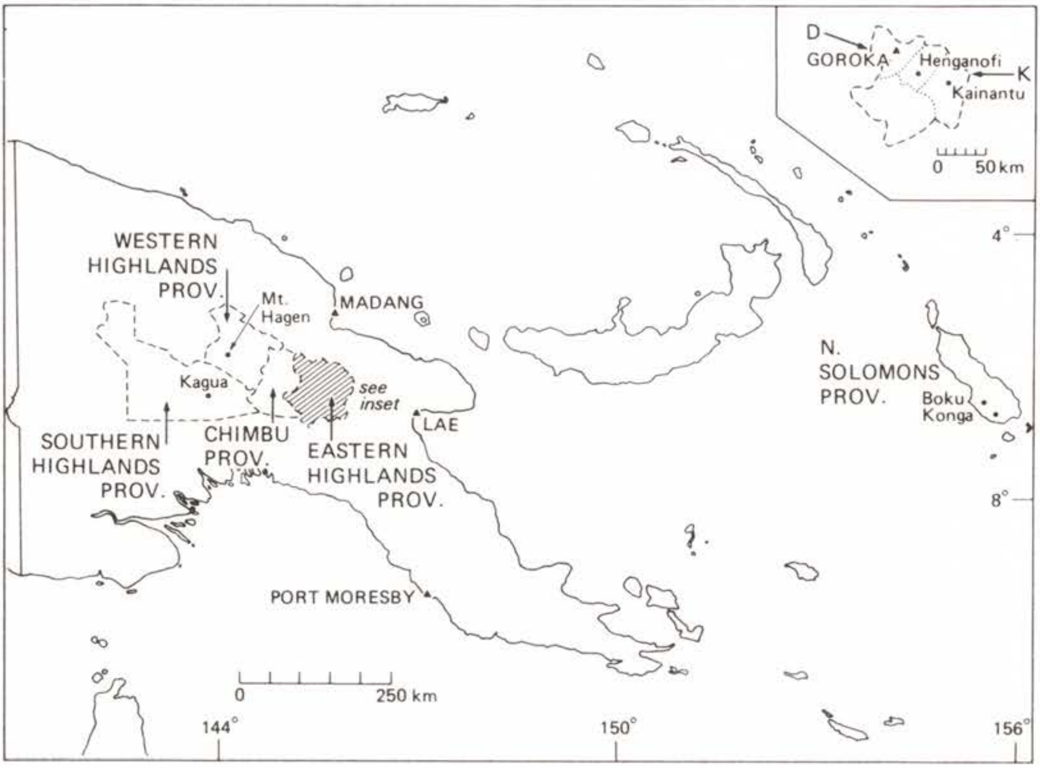

Figure 1. — **Map of Papua New Guinea showing the areas and places mentioned in the text. In inset, K = Kassam Pass and D = Daulo Pass.**

RESULTS

EASTERN HIGHLANDS PROVINCE

The area provides a fairly uniform environment for muscid flies. Temperatures range from an average daily maximum of about 25°C to an average daily minimum of about 13°C, with only small variations throughout the year. There is a distinct 'dry' period mid-year, but some precipitation in all months.

A total of 441 samples of flies were collected in 20 of the months of the five years involved. Notes on the species of flies secured are as follows:

Musca domestica Linnaeus, the cosmopolitan housefly. This fly is not strongly attracted to cattle, but it is almost always common around cattle yards. The few specimens taken occurred in 11 samples, and on 6 of the monthly sampling occasions.

Musca vetustissima Walker, known in Australia as the bushfly. This insect sometimes causes serious worry to cattle in the drier regions of Australia, but it is generally scarce in Papua New Guinea. The few specimens caught occurred in 35 of the samples, and in 6 of the months sampled.

Musca ventrosa Wiedemann. Like *M. vetustissima*, this species shows a moderately strong attraction to cattle. It was present in small numbers in 49 samples, and in 9 of the months.

