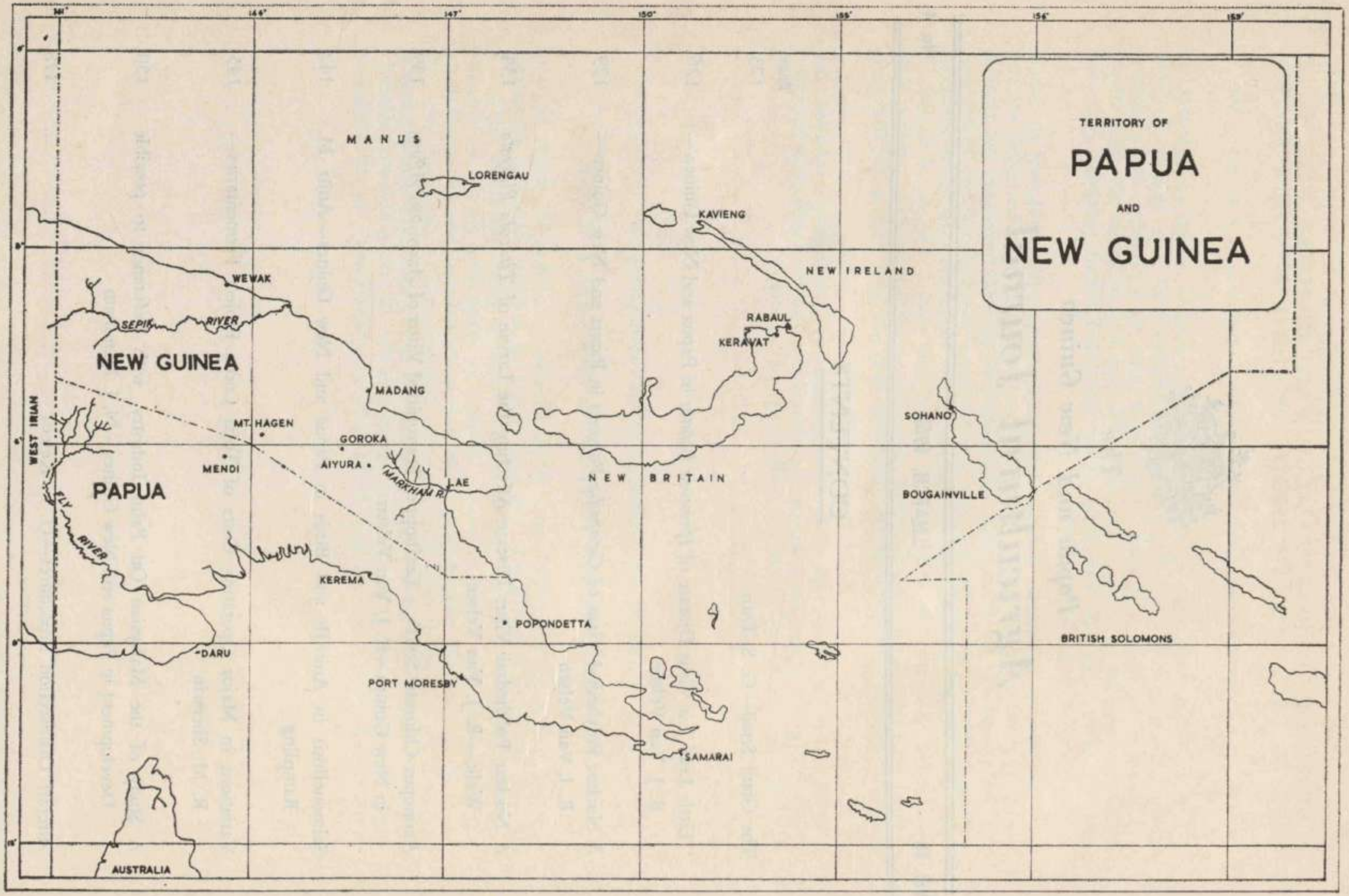
The

Papua and New Guinea

Agricultural Journal

Vol. 18 MARCH, 1967 No. 4

CONTENTS


TERRITORY OF
PAPUA
AND
NEW GUINEA
MANUS
LORENGAU
KAVIENG
NEW IRELAND
WEWAK
SEPIK RIVER
RABAUL
KERAVAT
NEW GUINEA
MADANG
SOHANO
WEST IRIAN
MT. HAGEN
GOROKA
AIYURA
MENDI
MARKHAM R.
LAE
NEW BRITAIN
BOUGAINVILLE
PAPUA
FLY RIVER
KEREMA
POPONDETTA
BRITISH SOLOMONS
DARU
PORT MORESBY
SAMARAI
AUSTRALIA
141°
144°
147°
150°
153°
156°
159°

The Giant Snail.

G. S. Dun.*

ABSTRACT.

A brief history is given of the introduction of the Giant Snail (Achatina fulica hammilei *Bowdich*) *to New Guinea and its subsequent spread and present distribution within the area. The appearance, life history, habits and diet of the pest are described, and its control by chemical, cultural and biological methods is discussed.*

INTRODUCTION.

THE Giant Snail (*Achatina fulica hammilei* Bowdich) is native to the east central coast of Africa and to several of the off-lying islands. During the past 150 years is has succeeded in extending its range, either accidentally or by deliberate introductions, to most tropical and sub-tropical areas as far east as Hawaii.

Its appearance in the Territory dates from the days of the Japanese Occupation and it seems likely that its introduction was accidental as there is no evidence that it was used to any extent by the Japanese as a source of food. After the War, the snail was soundly established in the vicinity of Rabaul and Kavieng in the Bismarks, and at Hansa Bay on the mainland of New Guinea. From the first two places considerable spread has occurred ; in New Britain, gradually, and in several instances, discontinuously, along the north and east coasts of the Gazelle Peninsula and in New Ireland almost along the full length of the east coast road. On the mainland, the infested area has been largely contained in the general vicinity of the original site where it became established apart from its introduction to Manam Island which occurred when the island was resettled after the eruption of Manam volcano.

As far as is known the presence of the snail in western New Guinea is confined to two centres—Manokwari, its original point of establishment, and Sukarnapura, to which place it is thought to have been introduced accidentally. While the discontinuous spread of the snail in the Australian Territory since the War has been remarkably slight, the possibility of its further spread is continually present and the necessity of checking its spread from western New Guinea and keeping it within its present confines in our own Territory are self-evident. Accordingly, the following brief description of the Giant Snail, its habits and general methods for its control may help to achieve these aims.

Description.

When fully grown, the shell of the Giant Snail consists of from seven to nine whorls with a moderately swollen body whorl and a sharply conical spire which is distinctly narrowed but scarcely drawn out at the apex. When young (i.e., up to about two months old) the shell is almost spherical. It is then very fragile and almost completely transparent, its greyish appearance being due to the body colour of the snail. After this stage, the snail's shell becomes calcified to varying degrees and opaque, the first-formed whorls becoming tan or whitish-grey in colour and the subsequent and body whorls tan with very dark tan or almost blackish transverse streaks. The degree of colouration is, however, very variable and the shell may be either predominantly tan, dark brown or almost black.

In exceptional cases, the shells may attain a length of 150 to 200 mm., but the ones normally encountered range from 50 to 100 mm.

Life-History.

The Giant Snail is oviparous and hermaphroditic. Thus, mutual fertilization is the rule although self-fertilization has been noted to occur in Java.

The eggs are almost globular in shape being about 4.5 by 5.5 mm. in size. They are white or bright yellow when laid and are covered with a clear mucus which gives them a glistening appearance. This mucus dries within a short time leaving them dull and opaque in appearance. The eggs are deposited, sometimes in twos or threes, but usually as a complete setting whose numbers range from as few as 50 to over 200. Probably an average egg batch would be in the vicinity of 120 to 150. They are laid within 8 to 20 days after mating has occurred. Their incubation period ranges from 8 to 14 days and, on hatching, the young remain at the site where

* Formerly, Principal Entomologist, Lowlands Agricultural Experiment Station, Keravat, New Britain.

they emerge for several days, during which time they feed on the cast shells and indulge in a certain amount of cannibalism. For the first month or so, the young snails move around only slightly and do not move far from shelter. As they approach sexual maturity their area of search widens considerably and it is not unusual for a recently matured snail to move 50 ft. or more in the course of a night's foraging.

Under local conditions sexual maturity may be reached at the age of three to four months. However, it is likely the normal period is somewhat longer—six to eight months. They are then from 1½ to 2 in. in length. It appears likely that full sexual maturity is attained by the end of the second year and thereafter their fecundity declines. The total production of eggs probably seldom exceeds 1,000 altogether. After the snail has reached a length of some 4 in. it virtually ceases to lay eggs and, indeed, does very little feeding.

Usually two batches of eggs are laid each year but the number of eggs and the number of layings is very dependent on seasonal conditions.

Habits.

The snail is active mainly during the night, coming out to feed at dusk and retiring to a sheltered spot before the sun is fully up. However, during dull, overcast days, some snails will remain active during the daylight hours. Weather conditions have the effect of making the snail a seasonal animal. During the dry season they seek out a sheltered spot where they may remain for weeks, or even months, on end protected by an opaque, white operculum which they secrete across the mouth of the shell. Intermittent activity may occur during the dry season following falls of rain. However, their main seasonal activity begins with the onset of the rains. Shortly after activity has been resumed, egg-laying will commence and the young snails will make their appearance in immense numbers a few weeks later. The second annual oviposition follows after an interval of two to three months.

The sites used for daytime sheltering and aestivation include crevices, stones, tree roots, rotting logs, banana clumps, leaf litter, etc. : in fact, any place that will provide adequate protection from light and desiccation. In primary rain forest this need is not so urgent and the snails will frequently rest on the bare ground or the litter. During the rainy season they will often ascend quite considerable distances up tree trunks or the walls of houses, embankments, etc., to rest during the day. The sites chosen for egg-laying are similar to the ground resting spots, although if the cover is too sparse the snail may turn some loose soil and deposit the eggs an inch or so below the surface. Under heavy cover crop or in dense forest the eggs are often simply laid on the surface. Fertility of the eggs is usually very high but any sudden dry spell will have an adverse effect on the rate of emergence.

Feeding Habits.

The range of feeding materials acceptable to the snail is extremely wide. Perhaps the largest proportion of the normal diet is derived from scavenging rotting leaves and branches, fallen fruit, excrement, garbage and other miscellaneous items too numerous to mention. It will, however, attack living plant material readily, particularly when it is succulent or in the seedling stage. For these reasons, the snail is usually most frequently found in settled areas and is the cause of considerable and consistent damage to horticultural and vegetable crops. In the seedling stage it can cause extensive damage to such crops as cacao, rubber, etc., often sufficiently to necessitate a considerable amount of replanting if the seedlings are not adequately protected. The snail is even capable of eliminating certain favoured plants from the community when its numbers are very high. As an instance of this, *Pipturus argenteus*, a native host plant of the Cacao Weevil, has been virtually eradicated in many parts of the Gazelle Peninsula.

Control.

1. *Chemical.*

Like all the Gastropods, the snail requires considerable quantities of lime for the development of its shell. The abundance, or lack of it, results in the formation of either very stout, strong shells or thin, fragile ones. Whether the lime is abundant naturally or not, the snails will readily accept any available sources of supply that are put in their way. Accordingly, the addition of calcium arsenate to a diluent such as bran makes an effective bait. The arsenate can also be made up as a 1 per cent. spray and applied to white-washed walls, cement piles or similar objects from which snails can obtain a lime supply. It can also be made up into pellets using a weak cement mix.

In contrast to the above lethal effect of calcium arsenate which takes several days to have effect, the specific attractant, metaldehyde, is widely used. The effect on the snail of the ingestion of a minute quantity of this is almost immediate. It is possible to make it up as a dispersion for use as a spray which is very useful for short term control. However, the mixing procedure is rather difficult. Normally, the substance is used as a bait in much the same way as calcium arsenate except that, being an attractant, it is possible to use an inert carrier such as sawdust instead of bran. It can also be made up as cement briquettes which are scattered at strategic points around the infested area. These have the advantage of being long-lived and are not affected by the weather. Small pellets of the prepared bait can be simply made by incorporating the metaldehyde in a weak cement mix which is allowed to set in a layer about ½ in. thick. This is then shattered into small pieces and distributed as required. Protection of valuable horticultural seedlings such as ornamentals, cacao or rubber can be provided during their vulnerable period by ringing them with a strip of cardboard which has been dipped in a dispersion of metaldehyde in "Flintkote", the dispersion of the former material being aided by the addition of a detergent (Bridgland and Byrne 1956).

2. *Cultural.*

Cultural methods of control have a definite use if applied systematically. Especially susceptible plants should be positioned so that they are out of the normal run of the snail's path. The clearing of dense bush near gardens or field plantings is valuable, particularly in areas where the population is dense. In home gardens, the maintenance of wide stretches of lawn will materially help to keep the amount of damage at a minimum.

3. *Biological.*

Locally occurring predators of the snail are not common and their action can only be described as incidental. Centipedes will occasionally attack small snails, and toads have been observed to take very small snails when they have been in a position to observe the snail withdraw quickly into its shell. Here the feeding reaction would be to the movement and not to the snail itself.

Pigs and ducks can exert a considerable degree of localized control in the vicinity of villages and plantations. However, for these animals to make full use of their not inconsiderable capacity for the snail as a food, the latter have to be collected by hand in the first instance thus making them disposal, rather than controlling agents. The ubiquitous Fire Ant (*Solenopsis geminata rufa*) accounts for a considerable number of snails by stinging them into immobility and then feeding on them. However, such victims are almost invariably those that have been late in returing to their daytime shelters and have been partially immobilized by the heat of the sun ; most of these would probably have succumbed to desiccation later in the day even without the help of the ants.

