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 mist-blower 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

* Entomologist, Department of Primary Industry, Popondetta, Northern Province, Papua New Guinea.
Present Address: CSIRO Division of Tropical Crops and Pastures — Kimberley Research Station, Kununurra, W.A. 6743, Australia.

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

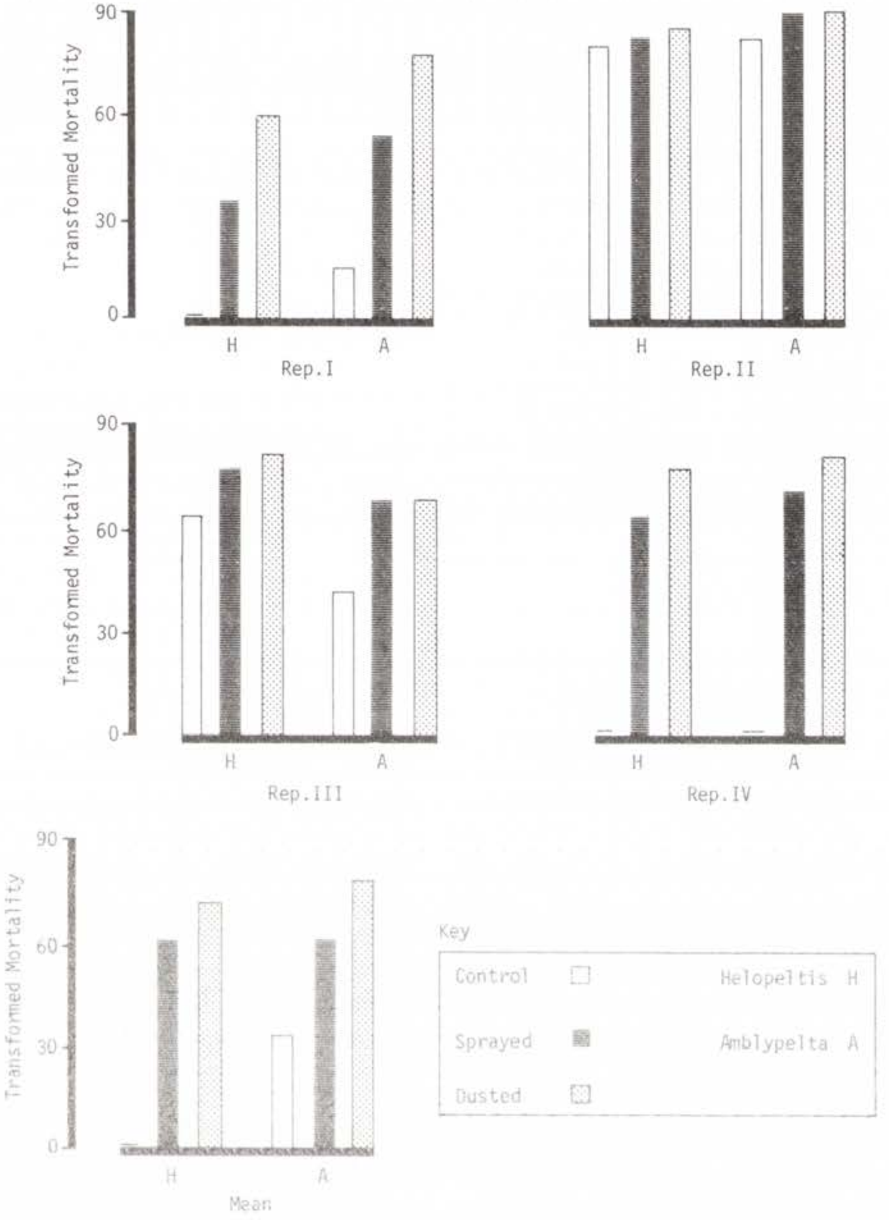

Figure 1.—Arcsin transformation of percent mortality of *H. clavifer* and *A. theobromae* in control plots or those sprayed or dusted with gamma-HCH

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)