Musca conducens Walker. There were

more specimens per sample, on the average, than of any other fly, and it was represented in 361 samples (82%), and in 17 of the months sampled.

Musca inferior Stein. This blood-sucking fly was present in 12 samples, and in 7 of the months. Its predilection for attacking the lower parts of cattle, combined with its habit of clinging tight, deeply ensconced in the hair, would make it a poor candidate for capture by sweeping above cattle with a net.

Morellia hortensia (Wiedemann). An abundant fly, which was present in 209 of the samples (47%), and in 19 of the months sampled.

Stomoxys calcitrans (Linnaeus), the blood-sucking stable fly, was present in small numbers in 12 samples, and in 7 of the months sampled. Like *Musca inferior*, its tendency to feed principally on the legs and belly of cattle would make it less likely than most of the other species to be caught by the method used.

Haematobia irritans exigua, the buffalo fly, was present in 19 samples, in 8 of the months, and in all years. The habits of this fly would make it highly likely to be taken by the sampling method used, but its high specificity to cattle make it much more susceptible to insecticide deposits on the cattle than the other, less specific flies. Thus its absence from many samples could well have been due to the operation of the control and eradication programme.

Other species. A number of species of Diptera and a few other insects in the samples were obviously in no way associated with the cattle. However, several species of Muscidae taken are known to breed in cattle dung, though not to infest cattle, other than as casual resting places. They included *Hebecnema uniseta* Hennig, *Gymnodia ruficornis* Malloch, *Orthellia timorensis* Robineau-Desvoidy and *O. australis* Macquart. The *Orthellia* species occurred in 11 samples, in 7 of which no other flies were present, a circumstance suggesting that the samples in question were swept from dung, not cattle.

OTHER AREAS

Three samples from Mount Hagen, Western Highlands Province, July 1976, each contained only *Musca conducens* and *M. inferior*.

One sample from Kagua, Southern Highlands Province, contained only *Musca conducens*.

A 'January' sample from Konga, south North Solomons Province, contained only *Musca inferior*, and a similarly labelled sample from Boku contained *Musca conducens* and *M. inferior*.

DISCUSSION

Musca domestica, M. vetustissima and *M. ventrosa* are only minor nuisances of cattle, and of little veterinary importance, especially in Papua New Guinea. Of somewhat greater economic consequence (e.g., Fadzil 1973) is the abundant and more closely cattle-oriented *Musca conducens*, which, although having only incipient adaptations for direct blood-feeding, is nevertheless more efficient than the above species in feeding on and enlarging sores and wounds, and is a proven vector of *Stephanofilaria* species (Nematoda) (Fadzil 1973). Though it is possibly now of general occurrence in Papua New Guinea, its dispersal to Australia and other South Pacific countries should be guarded against.

The probably recent introduction of *Musca inferior* to Papua New Guinea was pointed out by Norris and Ferrar (1974). This active blood-sucker causes great irritation to cattle, and, though it may be too late to prevent further inter-island dispersal in Papua New Guinea, Australian and other South Pacific authorities should make every effort to exclude it.

Although an efficient blood-feeder at wounds and a rasper of scabs, *Morellia hortensia* is considered a minor pest of cattle: a nuisance, but not known to be a vector of any disease. Ferrar (1974) pointed out that *M. hortensia* may well have been introduced to Papua New Guinea from Australia, where it had been resident long enough to have undergone slight anatomical differentiation from Asian stocks (Pont 1973). Prevention of further spread, if this is possible, is, of course, desirable.

Stomoxys calcitrans is virtually cosmopolitan, but restriction of interchange between countries is still desirable because of the possibility that blood-fed adults could spread animal diseases.