There are several known specific predators of snails in various parts of the tropics ; the principal ones are predatory snails or beetles. Several of these have already been introduced to the Territory but only one has managed to establish itself satisfactorily. This is *Gonaxis quadrilateralis* which was introduced some years ago and is now established in several localities in the Gazelle Peninsula. This snail has been distributed to a number of other localities in the Territory.

Three other predators, a snail (*Euglandina rosea*) from Florida, a drilid beetle (*Selasius* sp.) from Nigeria, and a carabid (*Tefflus planifrons*) have also been introduced.

Euglandina seems not to have established itself. Populations of *Selasius* and *Tefflus* were released in the field, but it is far too early to tell whether they will eventually become established, as both species have very long life cycles.

(Received February, 1966.)

REFERENCE.

BRIDGLAND, L. A. AND BYRNE, P. N. (1956). Control of the Giant Snail (*Achatina fulica*) by Baiting. *Papua and New Guinea agric. J.*, 11 : 67-68.

" Little Leaf ", a Virus Disease of Ipomoea Batatas in Papua and New Guinea.

R. J. VAN VELSEN.*

ABSTRACT.

A virus disease producing little leaves and vein-clearing symptoms of sweet potato (Ipomoea batatas *L.*) *has been recorded in the Keravat area of New Britain, and Dogura, Goodenough Bay in Eastern Papua. The condition is readily transmitted by stem grafting to* I. batatas, I. setosa *ker.*, I. purpurea *Lam.*, I. purpurea *variety " Crimson Rambler "*, *and* I. nibro-coenilia *Roth.*, *and by core grafting to* I. batatas. *Attempts to transmit the virus mechanically, by white flies* (Bemesia tabaci), Myzus persicae (*Sulzer*), *and* Planococcus citri (*Rossi*) *were unsuccessful. However, it was found to be transmitted by* Halticus tibialis, *and by vegetative propagation, and also to be soil borne. Diseased plants show a marked reduction in yield when infected in the early stages of growth, and rogueing of infected plants in the field has little effect as a control measure.*

INTRODUCTION.

VIRUS diseases of sweet potato (*Ipomoea batatas*) have been reported from many parts of the world. Magee (1954) recorded sweet potato in the Territory of Papua and New Guinea to be free of virus diseases, mentioning that conditions termed ' rosette ' or leaf ' curl ' to be probably caused by insect attack. His visit however, was only cursory. During the Japanese occupation of the Gazelle Peninsula from 1941 to 1945, many food crop plants were introduced and it is suspected that sweet potato plants may have been introduced. In 1961, Rast reported a complex virus disease of sweet potato in New Guinea (West Irian) suggesting the feathery mottle virus complex as the agent.

Summers (1951) recorded a dwarfing (' Ishuku-Byo ') of sweet potato in the Ryuku Islands which resulted in no edible tubers being produced on diseased vines. The visible symptoms consisted of excess proliferation of the young shoots from the leaf axils and a dwarfing of subsequent growth. The latex content of the diseased plants and roots was markedly reduced.

In Ghana, Clerk (1960) reported an investigation on a vein-clearing virus of sweet potato, which he confirmed to be due to a virus disease. The virus was transmitted by grafting, tuber core-grafting and by *Bemesia tabaci*. There are other virus diseases of sweet potato reported from Israel (Loebenstein and Harpaz 1960), U.S.A. (Webb and Larson 1954), and elsewhere.

In 1956, sweet potato plants showing little leaves and vein-clearing symptoms were observed in the variety trials at the Lowlands Agricultural Experiment Station, Keravat, New Britain. Attempts to eradicate the disease by rogueing were unsuccessful. Investigations were commenced in 1958 to determine the cause and possible control measures, for the condition.

INVESTIGATIONS.

Field Symptoms.

Diseased sweet potato (*I. batatas*) plants are conspicuous due to the erect habit of the tips of vines which are usually reduced in length compared with healthy plants. The leaves are a quarter to an eighth the size of healthy leaves and the veins are a yellowish green (vein-clearing) compared with the darker green interveinal tissue. The internodes between leaves on the diseased vine rarely exceed 1 in. compared with 2 to 6 in. on normal vines. The latex content of the vines and roots is greatly reduced.

Plants affected when nearing maturity exhibit vein-clearing symptoms with a slight reduction in leaf area. Plants infected in the early growing stages yield poorly, giving no edible tubers. In a yield trial of 16 diseased and 16 healthy plants, yields per plant at maturity were 28 and 618 grammes respectively.

Symptoms following inoculation.

Ipomoea setosa.

Following the establishment of stem grafts between infected *I. batatas* and healthy *I. setosa* plants, severe chlorotic spotting appears 28 to

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

40 days later. The spots are irregular in shape and a pale yellowish green. As the leaves mature, the chlorotic spots enlarge and coalesce giving the leaves a mottled appearance. The symptoms are systemic. The vigour of the plants is not reduced.

Ipomoea purpurea.

Pale, rather indistinct mosaic symptoms appear 30 to 60 days after the establishment of successful stem grafts with *I. batatas*. The plants are reduced in vigour with smaller leaves and reduced vine lengths. The symptoms are systemic.

Ipomoea purpurea variety " Crimson Rambler ".

Pronounced mosaic leaf symptoms appear 25 to 30 days following stem grafting, which are persistent. The plants are not reduced in vigour.

Ipomoea nibro-coenilia.

Pale, indistinct mosaic symptoms on the leaves appear 30 to 40 days after stem grafting, and are persistent and systemic. The leaf size and vine length are slightly reduced compared with healthy plants.

TRANSMISSION.

Mechanical.

Attempts made to mechanically transmit the virus to indicator plants of *Ipomoea batatas*, *I. setosa*, *I. purpurea*, *I. nibro-coenilia*, *Nicotiana tabacum*, *N. glutinosa*, *Datura stramonium*, *Phaseolus vulgaris*, *Capsicum anuum* and *Convolvulus* sp. using various buffers were unsuccessful.

Grafting.

Diseased tips of *Ipomoea batatas* were established in sterilized soil alongside healthy tips of *I. batatas*, *I. setosa*, *I. purpurea* and *I. nibro-coenilia* in insect-proof cages. The runner tips were carefully washed free of soil and when established regularly dusted with insecticide. When the plants were established, diseased and healthy vines were approached grafted. Twenty days later when the grafts had 'taken', the runners from the healthy plants were severed between the graft and the parent plant. Control cages were set up with the diseased and healthy plants growing intermingled. After 84 days, the results, as given in *Table* 1, were recorded. None of the control plants became infected.

Tuber core-grafting.

Cores, ½ in. in diameter and 1 in. long were cut from tubers collected from diseased *I. batatas* plants and inserted into healthy sweet potato tubers. The wounds were covered with grafting mastic and the treated tubers planted out in sterilized soil. After 12 weeks growth, the results were recorded. Of the 20 cores inserted into 20 separate tubers, 18 tubers germinated, and 14 exhibited " little leaf " and vein-clearing symptoms. None of the 20 control tubers became infected.

Insect.

Attempts to transmit the virus from infected *I. batatas* to *I. purpurea* variety " Crimson Rambler " with *Planococcus citri*, *Myzus persicae* and white flies (*Bemesia tabaci*) using various acquisition and test feeding times were unsuccessful.

With *Halticus tibialis* adults, infected *I. batatas* runner was planted in sterilized soil with healthy runners of *I. purpurea* variety " Crimson Rambler ". When the plants were established, the pots were caged and 20 adult *H. tibialis* were released, and maintained in the cages for eight days. At the end of this period, the cages were sprayed with 0.1 per cent. Dieldrin. Control pots were also set up. After 12 weeks the results were recorded. In two separate experiments each of 20 pots, the results were five and six infected plants respectively. None of the control plants became infected. Thus it is concluded that the virus can be transmitted by *H. tibialis*. During dry periods in the field, large populations of *H. tibialis* could be found feeding on sweet potato plants.

Soil.

Soil to a depth of 6 in. was collected from around field infected plants, sieved to remove large pieces of vegetable material and put into 12 in. pots. Healthy *I. batatas* runners from a single plant were planted in each pot. Control pots with sterilized soil were also set up in the greenhouse. The pots were placed in the greenhouse and sprayed regularly with 0.1 per cent. Dieldrin to kill any emerging insects from the soil. In the 20 pots of field soil, 16 plants exhibited little leaf and vein-clearing symptoms after 12 weeks. Runners in the sterilized soil remained disease-free.

The soil from the 16 infected pots was then sterilized and again planted with healthy runners from the control pots, and kept under observation for a further 12 weeks. None of these plants became infected. Since the " little leaf " and vein-clearing symptoms could not be removed by full fertilizer treatments, these experiments indicate that the virus is soil borne. No attempts have been made as yet to determine the vector in the soil.

CONCLUSION.

From the description of " Ishuki-Byo " of sweet potato in the Ryuku Islands by Summers (1951), the " little leaf " virus disease present at Keravat is possibly the same. Both diseases have a long incubation period in *Ipomoea batatas* with no edible tubers being produced. The field symptoms are also similar with respect to erectness of habit, leaf size reduction and the reduction of latex in runners and roots. At Keravat, attempts to eradicate the disease by rogueing were unsuccessful. Summers recorded no vein-clearing symptoms on sweet potato, and it is possible that the disease at Keravat is a virus complex consisting of " Ishuki-Byo " and a vein-clearing virus.

Loebenstein and Harpaz (1960) reported a vein clearing virus of sweet potato in Israel to be readily transmissible by stem and tuber core grafting, and by *Bemesia tabaci*, but not to be soil borne, nor transmitted by mechanical inoculation. Clerk (1960) reported a vein clearing disease of sweet potato in Ghana to be also transmitted by *Bemesia tabaci*. The feathery mottle virus described by Webb and Larson (1954) was reported to be transmitted by *Myzus persicae*. However, the " little leaf " and vein clearing virus at Keravat could not be transmitted by this aphid.

The field symptoms do not resemble those of internal cork disease of the U.S.A. (Hildebrandt 1956), and it is concluded that the " little leaf " disease of sweet potato at Keravat is similar to that reported by Summers.

(Received April, 1966.)

ACKNOWLEDGEMENTS.

The author gratefully acknowledges the indentification of the insects by Dr. J. J. H. Szent-Ivany and Commonwealth Entomological Institute and the supply of the seed of the *Ipomoea* sp. by the Instituut voor Plantenziektenkundig Onderzoek, Wageningen, Netherlands.

REFERENCES.

CLERK, G. C. (1960). A vein clearing of sweet potato in Ghana. *Plant Dis. Reptr.*, 44 : 931-933.

HILDEBRANDT, E. M. (1956). Sweet potato internal cork virosis indexed on Scarlet O'Hara morning glory. *Science*, 123 : 506-507.

LOEBENSTEIN, G. AND HARPAZ, L. (1960). Virus diseases of sweet potato in Israel. *Phytopathology*, 50 : 100-105.

MAGEE, C. M. (1954). Report on a survey of virus diseases of food crops in the Territory of Papua and New Guinea, with special reference to Plant Quarantine—Part II. *Papua and New agric. J.*, 9 : 17-26.

RAST, A. T. B. (1960). A complex virus disease of sweet potato in New Guinea. *Netherlands J. Plant path.*, 69 : 148-160.

SUMMERS, E. M. (1951). " Ishuki-Byo " (dwarf) of sweet potato in the Ryuku Islands. *Plant Dis. Reptr.*, 35 : 266-267.

WEBB, R. E. AND LARSON, R. H. (1954). Mechanical and aphid transmission of the feathery mottle virus of sweet potato. *Phytopathology*, 44 : 290-291.

***Table* 1.—Infection of *Ipomoea* spp. following approach graftings to " little leaf " infected *I. batatas* plants.**

Test Plant.	No. of Infections/ No. of grafts.
Ipomoea purpurea variety " Crimson Rambler "	12/20
I. purpurea	12/20
I. nibro-coenilia	14/20
I. setosa	14/20
I. batatas	36/40

A Nuclear Polyhedral Virus of Catopsilia Pomona *in Papua and New Guinea.*

R. J. VAN VELSEN.*

ABSTRACT.

A virus located at Popondetta in the Northern District of Papua affecting the larvae of Catopsilia pomona *is a new record and the virus belongs to the nuclear polyhedral group of insect viruses. The virus appears to be restricted to* C. pomona *and readily infects with resulting death all larval stages of* C. pomona. *The polyhedra range from* 1,000 *to* 2,000 *mμ in diameter with an average diameter of* 1,170 *mμ. A prepared suspension was still highly infectious after seven months when stored in suspension in the laboratory, but persistence in the field could not be maintained for a long period.*

INTRODUCTION.

IN the Territory of Papua and New Guinea many ornamental *Cassia* spp. which are grown in household gardens are periodically infested with larvae of *Catopsilia pomona* F. The larvae feed on the young emerging leaves and often continually destroy the leaf flushes of young trees, resulting in their death. At Keravat, in the New Britain District of New Guinea larvae of *C. pomona* were observed feeding on the leaves of *Cassia grandis* L., *C. fistula* L., *C. alata* L. and *C. moschata* L. In January, 1966, *Catopsilia pomona* larvae were found infected with a polyhedral virus at Popondetta, in the Northern District of Papua by Mr. T. Bourke. Investigations were carried out at Keravat to determine the effectiveness of the virus in reducing larval populations of *C. pomona.* The experimental data and the results of the investigations are described in this paper.

DESCRIPTION OF THE DISEASE.

The pigmentation of healthy larvae of *Catopsilia pomona* varies from a pale green to dark metallic blue on the dorsal surface, with a narrow white longitudinal stripe along the length of the body on both sides. The larvae of *C. pomona* infected with the nuclear polyhedral virus within 24 hours preceding death exude a dark brown fluid containing many polyhedral particles from the mouth and anal orifice. At death the body contents are a pale yellow to light brown fluid containing numerous polyhedra and the skin is readily ruptured. The skin is a yellowish-green in the case of the green coloured larvae and the dark blue larvae are usually pale yellow on the ventral surface.