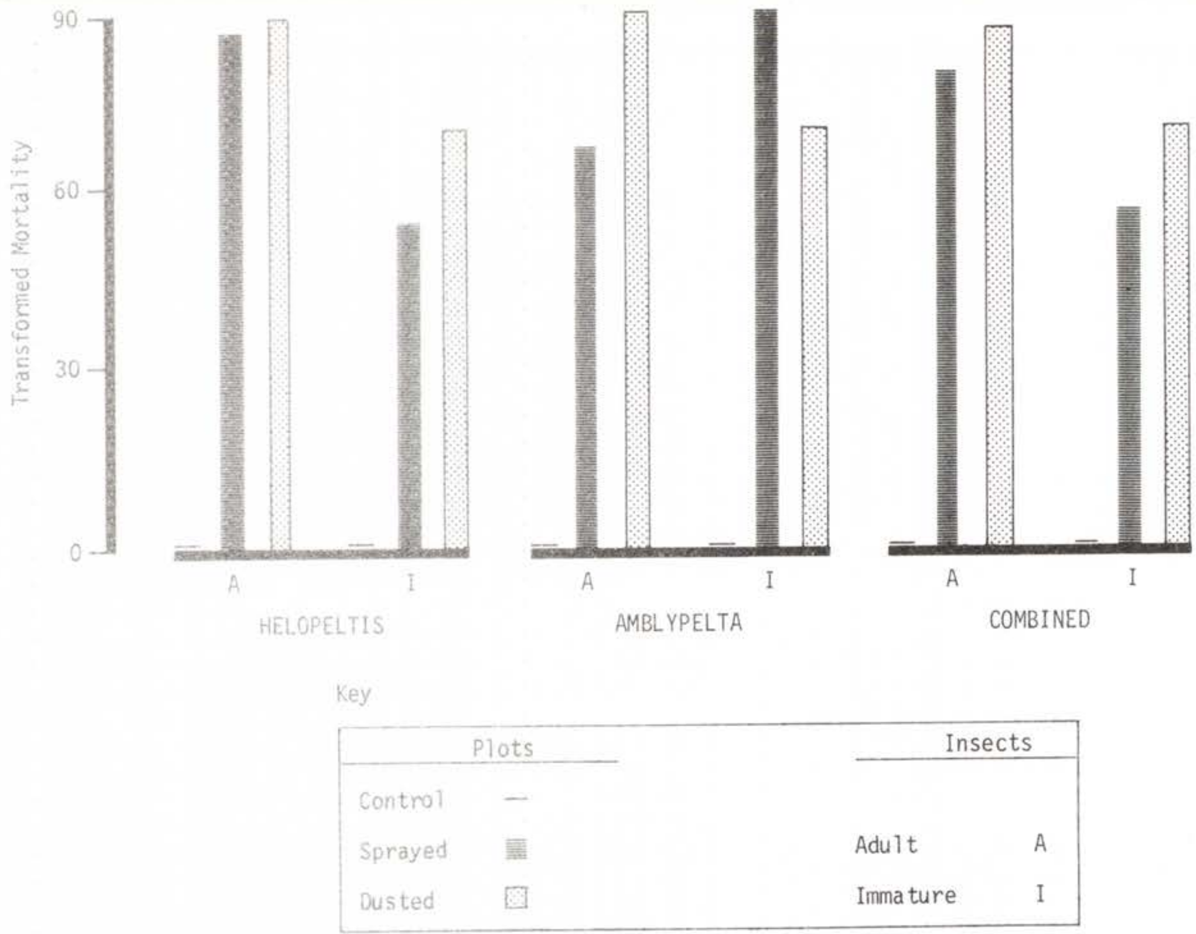

Figure 2. — **Arcsin transformation of percent mortality of adult and immature podsuckers in control plots and those sprayed or dusted with gamma-HCH. Results of replicate IV only**

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	—

$126\,kg \cdot ha^{-1} \cdot yr^{-1}$ 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 $K80\,ha^{-1} \cdot yr^{-1}$. 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 $ha^{-1} \cdot yr^{-1}$ 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] ($kg \cdot ha^{-1}$)	No. sprays per year	Spraying costs ($Kina \cdot ha^{-1} \cdot year^{-1}$) 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 $2\,ha \cdot day^{-1}$ @ daily labour rate of K2.40.
3. At rate of $154\,g\,a.i. \cdot ha^{-1}$ 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.