There are several notable absences among the flies from the samples: (a) *Musca cassara* Pont (Pont 1973), a species described from material collected from the Solomons, Sarawak, Sri Lanka and Prince of Wales Island, Torres Strait. It is also present in Cape York Peninsula, where Colless (1981) suggests it is a recent arrival. In view of this distribution it is highly probable that it also occurs in Papua New Guinea, though it may be restricted to lowland areas. (b) Another absentee from the samples was *Hydrotaea australis* Malloch, which is widespread in the warmer parts of Australia, and also occurs in Malaysia and Sri Lanka. This fly associates closely with cattle, licking sweat and blood and infesting eyes and body orifices. Its exclusion from Papua New Guinea and South Pacific countries is desirable. (c) Papua New Guinea also appears to lack the Australian *Musca terrae-reginae* Johnston and Bancroft, though it is known from several Torres Strait islands. Detection of this fly as a new invader would be difficult because of its similarity to *Musca domestica*, but if it does become established it is unlikely to become of significant veterinary importance. (d) *Hippobosca equina* Linnaeus. Though belonging to a different family of Diptera (Hippoboscidae) from the other flies (Muscidae) dealt with in this paper, it is worthwhile to record that this fly has not been encountered by either author in Papua New Guinea, nor was it reported by Anderson (1960), Egerton and Rothwell (1964) or Talbot (1969). This fly might not be easy to sample by the method used, but it is a very conspicuous insect, and unlikely to be overlooked. Its absence from Papua New Guinea is surprising, in view of the fact that it is widespread in Indonesia (e.g. Stekhoven 1926), and it was recorded from Vanuatu (New Hebrides) by Maa (1963) and also collected there recently by government officers.

ACKNOWLEDGEMENTS

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SHORT COMMUNICATION:

NOTE ON THE PREVALENCE AND DISTRIBUTION OF THE EYEWORM OF THE DOMESTIC FOWL IN PAPUA NEW GUINEA

J.D. Humphrey*

ABSTRACT

Oxyspirura mansoni, *the eyeworm of the domestic fowl, was recovered from the conjunctival sacs, nictitating membranes or nasolacrimal ducts of 55 out of 240 domestic fowls from throughout Papua New Guinea. Of the fowls examined, 42% of those reared under extensive systems of management were infected, whereas only 2% of those reared under semi-intensive systems and none of those reared intensively were infected. No worms were recovered from fowls originating from highland areas.*

INTRODUCTION

Oxyspirura mansoni, the eyeworm of the domestic fowl, has been recognised in Papua New Guinea for many years (Rothwell 1961) but the extent to which it occurs has not been defined. This communication describes the prevalence of eyeworm in fowls reared under different systems of management and the geographical distribution of the parasite throughout Papua New Guinea.

MATERIALS AND METHODS

The conjunctival sacs, nictitating membranes and nasolacrimal ducts of 240 domestic fowls were examined post-mortem for the presence of *O. mansoni*. Fowls were collected between September 1975 and May 1977. Systems of Management were classified as intensive (fowls maintained on wire mesh or deep litter), semi-intensive (fowls confined in outdoor pens on the ground) and extensive (fowls unconfined). Geographical locations were divided into highland (above 1200 m altitude) and lowland (below 1200 m altitude). The worms were identified by comparison with specimens identified by the British Museum and by reference to standard texts.

RESULTS

The prevalence of *O. mansoni* in fowls reared under each system of management and their geographical distribution are shown in *Table 1*. None of the fowls reared intensively, and only one of the fowls reared semi-intensively, was infected with eyeworm. Conversely, 54 (42%) of the fowls reared under extensive systems of management were infected. Of the 128 fowls reared extensively, 106 originated from the lowlands and 22 from the highlands. Of the lowland fowls, 51% were infected whereas none of the highland fowls harboured *O. mansoni*

DISCUSSION

The results of this survey show that eyeworm is common in fowls reared under extensive methods of management in the lowlands of Papua New Guinea.