In the field, infected larvae move to mature leaves and usually cease to feed within 24 hours preceding death. At death, the larvae appear flattened on the upper leaf surface surrounded

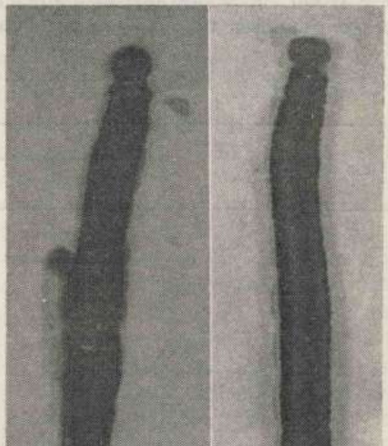


Plate I.—Photograph of the fourth instar larvae of *Catopsilia pomona.* The larva on the left is dead due to the nuclear polyhedrosis, with the skin ruptured and brown fluid oozing from the break. The larva at the right is healthy.

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

Table 1.—The susceptibility of seven larval species to the nuclear polyhedral virus of *Catopsilia pomona* at a concentration of 135,000 particles per ml.

Insect Species.	Number of Larvae Fed with Virus.	Number of Deaths	
		Bacteria.	Virus.
Catopsilia pomona	50	4	46
Acheae janata L.	50	3	0
Spodoptera litura F.	50	0	0
Orgyia postica Walker	50	0	0
Ectropis sabulosa Warr.	30	0	0
Hyposidra talaca Walker	30	4	0
Euproctis sp	30	3	0

by a pale yellow to light brown exudate (*Plate* I). In laboratory feeding trials no adults emerged from pupae formed from larvae which had ingested polyhedra. Four to six days after pupation, the pupal cases were found to contain a yellowish to light brown fluid containing masses of polyhedral particles.

The polyhedral particles were observed in the nuclei of the cells of fat bodies and the blood and were 1,000 and 2,000 mμ in diameter, with an average diameter of 1,170 mμ. From the observations of infected larval cells and differential staining, the polyhedral virus is of the nuclear group.

Table 2.—The effect of virus concentration of the nuclear polyhedral virus on six-day-old larvae of *Catopsilia pomona*.

Particles per ml.	Number of Deaths due to.	
	Virus.	Bacteria.
24×10^6	58	2
2×10^6	57	3
2.8×10^5	53	7
3.4×10^4	56	4
9×10^3	50	10
1,250	46	14
100	51	9
CONTROL	0	11

EXPERIMENTAL STUDIES.

Host range.

Seven different larval species from two different families were fed the *Catopsilia* nuclear polyhedral virus at a concentration of 135,000

Table 3.—Effect of the age of larvae of *Catopsilia pomona* on susceptibility to *Catopsilia* nuclear polyhedra virus.

Day of Count.	Age of Larvae in days.						
	1	3	5	7	9	11	13
0	0a	0a	0a	0a	0a	0a	0a 15p
1	0	0	0	0	0	0	0c 38p
2	0	0	0	0	0	18 12p*	0 6p
3	0	0	0	0	16	15 6p*	....
4	0	0	12	4	27	5	....
5	33 2b	12	19	24	16	3	....
6	9	38 2b	13	25	....	....	....
7	14	7	16	5	....	....	....
8	....	1	....	....	....	....	....
9	....	....	....	....	....	....	....

Undesignated numbers refer to the number of larval deaths due to virus infection.

a—Day on which 60 larvae were fed the virus suspension.

b—Deaths due to bacterial infection.

c—Pre-pupal larvae did not feed on the treated leaves.

p—Number of pupal cases.

*—Pupae died four to seven days later with virus infection.

Table 4.—The effect of storage at 25 degrees C. on the infectivity of the nuclear polyhedral virus of *Catopsilia pomona.*

Storage period of virus in Months.	Days after Treatment.								
	1	2	3	4	5	6	7	8	9
1	0*	0	0	5	27 5b	6 3b	2 2b	....	....
3	0	0	0	3 1b	23 3b	14 1b	3 2b	....	....
5	0	0	0	1	25 2b	12 2b	7 1b	....	....
7	0	0	0	0	21 3b	17 2b	6 1b	....	....

Undesignated numbers refer to the number of larval deaths due to virus infection.

*—Fifty six-day-old larvae were treated with the virus applied to young leaves of Cassia fistula.

b—Number of larvae dead due to bacterial infection.

particles per ml., applied to young cacao leaves at the rate of one ml. per 100 square cm. of leaf area. For *Catopsilia pomona* larvae, the virus suspension was applied to young *Cassia fistula* leaves. The larvae were fed the virus treated foliage when five days old and maintained until they pupated and adults emerged, or until death. Control colonies were also set up. The results given in *Table* 1 show that only the larvae of *Catopsilia pomona* were found susceptible to the virus.

Effect of virus concentration on infectivity.

Eggs of *C. pomona* were collected from stock colonies and hatched in petri dishes on young *Cassia fistula* leaves in the laboratory. When the larvae were six days old, they were fed *C. fistula* leaves treated with the nuclear polyhedral virus at various concentrations, applying the virus suspension at the rate of one ml. per 100 square cm. of leaf surface. The larvae were counted every 24 hours and the dead larvae checked for the presence of the virus. Control populations were also maintained and remained virus-free throughout the experiment. From the results in *Table* 2, the populations of *Catopsilia pomona* were killed with a concentration of 100 particles per ml.

Effect of larval age on susceptibility.

C. pomona larvae of ages ranging from 1 to 13 days old, hatched from a stock colony, were fed *Cassia fistula* leaves which had been treated with nuclear polyhedra at the rate of one ml. per 100 square cm. at a virus concentration of 9,000 particles per ml. The larvae were fed and checked every 24 hours and any dead larvae were checked for virus infections. Control cages were also set up for each age group.

It is evident from the results given in *Table* 3 that the age of the larvae of *Catopsilia pomona* has no influence on the susceptibility of the larvae to virus infection. However, the incubation period, that is the time from ingestion to death, was shorter in the larvae of 11 days old compared with one-day-old larvae. It is interesting to note that pupae developed from infected larvae died due to viral infections.

Longevity of the virus in suspension.

A suspension of *Catopsilia* nuclear polyhedra of a concentration of 9,000 particles per ml., was prepared three weeks after field collection and stored at 25 degrees C. in water. Every two months after the date of field collection six-day-old larvae of *C. pomona* were fed the suspension applied to young *Cassia fistula* leaves, at the rate of one ml. per 100 square cm. of leaf tissue. Daily counts were made of the larvae and any dead larvae checked for virus infections. The results are presented in *Table* 4, and show that the infectivity of the preparation has not apparently deteriorated over a period of seven months.

Field persistence.

As there are no extensive areas of young cassia trees in the Gazelle Peninsula, field spraying to test the persistency of the virus in the field was carried out on scattered individual trees. A virus suspension at a concentration of 200,000 particles per ml. was applied to young leaf flush when eggs and young larvae of *Catopsilia*

Table 5.—The efficiency of the nuclear polyhedral virus of *Catopsilia pomona* in controlling infestations of *Catopsilia pomona* on five cassia trees in the field. The virus suspension applied had a concentration of 200,000 particles per ml.

Tree No.	Days after Spray Application.																															
	0		4		8		12		16		20		24		28		32		36		40		44		48		52		56		60	
	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H	V
1	30	0	2	22	7	6	12	5	10	3	7	2	8	0	15	0	31	0	48	0	46	0	33	0	35	0	28	0	17	0	21	0
2	16	0	0	12	3	1	5	3	2	4	3	1	2	0	3	0	3	0	3	0	2	0	2	0	1	0	5	0	8	0	15	0
																			No flush present													
3	10	0	0	6	3	0	8	2	3	3	9	2	7	0	4	0	2	0	2	0	2	0	0	0	3	0	6	0	12	0	17	0
																			No flush present													
4	13	0	1	9	5	3	8	2	7	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	8	0	13	0	43	0
															Ants present (a)																	
5	15	0	0	9	3	0	8	2	11	5	8	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	15	0	28	0
																			No flush present													
Rainfall in points			34		16		146		11		4		4		34		85		8		248		69		307		80		291			

H—Figures in this column are the number of healthy larvae of C. pomona.
V—Figures in this column are the number of virus infected larvae of C. pomona.
(a) Oecophylla smaragdula.

pomona were present. The trees were checked every four days for a period of 60 days recording the number of feeding larvae present and, if any, dead larvae containing viral polyhedra. The results are given in *Table* 5.

In the first three weeks after the virus application, larvae infected with viral polyhedra were located on the treated trees, with the number of infected larvae decreasing with time after spraying. In the remaining six weeks no diseased larvae were located on the trees. However, the results are limited in that three trees had no flush for the larvae to feed on for a period of 20 to 24 days and another tree became infested with kurukum ants (*Oecophylla smaragdula*) which preyed on any *Catopsilia* larvae present on the tree. During this observation period 13.27 in. of rain were recorded, and on examining leaf material from the treated trees, it was evident that a concentration of viral polyhedra was not being maintained on the young emerging leaves. Thus it is considered that field control of *Catopsilia pomona* larvae by *Catopsilia* nuclear polyhedrosis virus can only be obtained by regular application of the virus material to infested trees.

CONCLUSIONS.

The virus located at Popondetta affecting *Catopsilia pomona* is a new record and belongs to the nuclear polyhedral group of insect viruses, and appears from the limited host range test conducted to be restricted to *C. pomona*. The virus readily infects with resulting death all laval stages of *C. pomona*. A prepared suspension was still highly infectious after seven months when stored in suspension in the laboratory, but persistence in the field could not be maintained for a long period.

(Received October, 1966.)

ACKNOWLEDGEMENTS.

The author is indebted to Dr. J. J. H. Szent-Ivany and Mr. T. Fenner for the identifications of the insects and to Mr. G. S. Dun for the identification of several *Cassia* spp.

A Nuclear Polyhedral Virus Disease Affecting the Larvae of Tiracola Plagiata *Walk.*

R. J. VAN VELSEN.*

ABSTRACT.

A nuclear polyhedral virus of Tiracola plagiata *was located at a plantation at Popondetta in Papua. The larvae are readily susceptible up to* 18 *days old at a virus concentration of* 20,650 *particles per ml. The incubation period was found to be up to eight days for* 12*-day-old larvae. From the evidence of field trials at a plantation near Lae, the virus is of limited use for the control of* T. plagiata *due to the prevailing climatic conditions and the preference of the larvae to feed on flush growth.*

INTRODUCTION.

FROM 1962 to 1965, *Tiracola plagiata* (commonly termed cacao army worm in Papua and New Guinea) caused considerable damage to cacao (*Theobroma cacao*) plantings in the Popondetta-Sangara area of the Northern District of Papua and at a plantation at Lae. The larvae of *T. plagiata* appeared regularly during this period every six weeks devouring the young cacao flush and damaging the terminal buds resulting in the loss of vigour and growth of the trees. In September, 1965, investigations were carried out with several noctuid polyhedral viruses on *T. plagiata* and also a suspect polyhedral virus of *T. plagiata* collected by Mr. T. Bourke at a plantation at Popondetta. A search on this plantation by the author resulted in the findings of seven specimens of *T. plagiata* with nuclear polyhedral infection. This paper gives the investigations carried out on the polyhedral virus of *T. plagiata* found at the plantation at Popondetta.

DESCRIPTION OF THE DISEASE.

T. plagiata are highly susceptible to this disease during the early larval stages up to 18 days old. The disease is highly infectious and fatal with an incubation period of up to eight days. The larvae cease to feed within 24 hours of death showing little movement, becoming soft and limp. The skin appears to be thin and readily ruptures when touched liberating large quantities of white to pale pink fluid containing large numbers of polyhedra. Infected larvae, within 48 hours of death, appear pale brown in colour compared with the greenish-brown colour of the healthy larvae. Diseased larvae in the field are usually found flattened on the upper leaf surface surrounded by whitish liquid containing the polyhedra (*Plate* I). Older larvae are not readily susceptible to the disease.

The polyhedra produced are approximately 1100 to 2400 mμ in diameter and angular in outline (*Plate* II).

Plate I.—Photograph of third instar larvae at death with surrounding whitish fluid which contains the polyhedral particles.

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

EXPERIMENTAL STUDIES.

Effect of age of larvae on susceptibility.

Several egg masses collected in the field at the plantation near Lae, were used to obtain a stock colony of larvae of *T. plagiata*. Every two days, 50 larvae were collected from the colony and fed with young cacao leaves on which 5 ml. of virus suspension had been smeared. The virus suspension contained 20,650 polyhedra per ml. Each day the larvae were counted and any dead larvae examined for virus infection. The larvae were kept under observation until they had pupated. The results are given in *Table* 1.

From these results, it is evident that the larvae from 2 to 18 days old are highly susceptible to infection, after which susceptibility rapidly decreases.

Effect of virus concentration on infectivity.

A stock suspension of virus material was diluted with distilled water and applied to the surface of young cacao leaves at the rate of 1 ml. per 15 sq. in. of leaf area. Larvae, four days old, from a stock colony were fed on the prepared leaves and maintained until they pupated. Larval counts were made daily and any dead ones examined for virus infection. The results are given in *Table* 2.

It is evident that a virus particle count of 20,650 particles per ml. will result in approximately 100 per cent. death of larvae, while a count of 13,400 particles per ml. yielded approximately 50 per cent. Thus a concentration of 20,650 particles per ml. was used for the remaining experiments and the field trial.

Table 1.—The influence of the age of larvae of *Tiracola plagiata* on susceptibility of *Tiracola* nuclear polyhedral virus.