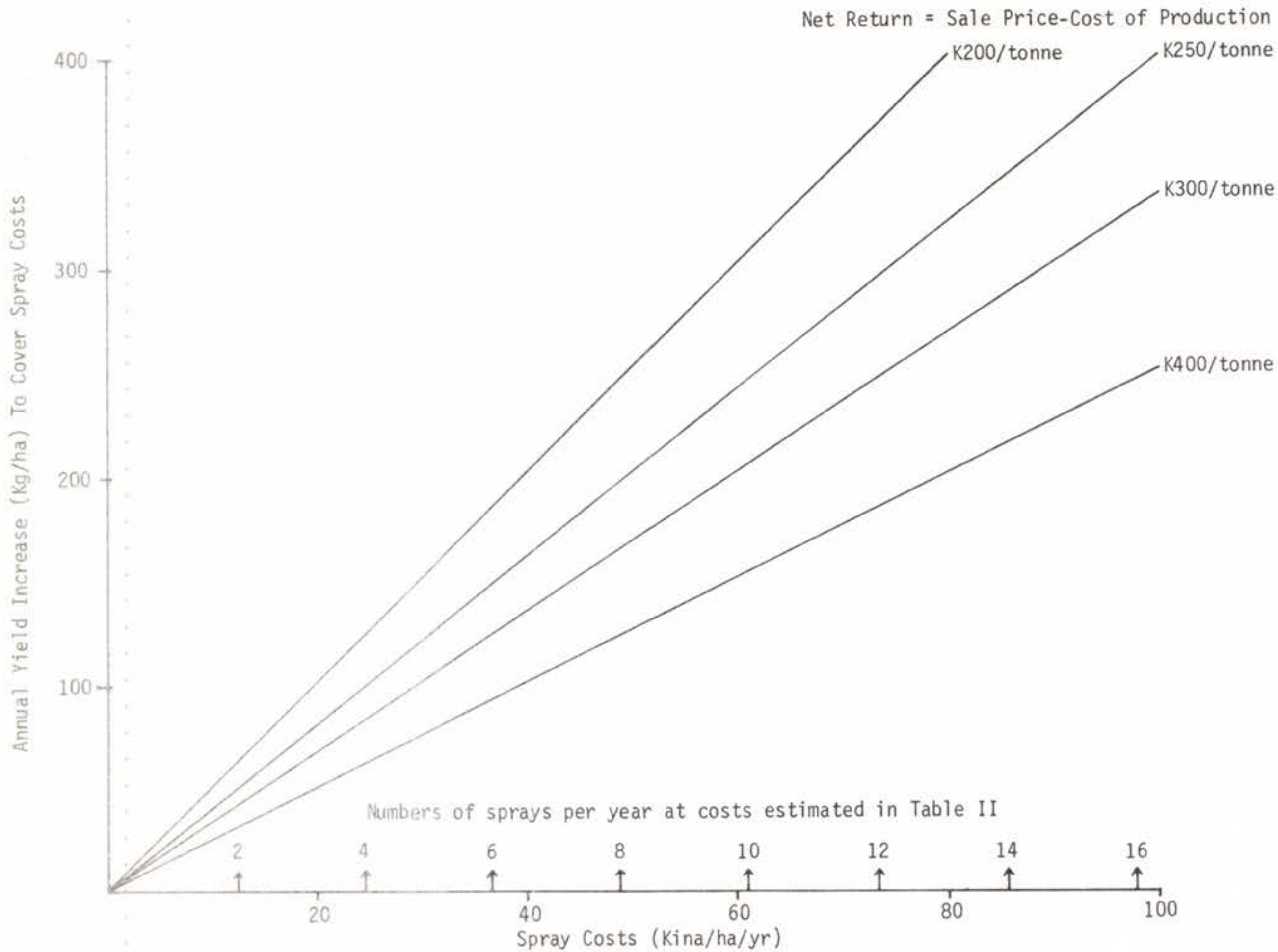

Figure 3. — **Yield increases required at various net returns per tonne of dry cocoa to cover spraying costs**

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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