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Table 1.—**Prevalence of *Oxyspirura mansoni* in 240 domestic fowls reared under different systems of management in Papua New Guinea and a comparison of infection rates in highland and lowland fowls**

	Extensive management			Semi-intensive management			Intensive management		
	High-land	Low-land	Total	High-land	Low-land	Total	High-land	Low-land	Total
No. of fowls examined	22	106	128	10	33	43	11	57	68
No. of fowls infected	0	54	54	0	1	1	0	0	0
Percent fowls infected	0	51	42	0	3	2	0	0	0

One known intermediate host of *O. mansoni* is the cockroach, *Pycnoscelus surinamensis* which has a preference for warm tropical climates (Mackerras 1970). This cockroach is common in the lowlands and islands of Papua New Guinea with only one record of its occurrence in the highlands above 1200 m altitude. The occurrence and distribution of eyeworm in the domestic fowl thus seems to reflect the availability of the intermediate host under the different systems of management practised and the geographical distribution of the intermediate host.

ACKNOWLEDGEMENTS

I wish to thank Mr. S. Prudhoe and staff of the British Museum for the identification of specimens of *O. mansoni*; Mr. E. Fenner, Chief Entomologist, Department of Primary Industry, for making available the cockroach collection of the Entomology Section; and all officers of the Department of Primary Industry throughout Papua New Guinea who assisted with the collection of fowls for examination.

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BOOK REVIEW

"POULTRY DISEASES"

Gordon, R.F. and Jordon, F.T.W. (Editors) (1982). Second edition, English Language Book Society and Balliere Tindall, London. 401 pp.

This book is the second edition of Dr. Gordon's "Poultry Diseases", originally published in 1977. The first edition met wide acclaim for its precise account of the clinical signs, diagnosis and control of major poultry diseases. This second edition will receive similar acclaim, and can be expected to be widely used by veterinarians and others who need information on poultry diseases but who are not specialist poultry pathologists.

The book is divided into eighteen chapters, of which four (on the poultry industry in the United Kingdom, specific-pathogen-free flocks, artificial insemination, and stress and welfare) are of little relevance to workers in Papua New Guinea. Four chapters on infectious diseases of the domestic fowl comprise nearly half of the book and are the text's greatest strength. In these chapters, each disease is discussed under the headings of causative agent, epidemiology, clinical signs, post-mortem lesions, diagnosis and control. The discussion of each disease is succinct and up to date, and each entry is accompanied by a list of selected references for further reading, mainly recent reviews in the more common journals in English.

Separate chapters are devoted to neoplasms, nutritional diseases, skeletal disorders and kidney diseases, reflecting the importance of these conditions in intensive poultry husbandry. Two useful chapters concentrate on the diseases of ducks and turkeys, and another, on "miscellaneous diseases", includes several conditions which otherwise defied the editors' attempts at classification by cause of each disease.

One chapter is devoted to methods of investigation of field problems, including collection of a detailed history and investigation of decreased productivity, hatchability, and feed quality. This chapter should be compulsory reading for all persons (veterinarians, livestock officers, managers etc.) involved in intensive poultry production in Papua New Guinea, where, fortunately, many of the most serious infectious diseases of poultry are not present and more complex multifactorial problems such as egg drops are frequently reported. It is to be hoped that this chapter will be further expanded in future editions to include more detail on the practical aspects of investigation of poultry problems and the selection and submission of specimens for laboratory examination.

A chapter is also devoted to methods of disinfection and hygiene in poultry farms and hatcheries, and quite adequately covers the principles involved. It does not, however, provide practical details of compounds, dilutions or methods of application. This is a serious omission which, for the sake of the many readers who would not have ready access to such data, ought to be corrected in future editions. Similarly, the chapter on the avian immune system provides a precise review of the development of the immune system of the domestic fowl, but does not, unfortunately, attempt to apply this by examining various recommendations for vaccination programmes.