Age of larvae when fed on virus in days.	Deaths due to virus infection.*	Control.*	Deaths due to bacterial infection.	Control.
2	50	0	0	5
4	48	0	2	3
6	49	0	1	2
8	47	0	3	4
10	48	0	2	1
12	50	0	0	3
14	47	0	3	2
16	45	0	5	2
18	47	0	3	3
20	16	0	7	5
22	12	0	6	6
24	3	0	2	1
26	2	0	8	5

* Fifty larvae were used for each test.

Table 2.—The effect of virus concentration in respect to the minimum lethal dosage for four-day-old larvae of *Tiracola plagiata*.

Number of virus particles/ml.	Deaths due to virus infection.*	Deaths due to bacterial infection.
0 (Control)	0	2
950	0	4
2,550	3	3
6,600	8	4
13,400	21	3
20,650	49	1
41,600	46	4

* Fifty larvae were used for each test.

Period of incubation of the virus in the larvae.

Thirty larvae from the stock colony, four and twelve days old, were fed with the virus suspension (20,650 particles per ml.) on cacao leaves and the period of incubation determined. The results are given in *Table* 3.

For four-day-old larvae, the incubation period was found to be from three to six days, and for the 12-day-old larvae, three to eight days.

Field Trial.

In November, 1965, and January, 1966, field trials were laid down at the plantation near Lae to determine the efficiency of the virus in controlling *T. plagiata*, in the field. A limited trial was laid down in November and January ; 100 cacao seedlings (18 months old) were sprayed with virus suspension (concentration 20,650 particles per ml.) with a "Motoblo" super-seventy, powered knapsack sprayed with a nozzle setting of No. I and minimum engine power. Five litres of spray were used for 100 trees.

Table 3.—Determination of the incubation period, in four and twelve-day-old larvae of *Tiracola plagiata*, of the *Tiracola* nuclear polyhedral virus.

Age of larvae in days.	Days after feeding on virus suspension.								Total virus deaths.
	1	2	3	4	5	6	7	8	
4a	1b	0	2*	17	9	1	0	0	29
12	0	2b	3	7	8	6	4	1 1b	27
Control									
4	0	0	1b	0	0	0	0	0	0
12	0	0	0	0	2b	0	0	0	0

a. Thirty larvae used in each age group.

b. Death due to bacterial infection.

* Numbers in table refer to the number of larvae found to be dead on that day.

Table 4.—Recordings in the field trial carried out at a plantation near Lae, in January, 1966, on the number of dead larvae of *Tiracola plagiata* infected with *Tiracola* nuclear polyhedral virus.

Tree Number *	13/1	16/1	17/1	18/1	19/1	20/1	21/1	22/1	24/1	25-28
3	0	T	1	11	T	0 hf	0	T	2	0
11	0	T	43	17	0	0 hf	0	T	0	0
12	0	T	T	3	0 hf	0	0	T	T	0
16	T	T	T	6	4	3	7	1	T	0
18	0	T	T	T	0	T hf	6	T	0	0
23	0	T	T hf	T	0	T	1	1	1	0
26	0	T	1	18	0	T hf	2	T	1	0
27	T	T	T	T	T	T	16	0	T	0
29	T	T	T	T	T	T hf	23	T	2	0
31	0	T	1	1	T	T hf	1	2	6	0
33	0	T	T	T	6	T hf	9	T	T	0
35	0	T	T	T	3	T hf	5	T	1	0
37	T	T	T	3	0	2 hf	5	T	0	0
38	T	T	T	T	0	T hf	9	T	T	0
52	T	T	3	16	2	T hf	17	T	0	0
55	0	T	T	T	4	3 hf	11	2	T	0
56	0 hf	T	T	T	T	T	5	0	3	0
57	0	T	T	T	3	T hf	2	T	T	0
63	T	T	2	29	T	6 hf	0	2	0	0
68	T	T	3	16	0	1 hf	T	0	T	0
70	T	T	3	2	3	2 hf	1	T	0	0
74	T	T	27	7	1	T hf	T	T	T	0
84	0	T	T	3	7	2 hf	6	T	3	0
97	T	T	T	1	6	T hf	7	4	T	0
99	T	T	T	2	0	1 hf	T	T	1	0

* The trial area consisted of 100 trees and 25 tree records were selected from the random numbers table from 'Statistical tables for biological, agricultural and medical research' by R. A. Fisher and F. Yates (1949).

hf = Hard flush on trees only.

T = Tiracola plagiata larvae present on the tree.

Most of the trees had a heavy infestation of *Ophiusa janata* larvae which had resulted in considerable flush damage. The cacao trees and smaller shade trees (*Leucaena leucocephela*) were examined daily for dead *Tiracola plagiata* larvae. Daily rainfall recordings were also carried out. The results from 25 randomly selected trees are given in *Table* 4.

Apart from tree II, which had an egg mass present when sprayed, the number of larvae per tree was low and a large number of deaths resulted. The trial was of limited use, due to the fact that on 20th January, 1966, no young flush was present on the trees, and on this date, larvae in plague numbers descended from the taller *Leucaena leucocephela*, onto the cacao, but few remained to feed. From field observations, the majority of *T. plagiata* eggs are laid on *Leucaena leucocephela*, but the larvae feed only for a short time as the young growth of cacao is preferred.

Effect of Tiracola nuclear polyhedral virus on several other species.

Ectropis sp. and *Ophiusa janata* are also cacao flush eating in the larval stages and can cause considerable damage in the field. Fifty young larvae of each species were fed cacao leaves treated with *Tiracola* polyhedral virus suspension in the laboratory. None of the larvae in this experiment died as a result of virus infection. Tachinid flies which are predators of *Tiracola plagiata* were found to be unaffected by the *Tiracola* polyhedral virus.

DISCUSSION.

From the experimental data obtained, the *Tiracola* nuclear polyhedral virus could be employed as a useful additive for the biological control of *Tiracola plagiata* outbreaks in cacao in Papua and New Guinea. It can be readily applied by conventional spray machinery. How-

Plate II.—Photomicrograph of *Tiracola plagiata* viral polyhedra (1) taken at a magnification of 2,700 times, stained with 0.1 per cent. methylene blue. Bacteria (2) are also present in the preparation. (Photograph by Dr. D. E. Shaw.)

ever, the virus suspension would need to be applied in the early larval stages and this is not always possible since *T. plagiata* moths lay their eggs mainly on the cacao shade tree and the larvae descend onto the cacao eight or more days after hatching. The amount of flush on the cacao trees will also influence the effectiveness, as the larvae will move off the trees onto the ground when no flush is present. Only limited persistence in the field was observed at a plantation near Lae over a period of three months due to the regularity of the rainfall. This is an important defect in natural field infection, as it does not allow the concentration of virus material to build up.

(Received April, 1966.)

ACKNOWLEDGEMENTS.

The use of plantation facilities and trial areas provided by the owner of the plantation near Lae is gratefully acknowledged. The photograph used in *Plate* II was taken by Dr. D. E. Shaw, and the size of the polyhedral particles was kindly determined by Dr. D. E. Shaw. Identification of the virus was made by Mr. C. F. Rivers of the Virus Research Unit, Cambridge, England.

Axonopus Chlorotic Streak, a Leafhopper Transmitted Virus of Axonopus Affinis *in New Guinea.*

R. J. VAN VELSEN.*

ABSTRACT.

The chlorotic leaf streak condition of Axonopus affinis *in New Guinea is due to a virus. The virus is only transmitted by the leafhopper,* Idyia fijiensis. *In the experimental studies,* Axonopus affinis *was found to be the only host of the virus.*

INTRODUCTION.

In 1960, areas of *Axonopus affinis* Chase growing near the research laboratories at the Lowlands Agricultural Experiment Station at Keravat, were found to be affected by a chlorotic streaking of the lamina. Subsequent searches of *A. affinis* growing in the Gazelle Peninsula area showed most plants to be affected by the condition. The grass is of no commercial value, at the present, either as a fodder crop or turf grass. Experiments were carried out to determine the cause of the chlorotic streaking and this paper gives the details and results of the experimental studies.

SYMPTOMS.

In the field, infected plants are not stunted, but exhibit a pale chlorotic discoloration of the leaves. The lamina and stipules have pale chlorotic streaks running approximately parallel to the mid-vein from 1 mm. in length, but more often the full length of the leaf blade (*Plate* I). The leaf symptoms are systemic and persistent. The flowering and seed habits of the diseased plants are not affected when compared with healthy plants. In the laboratory, the chlorotic streak symptoms appeared 16 to 20 days after inoculation and were persistent.

EXPERIMENTAL STUDIES.

Attempts to transmit the condition from infected to healthy plants of *Axonopus affinis* by mechanical means, through soil from infected plants, by seed and with nymphs of *Tetraneura hirsuta* were unsuccessful. Attempts to transmit the condition by mechanical means to *Triticum* *vulgare* variety "Minflor", *Zea mays* var. "SA5", *Andropogon sorghum* var. "Red Sorghum", *Oryza sativa* var. "Mekeo White", *Avena sativa* var. "Algerian", *Hordeum vulgare* var. "Skinless", *Secale cereale* var. "Black Winter", and *Saccharum officinale* were unsuccessful.

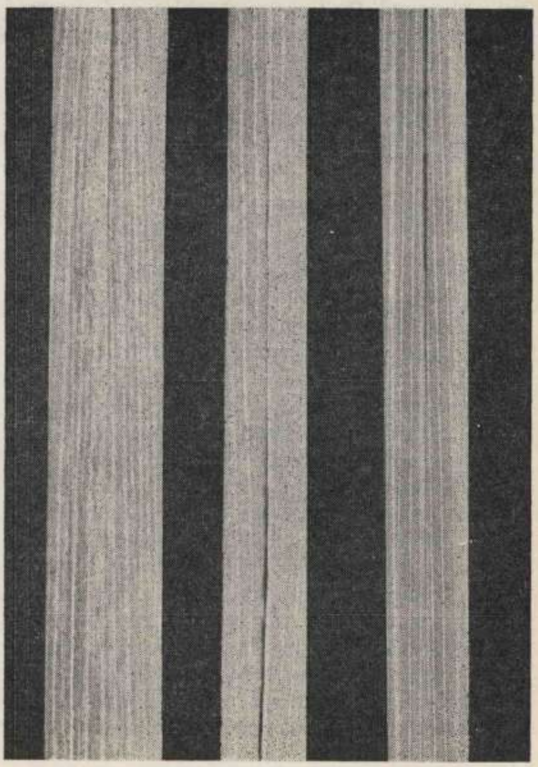


Plate I.—Two leaves of *Axonopus affinis* showing lamina streak. Healthy leaf is on the right.

---

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

Table 1.—The effectiveness of various leafhoppers in transmitting chlorotic streak virus of ***Axonopus affinis*** using *A. affinis* as the test plant.

Leafhopper.	No. of infections/ No. of Plants.
Nisia atrovenosa	0/30
Deltocephalus hospes	0/30
Idyia fijiensis	30/30
Green leafhopper	0/30

From field observations, numerous leafhoppers were observed feeding on healthy and diseased *Axonopus affinis* plants. Experiments were carried out to determine whether the condition was transmissible by leafhoppers. The leafhoppers were raised as stock colonies in the greenhouse on healthy *A. affinis* grown from seed.

Adult leafhoppers were fed on infected *A. affinis* leaf tissue in small glass cages for 24 hours and then released onto healthy seedlings approximately 2 in. long in glass cages for four days (five leafhoppers per cage). The plants were then sprayed with 0.01 per cent. Dieldrin and kept free of insects for six weeks. From the results given in *Table* 1, the leafhopper, *Idyia fijiensis* was found to be a vector of Axonopus chlorotic streak. The streak symptoms on the lamina were not due to the feeding habits of *Idyia fijiensis* as all the control plants in the tests remained symptomless after being fed upon by healthy leafhoppers. The symptoms appeared 16 to 20 days after the leafhoppers had finished feeding on the test plants and the symptoms were systemic and persistent. Further experiments were carried out to determine the effect of various acquisition and test feeding times on the efficiency of transmission by adults of *Idyia fijiensis*.

Leafhopper transmitted viruses according to Bawden (1964) can be roughly classified into two groups ; one group of viruses whose vectors do not become infectious until several days after acquiring the virus and the other group whose vectors become infectious a few hours after feeding. Adults of *I. fijiensis* were allowed to feed from one to six hours on infected *Axonopus affinis* leaf tissue after which they were transferred to healthy seedlings to feed from one to six hours, in small glass cages. One adult leafhopper was placed in each cage, and 20 such cages set up with ten control cages for each test.

From the results in *Table* 2, it is evident that the adult of *I. fijiensis* is able to transmit Axonopus chlorotic streak after an acquisition and test feeding time of two hours, and the efficiency of transmission increased with increased acquisition feeding time. Thus Axonopus chlorotic streak virus is similar to beet curly top (Bennett

Table 2.—The effect of acquisition and test feeding times on the efficiency of transmission of chlorotic streak of ***Axonopus affinis*** by adults of ***Idyia fijiensis***.

Acquisition Feeding Time in Hours.	Test Feeding Time in Hours.	No. Infected/ No. Treated.
1	1	0/20
1	2	3/20
1	3	4/20
1	4	3/20
1	5	5/20
1	6	4/20
2	1	5/20
2	2	8/20
2	3	8/20
2	4	10/20
2	5	11/20
2	6	15/20
3	1	15/20
3	2	13/20
3	3	15/20
3	4	20/20
3	5	18/20
3	6	20/20
4	1	18/20
4	2	20/20
4	3	19/20
4	4	20/20
4	5	20/20
4	6	19/20
6	1	17/20
6	2	20/20
6	3	18/20
6	4	18/20
6	5	20/20
6	6	17/20

1935) and maize streak (Storey 1928) viruses in that the leafhopper vectors become infectious within a few hours of acquiring the virus.