Each chapter of the book is written by one or more specialists, and the editors have succeeded in ensuring a relatively uniform style and a minimum of repetition or overlap between contributors. The text is well written, but assumes a broad technical vocabulary which will limit its audience in this country to veterinarians and a few highly specialised poultry farm managers. The vocabulary used is far beyond that of most livestock or general extension officers, who will be better served by Departmental publications such as the "Poultry Handbook" (*Rural Development Series Handbook* No. 4, Department of Primary Industry, Port Moresby, 1976.)

For use in Papua New Guinea, this book provides an excellent review of diseases of intensive poultry, for those persons sufficiently specialised to have the vocabulary required to use the book. No information is given on more extensive husbandry and the problems seen in such systems as small-holder or village poultry production, for which far more information on practical nutrition and management is required and must be sought elsewhere. On specific diseases, more information could be provided on the control of parasitic diseases, renal forms of infectious bronchitis, mycotoxicosis, and fatty liver haemorrhagic syndrome, all of which are problems in this country but of far less importance in the United Kingdom where the book was written.

For veterinarians who are not specialists in poultry, this book provides a very useful introduction. Its value could however be greatly increased by the addition of further details of dose rates and methods of administration of the various drugs recommended for treatment and control of specific diseases. A chapter on vaccines, including information on vaccination programmes and techniques of administration, would also be a valuable addition.

The book is well produced, with very few printing errors, and illustrated by a large number of black and white photographs and line drawings, and two colour plates, each of six photographs. Most of these illustrations are informative, but some, especially the colour plates, are too small to demonstrate lesions to anyone who is not already familiar with the condition involved. This is, presumably, a constraint imposed by the cost of larger illustrations, but detracts from the value of the book for non-specialists.

Cost constraints presumably also led to the omission of several chapters which were included in the first edition. The loss of the chapter on diseases of pet birds, pigeons and birds of prey may be missed by veterinarians, and the reviewer would have preferred the expansion of the chapter on poultry meat inspection rather than its omission. But these are minor criticisms, and do not detract greatly from the value of this book for all who require a concise and up to date review of poultry diseases.

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BOOK REVIEW

"HANDBOOK ON COCONUT PALM"

Thampan, P.K. (1981). Oxford and IBH Publishing Co., New Delhi. 311 pp.

The preface of this book says that since the publication of the author's last book on coconuts five years ago, multidisciplinary research in coconuts has been substantial, especially in areas such as hybridization, management and post-harvest technology. Ostensibly, the volume is aimed at farmers and entrepreneurs, upon whom programmes of coconut development depend.

It is the feeling of the reviewer that the book is too technical and detailed to be of great value to the majority of farmers and entrepreneurs, but insufficiently comprehensive to be of real use to scientists already established in this field. The book will most probably be used by students studying plantation crops and research workers new to coconuts and who wish to gain a rapid insight into the crop. At 32 rupees per copy (about K4), it will serve that purpose well and cheaply. However, if the reviewer's copy is typical of the standard of production, it will not bear too much thumbing before disintegration sets in.

Useful though the book may be to newcomers to coconut studies, it is marred by important omissions, mistakes and evidence of sloppy editing.

Nowhere are polybags mentioned for use in the nursery, despite a good survey of nursery practice in the major coconut growing countries, where polybags are standard procedure. There can be no excuse for this in a book which is up to date in practically all other areas of coconut husbandry and technology.

The chapter on pests is rather short on details where possible agents of biological control are concerned, and often the name is the only detail given. *Brontispa* spp. and *Scapanes australis* Boisduval are not mentioned.

More rigorous editing might have spotted nonsensical statements such as (on p. 50), "For assisted pollination, the usual requirement of pollen is about 1 kg/ha" (over what period of time?), and (on p. 145, writing of yield in plantations) "Generally there are three main groups, viz., poor yielders, medium yielders and heavy yielders" (why not two or even ten groups?), and unsupported recommendations such as (p. 14) "In some areas husks are burnt and the ash applied to the palms. This practice, however, is not recommended."

This is the fourth general work on coconuts to have appeared in the last 25 years, and one wonders if more are really necessary. In a book of this nature, inevitably much has to be left out due to the vast nature of the subject, which limits its usefulness for the scientist. To cover adequately the current research on coconuts, perhaps several multi-author volumes on the subjects covered in each chapter of this book are necessary.

The bibliographies at the end of each chapter are comprehensive, and an adequate index is provided. In conclusion, many will find this book a useful introduction, especially at the price.

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INSTRUCTIONS FOR CONTRIBUTORS

Original research reports, review papers, notes, bibliographies and book reviews on Agriculture, Forestry or Fisheries in Melanesia and the South Pacific region will be considered for publication. Articles must not be previously or simultaneously published or submitted for publication elsewhere.

1. Presentation — Papers should be double-spaced throughout with wide margins on both sides. The first line of each paragraph should be indented three spaces. A4 size paper should be used. Send the top copy plus three carbon copies or photocopies to the editor of the journal. Captions to plates and figures must be typed on a separate sheet at the end of the text. Tables should also be typed on separate sheets. All pages of typing including references, appendices, captions and tables should be numbered consecutively at the top right.

2. Title — The title should be as brief as possible but should clearly indicate the content. It is not necessary to start the title with "A..." or "The..." or other non significant words.

3. Author's name — First names or initials can be used according to the preference of the author, however, authors are strongly advised to use the same style for their name in all publications to avoid giving the impression that they are two or more different authors. The address of each author at the place where the work was done is given in a footnote. If there has been a change of address, the present address is also given for the first author.

4. Abstract — An informative abstract suitable for use by abstracting publications and services should precede the introductory paragraph. Because it is not part of the paper an abstract should be intelligible on its own and should state the purpose, methodology, results and conclusions. It should be written as simply as possible to assist specialists in other countries for whom English is a foreign language. It should not include unfamiliar terms, acronyms, trade names, abbreviations or symbols without explanation. More than one paragraph may be used but the abstract should not exceed 2% of the total extent of the contribution; maximum 300 words.

5. Headings — In experimental papers the general order of headings is: Abstract, Introduction, Materials and Methods, Results, Discussion, Acknowledgements, References, Appendix. In descriptive, or other types of papers, refer to similar papers. No headings should be underlined.

6. Text — Papers should be concise. Extensive introductions referring to the work of earlier authors should be avoided. Lengthy discussions and detailed descriptions should be reduced by the use of tables and diagrams. The text should not repeat in detail what is apparent from a table or diagram.

Names of countries or organisations may be abbreviated to capitals without full stops but must be given in full at the first mention. Numbers under 10 should be spelt out unless qualifying a unit of measurement. If a number over 10 and a number under 10 appear in the same sentence, both are written as numerals. Do not begin a sentence with a numeral. Fractions should be given as decimals or spelt out. All decimal numbers less than unity should have a zero before the decimal marker, e.g. 0.25. All units should be in the S.I. system. All scientific names of animals and plants must be underlined to indicate that they should be set in italic type. The authority should be cited in full on the first occasion a scientific name is used. Where the same name is used repeatedly, the genus may be abbreviated to a capital letter after the first citation. For example, use *Homo sapiens* Linnaeus on the first occasion and *H. sapiens* thereafter.

Common or local names may be used but the scientific name should be quoted on the first occasion. An agricultural chemical must be referred to by its generic or common name when it is first quoted.

7. Tables — Tables are much more time-consuming and thus costlier to set than ordinary text so thought should be given to the possibility of replacing tables with a graph. The presentation of the same data in tabular and graphic form is not permitted. Numerical results should be displayed as means with relevant standard errors rather than as detailed data. Standard errors should be given to one place of decimals more than the means to which they refer and the number of degrees of freedom should also be quoted. Tables should be complete in themselves so that they can be understood without reference to accompanying text. Each table should have a brief title.