Further host range studies were conducted using adults of *Idyia fijiensis* as the vector, using an acquisition feeding time of three hours and a test feeding time of six hours. Five adults of *I. fijiensis* were used for each test plant and 40 plants of each host were used in the tests However, none of the cereal test plants listed in the attempted mechanical transmission tests became infected. Thus it appears as if the host range of Axonopus chlorotic streak virus is severely restricted.

CONCLUSIONS.

The chlorotic streak condition of *Axonopus affinis* has been found to be due to a virus which is transmitted by the leafhopper, *Idyia fijiensis*, and to be confined to *Axonopus affinis*. Several other graminaceous viruses which are transmitted by leafhoppers, such as rice stripe virus (Hashioka 1951), sugar-cane chlorotic streak virus (Abbott and Ingram 1942) and sugar-cane Fiji virus (Ocfemia 1934) also have restricted host ranges.

From the experimental data, the virus was found to be only transmitted by *Idyia fijiensis*, and the efficiency of this vector in transmitting the virus was increased up to a time of three hours by increasing the length of the acquisition feeding time. The virus is dissimilar to other reported graminaceous viruses in respect to host range and insect vector. Thus the name Axonopus chlorotic streak is proposed for this virus.

(Received July, 1966.)

ACKNOWLEDGEMENTS.

The indentification of *Axonopus affinis* was made by the Chief of the Division of Forest Botany, Lae. The author is also grateful to Mr. R. G. Fennah, of the Commonwealth Entomological Institute and to Dr. J. J. H. Szent-Ivany for the identification of the insects mentioned in this paper.

The photograph in *Plate* I was taken by the Department of Information and Extension Services.

REFERENCES.

ABBOTT, E. V. AND INGRAM, J. W. (1942). Transmission of chlorotic streak of sugar-cane by the leafhopper, *Draeculcephela portola*. *Phytopathology*, 32 : 99-100.

BAWDEN, F. C. (1964). Plant viruses and virus diseases. Ronald Press Co., N.Y., Fourth Edition.

BENNETT, C. W. (1935). Studies on the properties of the curly top virus. *J. Agric. Res.*, 50 : 211-241.

HASHIOKA, Y. (1951). Rice stripe (oryza virus 2). *Frmrs'. Bull.* Saitama agric. Exp. Sta. 6 pp. 1951.

OCFEMIA, G. O. (1934). An insect vector of Fiji disease in sugar-cane. *Amer. J. Bot.*, 21 : 113-120.

STOREY, H. H. (1928). Transmission studies of maize streak disease. *Ann. appl. Biol.*, 15 : 1-25.

Salmonellosis in Animals and Birds in Papua and New Guinea.

ANITA M. RAMPLING.*

ABSTRACT.

All salmonellae strains isolated at the Department of Agriculture veterinary laboratory, Port Moresby, are recorded for the period August, 1964, to July, 1966. A remarkably small number of clinical cases occurred, the most significant losses being in poultry enterprises. Isolations from clinical cases totalled seven and from symptomless carriers 12.

INTRODUCTION.

THIS paper is a continuation of the record, which was started in July, 1962, of Salmonellae strains isolated from birds and animals in Papua and New Guinea (Rampling and Egerton 1966). This record covers the period from August, 1964, to July, 1966, and includes a small survey on the carrier rate of Salmonellae by dogs and cats in the Port Moresby District.

MATERIALS AND METHODS.

Cultures were made from faeces, small intestine contents and organs of clinical cases and survey material consisted of faeces and pooled mesenteric lymph node, liver, spleen and bile from each post mortem.

Material was cultured directly onto desoxycholate citrate agar and also enriched in tetrathionate and selenite or Hajna's GN broth.

To ensure maximum cover of the different Salmonellae serotypes, two different enrichments were used for each specimen and these were sub-cultured onto desoxycholate citrate agar at 24 and 48 hours respectively. All suspect colonies were isolated on tryptose agar and submitted to standard biochemical tests. Those colonies which gave the biochemical reactions for the genus Salmonella were confirmed and grouped according to somatic antigens by slide agglutination tests using standard Commonwealth Serum Laboratory's sera. The definitive typing was carried out by the Institute of Medical and Veterinary Science, Adelaide.

DESCRIPTION AND DISCUSSION OF ISOLATIONS.

Cow—S. breukelen. This organism was isolated in mixed culture with *Staphylococcus aureus* from a cow with clinical mastitis.

Salmonellae may be excreted in the milk during acute septicaemic infection or in cases of localized udder infection. The organisms may also enter milk due to faecal contamination of the outside of the udder by a carrier animal. In the case under discussion a specimen of milk was taken with aseptic precautions and the isolated organisms must have come from inside the udder. The animal was in good condition and showed no signs of general infection so it must be concluded that the mastitis was caused by mixed Staphylococcus and Salmonella infection.

Salmonella infection of the udder seems to be fairly rare and there are few records in the literature of Salmonella mastitis, however, Pullinger and Millar (1945) describe an epidemic of milk borne food poisoning which was traced to a cow with Salmonella mastitis. The dangers of food poisoning in a case of Salmonella mastitis are very real in this country where pasteurization is not practiced.

Horse—S. anatum. S. anatum was isolated from the visceral organs of a horse which was found dead in the Markham Valley area near Lae. Several other horses in contact with this one showed signs of the "Markham Valley Colic" syndrome which occurs frequently in this area. Faecal specimens were taken from one animal which had recovered and from eight others in contact but with no signs of sickness, however, no Salmonellae were isolated.

Salmonellosis in horses is frequently associated with colic or gastro-enteritis but in the majority of cases the Salmonellae only play a secondary role in the infection (Buxton 1957) also *S. anatum* is quite commonly isolated from sporadic cases of Salmonellosis in horses (Buxton 1959).

* Formerly Pathologist Bacteriologist, Vet. Research Lab., D.A.S.F., Kila Kila.

In this case it seems likely that the Salmonellosis was a secondary infection which overcame an animal already weakened by colic. The cause of the "Markham Valley Colic" syndrome remains a mystery.

Chickens—S. kottbus. This organism was isolated from three batches of chickens which were imported from a Queensland hatchery. Two batches were sent to Madang and a third batch was sent to the Animal Quarantine Station, Kila Kila at Port Moresby. Heavy losses were experienced in the first batch which went to Madang and these were completely destroyed in an attempt to stop cross infection on the property. The second batch arrived about six weeks later and was housed in a separate shed from the previous batch, however, losses occurred once more. Only one death occurred in the chickens which were sent to Port Moresby and arrived at the same time as the first Madang consignment, however, *S. kottbus* was also isolated from this case.

In all cases the signs of sickness were weakness and paralysis of the legs before death which occurred during the first three days of life.

A thorough investigation of the hatchery was carried out by the Queensland Department of Agriculture but it was not possible to trace the source of infection or to prove that it had occurred at the hatchery.

Salmonella newington. A 95 per cent. loss in chickens imported to a property near Port Moresby was caused by this serotype. The bulk of the losses were experienced at the age of three to five days. The clinical picture was that of acute toxaemia, as seen in pullorum disease, but there was little evidence of diarrhoea.

Once more the Queensland Department of Agriculture made a thorough investigation of the hatchery concerned but *Salmonella newington* has never been recorded in chickens in Queensland and it did not seem that the infection could have been contracted at the hatchery. Also part of the same batch that went to Port Moresby was sent to Darwin where no losses were experienced.

Contamination of the Port Moresby premises by rodents, insects, etc., was suspected and a follow-up survey was carried out on rats and mice caught in the area, however, no further

RESULTS.

***Table* 1.—Isolations from clinical cases of Salmonellosis.**

Group.	Serotype.	Host.	No. of cases.	Location.
C	*S. kottbus*	Chickens	2	Madang, Port Moresby.
C	*S. breukelen*	Cow	1	Lae.
D	*S. pullorum*	Chickens	1	Lae.
D	*S. enteritidis*	Duck	1	Lae.
E	*S. anatum*	Horse	1	Markham Valley, via Lae.
E	*S. newington*	Chickens	1	Port Moresby.

***Table* 2.—Isolations from Animals showing no clinical signs of Infection.**

Group.	Serotype.	Host.	No. of isolations.	Location.
C	*S. virchow*	Deer Dog	5	Port Moresby.
C	Not identified	Cat	1	Port Moresby.
D	*S. enteritidis*	Dog	3	Port Moresby.
E	*S. anatum*	Dog	1	Port Moresby.
E	*S. new brunswick*	Dog	1	Port Moresby.
E	*S. weltevreden*	Dog	1	Port Moresby.

isolations were made. The remainder of the flock was sacrificed and thorough disinfection of the premises was carried out. No further outbreaks have taken place since then.

Salmonella pullorum. A 50 per cent. loss in chickens imported from Queensland to Lae as day-olds was found to be due to *Salmonella pullorum*. The losses occurred at about one week of age and it seems likely that, once more, the infection was picked up after arrival in the Territory.

Ducks—S. enteritidis. This serotype is fairly commonly isolated from ducks although it is the first time that it has been recorded in birds in the Territory. It was isolated from a duck which died at about three months of age. There was a history of losses in ducks on this property and also a number of losses were occurring in young chickens. It seems likely that this serotype was widely disseminated about the environment of the property.

Frozen deer meat. Locally killed deer are now being deep frozen and exported for human consumption. Representative samples are taken from the batches before export and are tested for Salmonellae. Out of 21 specimens examined, one isolation, *S. virchow*, was made. This particular batch of meat was condemned.

Dogs and Cats in Port Moresby area. A small survey was carried out on dogs and cats which were presented for post mortem over the four months January to May, 1966. None of these animals showed any clinical signs of disease. Faeces and pooled mesenteric lymph node, liver, bile and spleen were enriched in tetrathionate or selenite broths and Hajna's GN broth and plated at 24 and 48 hours onto desoxycholate citrate agar.

A total of 29 dogs and 24 cats were tested. Ten isolations were from dogs, one dog carrying two serotypes, *S. virchow* and *S. enteritidis*, and only one isolation of group C Salmonella, which unfortunately was not typed, was made from the cats.

An unexplained but interesting factor was that all of the isolations were during the month of January, no further isolations being made in February, March or April. Almost all of the animals were owned by Europeans so possibly one particular batch of imported canned pet food could have been incriminated.

GENERAL DISCUSSION.

Several new strains of Salmonellae have been added to the list of species isolated in the Territory but the record from the past two years confirms our previous opinion that Salmonellosis is not of great economic significance in livestock enterprises here (Rampling and Egerton 1966). The most important losses have been experienced by poultry farmers when Salmonella infection has occurred in stock during the first week of life. In none of the cases listed was it possible to prove that the infection had been imported with the chickens and the danger of Salmonella infection should be borne in mind in the management of Territory poultry farms.

SUMMARY.

A record of Salmonellae diagnosed in animals and birds in the Territory has been continued from the period August, 1964, to July, 1966. Seven isolations were made from clinical cases of Salmonellosis and three of these strains had not previously been isolated from animals or birds here. Twelve isolations including one new strain were from carriers showing no sign of infection.

(Received July, 1966.)

ACKNOWLEDGEMENTS.

The assistance of Veterinary Officers of the Department of Agriculture in submitting specimens and information is gratefully acknowledged. I would also like to thank Dr. K. F. Anderson of the Institute of Medical and Veterinary Science, Adelaide, for the serological typing of cultures.

REFERENCES.

RAMPLING, A. M. AND EGERTON, J. R. (1965). *Papua and New Guinea agric. J.*, 17 (4) : 149.

PULLINGER, E. J. AND MILLAR, J. W. S. (1945). *S. Afr. Med. J.*, 19 : 313.

BUXTON, A. (1957). Salmonellosis in Animals. *Rev. Series No. 5 of the Comm. As. Bureau*, Bucks, England.

BUXTON, A. (1959). *Infectious Diseases of Animals*, Vol. 11, Stableforth A. W. & Galloway, I. A., Butterworths, London.

Variations in Major Operating Costs of Tolai Cocoa Project Fermentaries.*

R. M. SHERWIN.†

ABSTRACT.

The article discusses average operating costs of some cocoa fermentaries in the Gazelle Peninsula, New Britain, and examines variations in costs. The aim is to find if economies are likely to occur through increasing scale of fermentary operations.

INTRODUCTION.

The Tolai Cocoa Project, since its beginning in 1951, has established itself on the north-east of the Gazelle Peninsula, New Britain, to provide Tolai village growers with facilities for processing and marketing cacao. As a non-profit making public utility it was the first of its kind in Papua and New Guinea. Capital for the scheme was obtained by bank overdrafts guaranteed by the Administration.

The assets of the Project were at first vested in local government councils that were helped by the Administration to foster the Project. Ownership was assumed by the Gazelle Peninsula Local Government Council upon amalgamation of the five councils in 1964.

A Field Officer, seconded from the Department of Agriculture, Stock and Fisheries, undertakes general management of the Project. Each fermentary, however, is in many respects an autonomous unit. Growers served by each fermentary are able to decide some matters concerning its finances, but the day-to-day operation of it is the responsibility of a Tolai clerk, who usually is from the locality where the fermentary is situated.

This note represents the results of a survey of the scheme, undertaken to obtain information about :—

(1) The average operating costs of Project fermentaries ;

(2) The extent and causes of variations in these costs amongst fermentaries ; and

(3) Possible economies of scale in processing operations.

Costs were obtainable from the Project for only six-monthly periods, each of which included a time of cocoa flush. The data therefore does not dampen seasonal variations. The years include both good and poor seasons, and times of high and low cocoa prices.

Seventeen fermentaries were operating in the Project from January, 1963, until September, 1964, when an extra Project fermentary was opened.

Table 1, with frequency distributions of output, reveals that most of the fermentaries each period produced less than 50 tons of dry cocoa.

The major operating costs of fermentaries are : (1) the cost of dieselene and oil used by cocoa drying equipment ; (2) wages of manual labourers ; (3) the cost of bags and twine (including also ink and stencils) ; and (4) charges for cartage of bagged cocoa from each fermentary to Rabaul.

Non-operating costs (which are not considered in this note) are : (*a*) a levy of $1.20 on each bag of cocoa produced, to cover wages of fermentary and headquarters clerks, and minor overheads ; (*b*) a redemption charge of $30 per ton

Table 1.

Dry Cocoa Production (tons).	1963. Jan.-July	June-Dec.	1964. Jan.-July	June-Dec.	1965. Jan.-July	June-Dec.
0 and under 25	5	1	2	6	2	2
25 and under 50	8	8	8	7	10	13
50 and under 75	3	2	4	4	3	2
75 and under 100	1	3	2	....	2	1
100 and under 125	....	3	1	1	....	....
125 and under 150	....	....	....	....	1	....
All Fermentaries	17	17	17	18	18	18

* The survey covers fermentary operations during three years from January, 1963, to December, 1965.

† Project Planning Team, Department of the Administrator, Port Moresby.

Table 2.

Period.	Components of Average Operating Cost per Ton.[1]				
	Fuel and Oil.	Wages.	Bags and Twine.	Cartage.	Total.
	$	$	$	$	$
1963					
Jan.-June	10.5	10.6	7.1	4.6	32.8*
July-Dec.	12.1	8.9	6.3	4.7	32.0
1964					
Jan.-June	12.2	9.3	5.3	4.6	31.4
July-Dec.	10.9	10.8	4.5	4.6	30.9*
1965					
Jan.-June	17.4	11.1	6.0	4.6	39.0*
July-Dec.	8.0	9.3	6.0	4.5	27.8
Average for Six Periods	12.1	9.8	5.9	4.6	32.5*

[1] Excludes data on Watom fermentary.

* Discrepancy in addition due to rounding of components.

of cocoa, in order to repay bank overdraft and interest; (*c*) repairs and maintenance to plant and machinery; and (*d*) bank charges on accounts, audit fees, and sundry other items.

The actual wages of the clerk, or clerks, in each fermentary are not charged to it.

AVERAGE OPERATING COSTS.

Average operating costs at Watom fermentary were lowest of all such costs between January, 1963, and December, 1964. Whereas Watom, the smallest fermentary, relies entirely on the sun for drying cocoa beans, others rely partly on the sun, and partly on oil-fired hot-air driers.

They have at least one combination sun-drier and hot-air drier (the 'Universal' sliding roof drier), and one rotary drum drier. Most but not all of the fementaries were equipped with rotary driers by the beginning of 1963.

The components of average operating cost per ton of cocoa produced by all fermentaries except Watom are given below in *Table* 2.

Actual costs of dieselene fuel, and 'bags and twine', include changes both in prices and quantities. A standard cost—the average cost per gallon of dieselene for the six periods—has been applied to the number of gallons of dieselene each fermentary used, in order to remove the effect of changes in Project pricing of dieselene; similarly, the average cost per bag, of bags, twine, ink, and stencils, has been applied to the number of bags each fermentary used, in order to remove the effect of changes in pricing of bags. (The cost of twine, ink and stencils is negligible, and for the purpose of analysis is assumed to have varied directly with numbers of bags.)

Table 3.

Period.	Components of Average Operating Cost per Ton (Adjusted for Price Changes).[1]					
	Dieselene.	Oil.	Total Dieselene and Oil.	Wages.	Bags and Twine.	Output in Tons.
	$	$	$	$	$	
1963						
January to June	9.5	0.2	9.7	10.6	5.9	640.7
July to December	11.1	0.2	11.3	8.9	5.9	1,007.4
1964						
January to June	11.5	0.2	11.6*	9.3	5.8	827.0
July to December	11.3	0.2	11.5	10.8	5.9	670.7†
1965						
January to June	18.1	0.3	18.5*	11.1	5.9	842.0
July to December	8.4	0.2	8.6	9.3	5.9	624.6
Average for Six Periods	11.9	0.2	12.2*	9.9	5.9	Total 4,612.4

[1] Excludes data on Watom fermentary.

* Discrepancy in addition due to rounding of components.

† Excludes fermentary opened in September, owing to neligible fuel consumption.

Table 4.

Period.	Output in Tons.	Regression of Average Cost of Dieselene on Output.	Correlation Co-efficient. (r)	r^2
1963				
January to June	640.7	Y = 9.4 + .005 X	+ .035	.001
July to December	1,007.4	Y = 13.2 — .029 X	— .423	.179
1964				
January to June	827.0	Y = 9.1 + .038 X	+ .368	.149
July to December	670.7*	Y = 8.5 + .051 X	+ .427	.182
1965				
January to June	842.0	Y = 18.5 — .007 X	— .045	.002
July to December	624.6	Y = 5.0 + .085 X	+ .330	.109

* Excludes fermentary opened in September.

Weekly wage rates were unchanged during the six periods, as was the pricing per gallon of oil. Variations in those cost items were therefore due solely to the quantities used.

A standard cartage rate per ton applied to each fermentary, but there were various rates. The lowest was charged to the fermentary closest to Rabaul, and the highest rate to three of the fermentaries most distant from Rabaul. Variants in the average cartage rate for all fermentaries indicate changing proportions of cocoa being taken to Rabaul from areas where differing rates were charged.

Each of the items 'fuel and oil' and 'bags and twine' priced at its respective standard rate, is set out in *Table* 3. The component 'fuel and oil' is divided into 'dieselene' and 'oil', to indicate the greater variability in the former.

It can be seen that the average cost of dieselene and average wages—the two major operating costs—were related less to output than were the other components of operating cost.

In order to measure the nature and strength of relationship between average dieselene cost and output, linear regression of the data on fuel costs (*Table* 3) has been calculated for all fermentaries each period, using the method of least squares. Regression equations are of the ordinary form $Y = a + bX$, where Y is the dependent variable (average cost of dieselene per ton), and X the independent variable (output in tons).

Regression of cost data in a arbitrarily chosen range of output is of less value than for the whole range. Similarly the value of regression of average cost data on output of individual fermentaries over the six periods is severely limited by the small range of output.

The regression equations, together with the respective correlation co-efficients that are derived, are given in *Table* 4.

The correlation co-efficients are too low to indicate a substantial relationship between average cost of dieselene and cocoa output. The fuel cost is affected by other stronger variables that cannot be quantified, such as weather conditions, efficiency of fermentary clerks, and the different equipment used amongst fermentaries. If these factors were quantifiable and controlled, one would expect a higher degree of linear correlation between average fuel cost and output. The low values of r^2 and the differing signs of the regression co-efficients suggest there were no economies in fuel cost each period over the range of output.

Fairly stable and low consumption of fuel per ton of cocoa was achieved in 1963, and 1964, by several fermentaries, of which some produced more than 100 tons of cocoa annually. In the first half of 1965, use of dieselene rose abnormally in many fermentaries (as can been seen from the rise in average cost in *Tables* 2 and 3). This sudden increase can hardly be explained by abnormal production ; the most likely reason is that widespread wet weather forced fermentary clerks to use hot-air drying equipment more than usual.

In the second half of 1965, prolonged dry and windy weather which prevented cocoa trees from bearing well also reduced the average operating cost of fermentaries significantly, mainly through the reduction in the use of dieselene.

The variability of wages per ton is much less than of average cost of dieselene. As one might expect, linear regression of average wages on output yields higher correlation co-efficients than for the equations in *Table* 4 above. Regression equations again are of the normal form, where Y is the dependent variable (average wages per ton), and X the independent variable (output in tons). *Table* 5 gives the regression equations and the derived values of r and r^2.

Even though the regression co-efficients are not very high, the squared co-efficients (r^2) in periods one to five indicate a fair percentage of relationship (between 40 per cent. and 64 per cent.) between the two variables. This, together with the consistency in sign of regression co-efficients, suggests that economies of labour cost were achieved each period over a rising range of output.

Project fermentary labour, of course, was influenced by other factors too. Labour was employed by the week, not just for the particular number of hours required each day, and the number of labourers was proportional more to the number of boxes of wet cocao beans being fermented rather than to drying requirements of beans. Because of this and the different methods of drying the beans, no attempt was made by the Project to set and adhere to a standard cost of labour per ton of cocoa.

The factors mentioned in regard to unexplained variations in average dieselene cost would certainly have affected average labour cost also.

The fermentary with tightest control over labour was Bitagalip, whose wages per ton of cocoa varied between \$6.90 and \$8.60, the lower figure at the highest output. This fermentary, the largest, produced approximately 180 to 220 tons each year. Amongst some fermentaries with larger outputs than Bitagalip, but in smaller fermentaries more especially, control over labour cost was considerably looser. Fluctuations of \$5 and more, with average wages from \$9 to \$14, were common.

CONCLUSION.

In general there were no economies in the average cost of dieselene each period as with a rising scale of output some large fermentaries were able to economize on dieselene, but other large fermentaries could not do so as much as smaller ones.

In each period economies of labour cost were apparent over rising scale of output.

These operating costs are also dependent in varying degrees upon weather conditions, upon the efficiency in control of cost, on the part of fermentary clerks, the different methods of drying beans, and perhaps other unquantifiable factors. As a consequence there is no guarantee that average wages or average fuel cost would be prevented from rising with an increase in the average scale of output. Greater competition by fermentaries with other buyers of Tolai wet bean could raise the average output but this possibly would add to buying costs.

Table 5.

Period.	Output in Tons.	Regression of Average Wages per Ton on Output.	Correlation Co-efficient.	
1963			(r)	r^2
January to June	640.7	Y = 15.2 — .100 X	—.752	.565
July to December	1,007.4	Y = 12.5 — .048 X	—.795	.632
1964				
January to June	827.0	Y = 12.0 — .043 X	—.596	.355
July to December	683.2*	Y = 13.7 — .057 X	—.639	.408
1965				
January to June	842.0	Y = 15.9 — .076 X	—.682	.466
July to December	624.6	Y = 10.8 — .034 X	—.340	.115

* Includes fermentary opened in September.

These points are of interest and significance if consideration is to be given to saving of non-operating costs. The two largest non-operating costs—redemption and levy charges—could be reduced more by other means than through an increase in scale. To lessen significantly the redemption rate could require that the Project's overdraft be partly capitalized through an issue of shares. This would affect the nature of the Project as a public utility. The average fortnightly clerical wage, and the average number of clerks per fermentary, are relevant to a reduction of the levy rate per ton. Considerations such as these are independent of the average scale of output per fermentary and could achieve significant saving on non-operating costs.

(Received July, 1966.)

ACKNOWLEDGEMENTS.

The author wishes to acknowledge the help of Mr. G. Dun, Mr. K. R. Gorringe and others of the staff of the Tolai Cocoa Project, Rabaul, in obtaining the data on fermentary operations. Mr. R. J. Cheetham, Mr. P. F. K. Emmery, and Mr. E. C. G. Gray, of the Project Planning Team, Department of the Administrator, Port Moresby, provided many useful suggestions. Helpful comments on an early draft were given by Mr. P. S. Ferguson, and Mr. M. J. Phillips, of the Papua and New Guinea Division, Reserve Bank of Australia, Sydney.

REFERENCES.

BLALOCK, H. M. (1964). Causal Inferences in Non-experimental Research 200 pp. The University of North Carolina Press.

KARMEL, P. H. (1957). Applied Statistics for Economists 452 pp. Melbourne: Pitman and Sons.

A Study of the Malaysian Oil Palm Industry, with Reference to possible Development in Papua and New Guinea.

N. J. MENDHAM.*

ABSTRACT.

Even though large areas of fertile land with a suitable climate are available, no commercial planting of oil palms has been undertaken until very recently in Papua and New Guinea. The high capital requirement to set up a plantation and processing factory has been the main inhibiting factor. The very high and relatively quick returns from oil palms, combined with stable prices and sound market prospects, make this a most attractive crop for the Territory.

The industry in Malaysia is as advanced as anywhere in the world, and the factors contributing to this are examined. Good economic conditions and a favourable environment have stimulated the development of improved management techniques and planting material. The new tenera *material now being released is capable of very high yields. Improved germination and nursery techniques, assisted pollination and heavy fertilizing based on foliar analysis can all be used to achieve these yields. The use of leguminous cover crops and effective weed control also plays an important part, together with control of diseases such as* Ganoderma *Basal Stem Rot, and pests such as the Rhinoceros beetle.*

As well as obtaining high yields, there is much scope for keeping production costs low by using an efficient estate layout, by streamlining and mechanising of harvesting and other operations, and by efficient mill design and operation.

INTRODUCTION.

THE oil palm, *Elaeis guineensis* Jacq., is one of the world's major sources of vegetable oil. Its yielding ability is well above all other oil crops, especially when grown under good environmental conditions as in Malaya, and with modern genetic material. At an Oil Palm Conference conducted by the Tropical Products Institute (1965) it was considered that all palm oil entering world trade, for as far ahead as it is possible to foresee, should meet a ready market. The world price for palm oil has been mainly above $A200 per ton for many years, and is particularly stable due to the versatility of the oil in its many industrial uses. The price for palm kernels follows copra prices closely; the two having similar uses.

With large areas of land in Papua and New Guinea likely to be eminently suited to this crop, future development may be of great importance to the economy. The industry in Malaysia is expanding very rapidly at present, and is in a very strong position. Much can be learned from results and experience obtained there, with conditions similar in many ways to Papua and New Guinea. It is the intention of this paper to discuss the industry, emphasising these aspects of research and estate practice likely to be most applicable to this country.