8. Figures and photographs — Line drawings should be drawn in black waterproof ink on smooth tough paper. Labelling should be clear and preferably produced with stencils using black waterproof ink and should be legible when reduced. No alterations or additions to artwork can be made by the editors. Figures should be no larger than an A3 page and no smaller than final published size. Photographs should be glossy prints of good quality and must make a definite contribution to the value of the paper. Indicate the top of figures and photographs on the back. Also indicate clearly on the back: the plate number of each figure and photograph, the author's name, and the title of the paper. Do not write on the back of photographs: use an adhesive lable with the data previously written on it. Artwork should be of appropriate proportions for the final page dimensions.

9. Acknowledgements — The names, initials and place of work of those the author wishes to mention may be included. It is not necessary to mention everyone who has been marginally involved in the work.

10. References — These should be cited in the text by the author's name and date as follows:

"Moran and Brown (1956) showed" or "Various workers (Wilson 1978, 1979a; Miller and Smith 1956; Adams *et al*. 1960) found. . ." The term *et al*. should be used when there are more than two authors. The letters a,b,c, should be used to distinguish several papers by the same author in one year.

All references in the bibliography should be given in full and in alphabetical order. For a journal the reference should include surname and initials of all authors, (year), title of paper, full title of the journal, volume, (part) and full page numbers. For a book the reference should include author's surname and initials, (year), title of chapter and page numbers if appropriate, full title of book, publisher and city and total page number. Conference proceedings should include the year and place of the conference. The title of the journal or book is underlined to be printed in italics. Examples are:

BOWET, C.M. and SMITH, L.N. (1950). Measurement of phosphorus. In *Methods of Soil Analysis*. Ed. C.A. Lack. Department of Primary Industry, Port Moresby. 400 pp.

SANDERS, A.J. (1940). Plant responses to molybdenum. *Papua New Guinea Agricultural Journal*, 48 (4): 981-995.

TROEN, M.M. (1973). Genetic fine structure in *Drosophila. Department of Primary Industry Research Bulletin* No. 102, pp.196-197.

Internal reports, communications and memoranda are not valid references. The criteria for valid publications (in the scientific world) are that publications are distributed widely among those interested in the subject and are available to the international public in major libraries and from the publisher. This therefore excludes reports circulated only within a department and to a few outsiders and conference documents available only to those who attended the conference and the like.

Work that has not been accepted for publication (unpublished data) and personal communications are not included in the list of references but may be referred to in the text. References cited in an appendix should be included in the list of references at the end of the paper.

Special care should be taken to see that every reference in the text is included in the list of references and vice versa, and that there is consistency in the spelling of authors' names and the citation of dates throughout the paper.

11. Review of papers — All copy will be submitted to suitable professional referees. Major changes will be referred to the author for consideration. Minor editorial changes will be made without consultation but will be presented to the author(s) at proof stage.

12. Offprints — Twenty five free offprints are given to the author. Where there are several authors, the senior author will be sent the offprints. Extra offprints may be ordered at the time the galley proofs are returned to the editor. Costs will be determined at the time of printing.

13. Recognised abbreviations in this journal are:

g — gram
kg — kilogram
t — tonne
l — litre
ml — millilitre
ha — hectare
mm — millimetre
cm — centimetre
m — metre
a.s.l. — above sea level
yr — year
wk — week
h — hour
min — minute
s — second
K — kina
n.a. — not applicable or not available
n.r. — not recorded
var. — variance
s.d. — standard deviation
s.e.m. — standard error of mean
s.e.d. — standard error of difference
d.f. — degrees of freedom

Levels of significance:

n.s. — not significant
* — $0.01 \leq p < 0.05$
** — $0.001 \leq p < 0.01$
*** — $p < 0.001$

Either kg/ha or $kg \cdot ha^{-1}$ is acceptable but larger combinations of units should be in the form $kg \cdot ha^{-1}$ to avoid possible mathematical ambiguity.