Malaya had about 130,000 acres of oil palm in 1960, producing 120,000 tons of palm oil. Since then the increasing interest in the industry, sound economics and improved management techniques and planting material have combined to cause a rapid expansion in acreage and productivity. The planted acreage will pass 200,000 in 1966, and will continue to expand if the economic climate remains favourable. Gray (1963) gives the average yield of eight to ten year old Deli *dura* palms on the fertile west coast clays of Malaya as 1.5 tons of oil per acre per year, and many cases of fields producing more than two tons were noted. The improved *tenera* material planted in recent years should give considerably higher yields than this. Large areas

* Lowlands Agricultural Experiment Station, Keravat.

of coconuts and rubber, as well as new forest areas, are being replanted with oil palm, particularly on coastal soils. The coconut cannot compete with the oil palm on a well organized estate, and rubber produces its best yields on the better drained inland soils, where oil palm yields are usually lower (Gray 1963). The Malayan climate, with sunlight and rainfall plentiful and well distributed throughout the year, appears to be ideal for the oil palm ; much higher yields being obtained than in West Africa, where the palm is indigenous.

For efficient production, large scale processing is necessary, as with sugarcane, and it is generally held that the desirable minimum sized mill is one that will handle fruit from about 3,000 acres. The large expatriate companies have been the main planters in Malaya, with estates normally of 5,000 acres or more (*Plate* I), but settlement schemes run by the Federal Land Development Authority are of increasing importance. There is none of the West African type of smallholder production with fairly primitive production methods, mainly 'natural' palm groves and much home consumption of the produce.

Possible types of development for Papua and New Guinea would be either full scale estates operated by a large company, organized smallholder schemes, or small estates supplying a central mill and owned by individuals or smaller companies. A combination of these types may be the best way to begin an industry, since processing is normally more efficient with a large mill and fruit can be transported economically from 25 or even 50 miles away. The International Bank for Reconstruction and Development has suggested in its report (1965) the combination of nucleus estates and smallholder schemes, similar to that now being employed for tea in the Highlands.

Publications dealing with the oil palm industry in Malaya have been few until recently, but this position is changing, and several books are due to appear shortly. One, "The Oil Palm In Malaya" (Department of Agriculture, Malaya, 1966), deals broadly with the subject, and another, "Planting Techniques for Oil Palms in Malaysia" (Bevan, Fleming and Gray 1966) deals more directly with practical aspects.

All currency figures mentioned in this paper are in Australian dollars.

BOTANY AND BREEDING.

The oil palm is monoecious, producing alternate phases of male and female inflorescences on the one palm. A new frond is produced about every 14 days and may bear in its axil a male or female inflorescence or occasionally a bisexual one when sex phases are changing. Each female

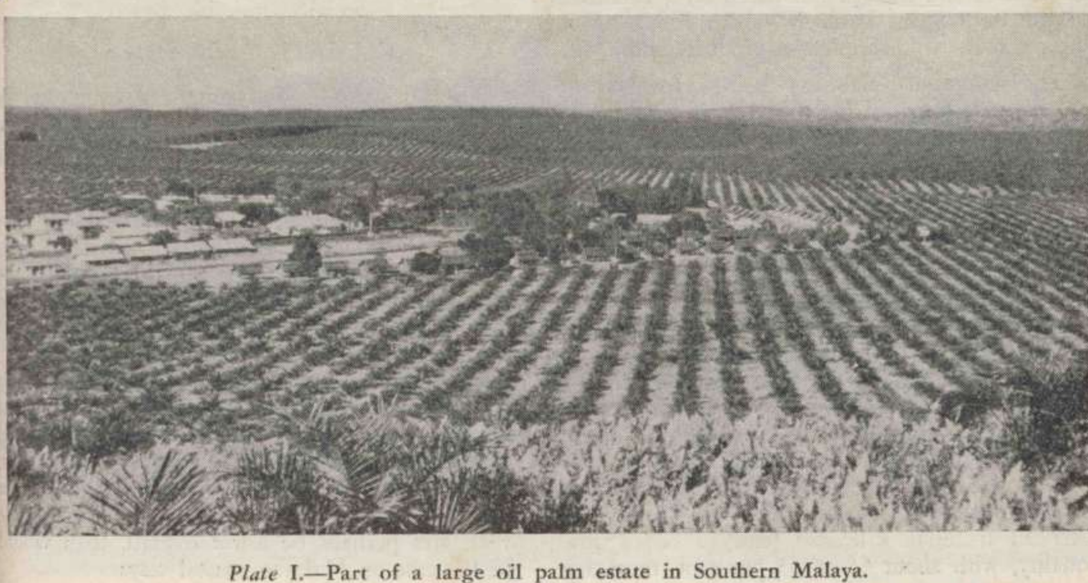


Plate I.—Part of a large oil palm estate in Southern Malaya.

inflorescence may bear 1,000 to 1,500 individual flowers, and each male many times this, but the whole structure is normally referred to as a 'flower'. The ratio of the number of female to total flowers in a given area is called the sex ratio, which is strongly influenced by environmental conditions, and tends to be lowered by any form of stress on the palm. Lack of female flowers tends to be a factor limiting yield in West Africa whereas lack of male flowers may be the main problem in Malaya, especially with young palms, leading to the use of assisted pollination techniques as an estate practice in many areas.

The fruit takes between five and six months from pollination to maturity. Palm oil is produced from the yellow fleshy mesocarp of the fruit, and the other main product is the palm kernel, which has similar properties and uses to copra. A hard shell, or endocarp, separates the two.

The varieties of the oil palm were described by Newton (1961). The most important classification is on shell thickness, the *dura* having a thick shell, the *tenera* a thin shell, and the *pisifera* no shell at all. The *tenera* type is a hybrid between the other two, and self pollinating a *tenera* will give *dura, tenera* and *pisifera* progenies in a 1 : 2 : 1 ratio, shell thickness being simply inherited. The oil palm industry in Sumatra and Malaya was based on a variation of the *dura* type, the Deli, which has a much thicker mesocarp, and hence produces more oil.

The tenera material now being grown commercially in Malaysia is derived from high yielding Deli *duras,* and *pisiferas* of Sumatran and African origin with a small proportion of Deli 'blood'. The female parents in the hybrid cross are the Deli palms since most pisiferas produce viable pollen but do not set fruit well. Pollen from the selected pisifera parents is dusted onto the receptive female flowers, with a number of precautions such as bagging the flowers being taken to avoid contamination from outside pollen. A good Deli *dura* (*Plate* II) may have 60 to 70 per cent. of the clean fruit as mesocarp, and 21 to 30 per cent. as shell, whereas a typical African *dura* may have about 46 to 56 per cent. mesocarp and 30 to 37 per cent. shell. *Teneras* produced initially from this African material will also tend to be of low quality, with about 55 to 65 per cent. mesocarp and 17 to 24 per cent. shell, whereas good commercial teneras in Malaya now have 75 to 85 per cent. mesocarp (Gray 1964 and personal communication). African *teneras* are being introduced into breeding programmes mainly because of their greater variability, and hence value in a long term breeding programme. It is expected that initial plantings in Papua and New Guinea will be all Malayan commercial tenera.

The Deli *dura* will normally give an extraction rate of about 17 per cent. oil in F.F.B., or fresh fruit bunches, whereas commercial *teneras* are now giving 22 to 24 per cent. Breeders claim that this can be lifted to 30 per cent. within four generations, or 30 years, which at 10 to 12 tons F.F.B. per acre would be a most attractive proposition.

Much breeding work in the past has centred around breeding short statured types, particularly using the 'dumpy' mutant of the Deli strain. However, the emphasis has shifted now to breeding high yielding teneras which come into full bearing at an early age, and which will probably be replanted at 20 to 25 years, before height is a limiting factor to efficiency of harvesting. The older Deli types were slow in coming into full bearing and still produced a worthwhile crop at 35 years, so replanting tended to be delayed as long as possible. Also, the availability of new high yielding material makes early replanting especially desirable now.

CLIMATE AND SOILS.

The oil palm is best suited to equatorial or wet tropical lowland conditions with the amount and distribution of sunlight and rainfall being most important features.

While a minimum of 70 in. annual rainfall is often quoted, and the best oil palm areas are usually in the range 80 to 120 in., the distribution is usually more important than the total. The lower limit of the ideal distribution will be very much influenced by soil type; heavy soils tending to modify the severity of a dry season. On most soils a dry season of about three months with a minimum monthly rainfall of 2 to 3 in. would be satisfactory, but palm yields on light sandy soils under these conditions may fluctuate more over the year, and perhaps be lower overall, than would be the case on Malayan coastal clays.

Plate II.—A good Deli *dura* palm being used as the female parent for commercial seed production. The female inflorescences have been bagged to prevent contamination by unwanted pollen during the receptive period.

The amount and distribution of sunlight should be considered in conjunction with rainfall figures. Measurement of sunlight as "hours of bright sunshine" is a useful guide, and desirable oil palm areas generally have 2,000 hours or more per year, with preferably not much below five hours per day in the minimum month.

The climate of Southern Malaya fits the above criteria very well, resulting in high yields, whereas the West African oil palm belt has a much less favourable climate, with a long distinct dry season and very low sunshine figures of less than three hours per day in several months of the wet season. Yields are mostly less than half those obtained in Malaya, with a greater seasonal fluctuation (Michaux 1961).

Oil palms are usually grown within 1,000 ft. of sea level, depending on latitude and local climate modifying factors, such as in the Congo basin where the main palm areas are at an altitude of between 1,200 and 1,500 ft. A temperature range of 65 to 90 degrees F., with a normal diurnal range of 70 to 88 degrees, is regarded as close to optimum. It may still be economic to grow palms under a wider temperature range, such as at higher altitudes or latitudes, but the effect of lower temperatures is usually seen as lower rates of growth and yield. Yields in the Congo are considerably lower than in Malaya, most probably due to lower night temperatures.

In selection of oil palm soils in Malaya, most emphasis is laid on soil physical properties and topography, with chemical fertility relatively less important. Rooting depth is one of the main criteria, and soils with a hard laterite band at less than 3 ft. are usually rejected. Coastal soils with a permanent water table at 2 ft. are considered marginal unless they can be drained, 3 ft. being usually considered quite good for the shallow rooting oil palm. A layer of up to 2 ft. of peat over the clay is considered satisfactory, particularly if the palm is planted in a hole to get its roots into the clay subsoil as quickly as possible.

Soil texture is of lesser importance, and any soil not subject to severe drought under the prevailing rainfall conditions would be considered suitable. The two main soil types used are the marine alluvial coastal clays, and the 'inland' soils which are red and yellow latosols and podsolics derived from granite or sedimentary rocks (Panton 1964). The granites have been the most used inland soils so far, and the sedimentary soils are of more variable fertility. One of the principal inland soils is granite derived, with a thin surface horizon of sandy loam and at least 4 ft. of sandy clay loam subsoil (Null, Acton and Wong 1965).

A slope of 12 degrees is considered marginal for a large area, although many estates have small areas of greater slope. The main problem on steep slopes is harvesting and fruit evacuation.

Most Malayan soils are quite acid. The coastal clays, which produce the highest yields, often have a pH of 4.0 to 4.5, and the inland soils about 5. The optimum for oil palms is often quoted as 5.0 to 5.5 and, with the shortage of data on oil palm yields on neutral and alkaline soils such as many in Papua and New Guinea, care will have to be exercized. Nutritional problems may be quite different on these types of soils.

Where the climate, topography and soil physical properties are suitable, then the highest fertility soils are preferred for development. The heavy yielding oil palm makes such strong demands on soil nutrient reserves that fertilizing is essential on most soils, at least after bearing for a few years.

Fertilizer use has been quite light on the coastal clays, so far, these having shown unusual powers of supplying nutrients, particularly potassium, but palms on a number of these soils are now responding to a range of nutrients (Gray 1963). On most other soils, fertilizing is now a routine practice, responses being found to many elements. Even poor soils, such as deep peats, can give good yields when properly fertilized, and it seems that initial soil fertility may not be of great importance. The ability to supply nutrients over a long period, and to use applied nutrients may be of greater significance.

GERMINATION.

The natural rate of germination of oil palm seeds is very low and many methods have been devised to increase this, mostly involving keeping seeds warm and moist until they germinate [Rees 1960(*a*)]. In Malaya, seeds were sown in sandbeds, which were hand watered, relying on solar radiation for heat, whereas in West Africa the best methods were based on the W.A.I.F.O.R. developed electrically heated germinating chambers (Rees 1959).

The best method now is the 'dry heat' method which is being used extensively in Malaya, and involves heating the seed at 38 to 40 degrees C. in one of these germinating chambers, but at a moisture content of 16 to 18 per cent. of dry weight, which is too low for germination. Rees [1960(*b*)] showed that the high temperature requirement of oil palm seed could be fulfilled at a low moisture content. The standard method now is to heat the dry seed in sealed polythene bags for about 40 days for seed that has been stored after harvest for about four months, or somewhat longer for fresher seed. Seeds are then soaked to bring them up to the required moisture content, which is about 22 per cent. for *tenera,* and then kept moist in sealed polythene bags until they germinate. Normally 85 to 95 per cent. should germinate within a month of soaking, whereas with the older 'wet heat' method 80 per cent. germination within three months was considered good. The wet heat method also gave a high incidence of 'Brown Germ', a fungus infection of the germinating seed.

Seed can be supplied by the main Malayan producers either fresh, 'preheated' with dry heating but not soaking carried out, or 'pregerminated' ready to plant. Pregerminated seed is supplied to most estates now, and this is probably the best method if transport can be arranged, and receiving facilities on the estate are adequate. Seed for some of the new estates in Sabah was airfreighted from Malaya, and this may be possible for Papua and New Guinea also, but if not, preheated seed can be used. Seed recently imported to the Territory has been sent by air in this form, and can be kept for about 30 days before soaking, or longer if maintained at about 15 per cent. moisture content.

Germinated seeds are removed during weekly inspection of the polythene bags, and these are kept moist for a further seven to ten days in sealed bags until the root and shoot can be clearly distinguished. The shoot is short and sharp, whereas the root elongates first, and has a blunt end covered by a rough root cap. Seed can be kept for two or three weeks after germination if handled carefully. 'Twins', or seeds with two germinating embryos, are best handled by rubbing off one, rather than trying to grow both seedlings and later separating them.

NURSERY TECHNIQUES.

The main methods now being used in Malaya are the older, though still widely used field nursery, and the more recently developed system using polythene bags. The field nursery is established by planting out young basketted seedlings at a 3 ft. spacing in a suitable area (*Plate* III). When palms are old enough to be planted out, they go through a root pruning process before lifting and transport to the field. The main polythene bag method until recently has been to grow seedlings to the four-leaf stage in small polythene bags as a prenursery and then transplant to larger bags for the main nursery stage. More recent work indicates that it may be desirable to plant germinated seed straight into the large polythene bags, and eliminate the prenursery.

The field nursery method is not really suitable where no clay soils are available, as it depends on being able to dig the seedling out in a block of earth which will then hold together until it can be planted in the field. A number of small trials have indicated that there is substantially increased early growth in the field from polybag palms compared to field nursery palms, probably due to a reduction in transplanting shock and elimination of root pruning.

Even without considering the growth differences, many people claim that the other advantages of the polybag system, such as simplified management and easier and more flexible arrangements for field planting, make it well worth while adopting as standard. The polybag nursery can be on a permanent site with an irrigation system installed (*Plates* IV and V), and the whole nursery and field planting operation can be independent of weather conditions. The field nursery must normally be shifted each year to avoid soil-borne diseases. Polybag seedlings can be transported easily, and the nursery spacing can be adjusted from close initially to conserve moisture to a wider spacing when the fronds begin to mesh. Nursery costs with the two methods up to field planting have been similar.

Plate III.—A field nursery. The palms in the background are about 35 years old, and due for replanting.

The Polythene Bag Method (no Prenursery).

This method, as developed by the Harrisons and Crosfield Research Station, eliminates the prenursery, as recent trials have shown quite marked improvements in growth, and at least two months should be saved. Uninterrupted growth is apparently desirable from germination to field planting; any disturbance such as the transplanting from the prenursery acting as a check on growth.

The polybags should be 15 x 20 in., and of .005 gauge polythene, with holes punched on the lower half. These are filled with loam top-soil; about 35 lb. per bag. A clay loam soil is preferred, as a sandy loam can be too free draining, possibly increasing susceptibility to Blast disease. The seed is planted in a small hole in the soil surface, orientated with the root pointing down and the shoot up, and covered with about half an inch of soil. A twisted seedling will result if the seed is planted up-side-down.

Light temporary shade should be provided until the seedlings are at the two-leaf stage, when it can be gradually removed over a two-week period, leaving them exposed to full sunlight thereafter. Seedlings should be watered daily, either by hand or with a sprinkler system. The young seedlings can be fertilized by watering with a 1 per cent. urea solution, washed off the leaves with water. After about the four-leaf stage, half to one ounce of one of the compound NPKMg fertilizers or a similar nursery mixture can be applied per month, increasing to 2 oz. after about seven months.

Nursery selection is highly regarded in Malaya, up to 30 per cent. of seedlings often being discarded. Obviously poor types can be removed after a few months, the main ones being 'grass leaf' types with long, narrow, rolled leaflets, and those with twisted leaves, usually planted up-side-down. A final selection is then made before field planting, the following being the main additional types rejected:—

1. Runts;
2. Sterile types, usually with acute angled leaflets and a coarse habit of growth;
3. Types with leaflets either very widely spaced, or bunched together, at the end of the frond particularly;
4. 'Flat top' types, where the centre leaves have not grown as well as the outside ones; and

5. Those with leaflets still fused together after about nine months, referred to as 'idolatrica' types.

Prenursery Method.

This has been the main polybag method used until recently. Germinated seeds are planted in 6 x 9 in. polybags, and raised in these to about the four-leaf stage, when they are transplanted into larger bags, using a similar technique to that described below for the planting of large bag seedlings in the field. The method is otherwise very similar to that already described. Space, labour, water and fertilizer are saved in the early stages, but this appears to be more than offset by the retarded growth.

Pest and Disease Control.

No spraying should be done before the first seedling leaf has developed, or injury may result. Outbreaks of leaf spot diseases can be controlled if recognized at an early stage, and sprayed at weekly intervals, with Captan or Thiram at 0.2 per cent., until new growth is free from infection (P. D. Turner, personal communication). An insecticide such as dieldrin can be used for caterpillar or other leaf eating insect attacks. Red spider outbreaks should be treated with an acaricide such as Tedion or a systemic insecticide such as Rogor or Metasystox, as dieldrin may only increase the pest.

'Blast' (see diseases section) must be guarded against by adequate watering and possibly shading, as the disease can be very severe, causing heavy losses in polybag nurseries.

FIELD ESTABLISHMENT.

The normal method of clearing forest is hand felling, then stacking and burning. If the cover is light secondary forest or grass, burning may be better avoided, especially on light soils. The palms and cover crop are planted among the logs, which are rearranged as much as possible to give the required spacing. Where logs are too heavy to shift, the planting points are adjusted in one direction only, to try and keep lines straight at least one way. If timber can be handled by a bulldozer, it may be desirable to clear it into, for example, every second row space, enabling mechanized maintenance and speeding up other operations. If this is not done, paths may need to be cut along alternate interlines by removing sections of logs with a chain saw, normally just before harvesting starts.

Plate IV.—A polythene bag nursery, with the different crosses kept separate and labelled.

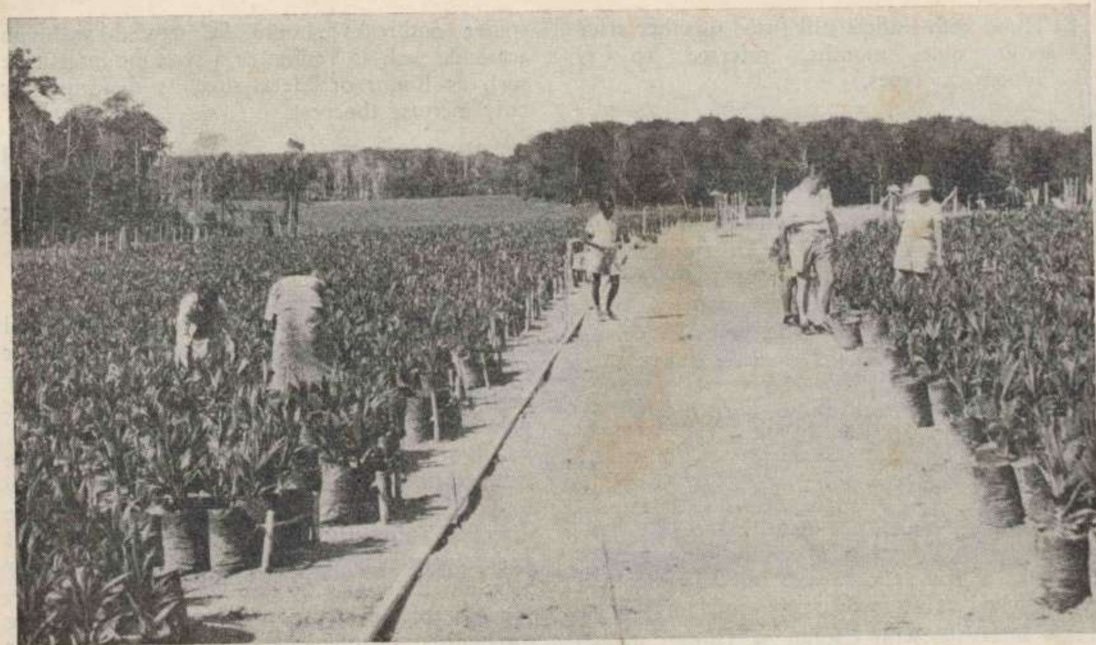


Plate V.—A large nursery with water supply installed. An area of established cover crop can be seen in the background.

Planting.

Field planting can be done with palms over a wide age range of roughly 6 to 15 months. The 15 x 20 in. polybag should be adequate for 12 to 14 months growth in the nursery, but if earlier or later planting than this is intended, smaller or larger bags could be used. Palms planted at earlier than 12 months may give very good results, as found by Gunn and Sheldrick (1963) in Africa with seven-month-old seedlings, but they may be liable to rat or other pest damage. If early planting has to be done and rat damage is likely or does occur, strong wire mesh collars can be used, combined with a baiting programme.

Several times in the last few weeks before planting bags should be lifted and turned around to prevent roots growing into the soil below. Palms should be watered heavily just before transport to the field. The planting hole needs to be no bigger than to take the polybag on light soils, but a larger hole filled with topsoil is often recommended on heavy soils. The bottom of the polybag is cut away with a razor or knife before placing in the planting hole, and then the side of the bag is slit. Earth is filled loosely around the bag which is then carefully pulled out, and the earth firmed. These measures are taken to minimise transplanting shock. Palms should be planted no deeper than in the nursery, or growth may be retarded.

Replacing of undesirable types or damaged palms, or ' supplying ', is usually done up to two or three years from planting.

Spacing.

The recommendations in Malaya have been a density of 49 per acre on the more fertile coastal soils, and 55 per acre on the inland soils, but recent Harrisons and Crosfield experiments have indicated that while this may give near to maximum yields from mature palms, early production can be improved by closer spacing. A standard density of 58 per acre (9 meter spacing) was used in Sumatra. While the yield of mature palms may vary little between 40 and 70 per acre, there is a close to linear increase in total yield for the first ten years over this range. A compromise density of 60 per acre has been recommended while results of further trials are awaited, and this would probably be the best for Papua and New Guinea also, giving a 29 ft. triangular spacing. It seems that conditions of less sunlight and higher soil fertility tend to make wider spacings more desirable, and the relative importance of the two in an area will influence the optimum spacing.

It was thought that thinning of an initially denser stand would be desirable, but further work showed that the stand took at least two years to recover, and that thinning is probably uneconomic.

COVER CROPS.

Most rubber and oil palm estates in Malaysia use leguminous cover crops, at least in the first few years after planting. The general policy is to sow a cover mixture, usually *Pueraria phaseoloides*, *Calopogonium mucunoides* and *Centrosema pubescens*, and to maintain this carefully with a thorough weeding programme (*Plate* VI). As palms grow up and shade out the legumes, usually in five to seven years, the policy is switched to keeping a natural cover free of noxious weeds, and usually maintaining it by hand slashing.

Many reasons are given for this emphasis on cover crops, and these are of varying importance under different conditions.

1. *Weed Control*. If this is the major purpose of the cover, the alternatives of hand, or mechanical slashing of a grass cover should be considered, as legume covers are expensive to establish. Pueraria seems to require more maintenance to keep it as a pure stand in Malaya than it does in Papua and New Guinea, and this may mean that the weed control function is of less value in Malaya.

2. *Pest Control*. Covers have been shown to play an important part in Rhinoceros beetle control. The number of larvae found in logs under covers is very much less than that in exposed logs and it seems that beetles cannot find breeding sites.

3. *Soil Cover and Erosion Prevention*. This is especially important in hilly country, and with light soils subject to washing, structure breakdown and organic matter loss.

4. *Effect on Soil Fertility*. All legumes do not necessarily have a positive effect on yield, and even the proven species need effective nodulation before they can make any contribution to nitrogen nutrition of the palms. Experiments on the coastal clays (Harrisons and Crosfield Annual Report, 1963) have shown the creeping legumes to give the best yields followed closely by bushy legumes, then grass and the native fern *Nephrolepis biserrata*, with the common broad-leaved weed *Mikania scandens* giving very poor results, similar to *Stylosanthes gracilis*. *Mikania* has been shown to have a growth inhibiting effect (Wong 1964), whereas Stylo appears to be strongly competitive for water and nutrients. It appears that under these conditions use of a cover crop including creeping and possibly bushy legumes will give best results. If the yield losses with a cover such as mechanically slashed grass can be made good economically with fertilizer, then it may be better not to use legumes.

The method generally used in Malaya to establish a first class cover is to clean weed the area first, and then sow the legume mixture in about three rows down each palm interrow. The seed is inoculated with the appropriate *Rhizobium* strain, and sown with a starter dose of fertilizer. The area is kept clean weeded until the legumes are established, usually about two months, and then selectively weeded until a good cover is obtained. After the first year, selective weeding is confined to removal of undesirables such as Lalang (*Imperata cylindrica*), Mimosa, Mikania and woody species. Circles of about 6 ft. diameter around young palms are normally kept clean weeded and clear of cover crop.

Species.

Pueraria phaseoloides has been the main legume used, and has generally given very good results, in estate practice and also in experiments, where it has been used as a standard to judge other covers by, as in the experiments mentioned above. It is slow to establish though, and *Calopogonium mucunoides* is usually used with it to give a quicker early cover. *C. caeruleum* is a promising alternative. *Phaseolus sublimatus* and *P. calcaratus*, both annuals, were seen used on several estates as a replacement for Calopogonium, and Siratro, *P. atropurpureus* may be

Plate VI.—An area of young palms with a good leguminous cover crop.

even better. *Centrosema pubescens* is commonly the third component of the mixture, and forms a useful addition to Pueraria in the permanent cover. *Desmodium ovalifolium* is very similar in habit to Centrosema, and is probably more shade tolerant. It was seen to be vigorous on several estates in Sabah and may be a useful alternative to the virus susceptible Centro in Papua and New Guinea.

The bushy *Flemingia congesta* has been shown in the experiments mentioned to have almost as good an effect as Pueraria on crop yield. It has rather uneven germination and is slow to establish, but produces a large quantity of mulch and suppresses weed growth well. A definite reduction in Rhinoceros beetle damage has been shown over treatments with creeping covers. if it is allowed to grow to 4 or 5 ft. This is apparently due to restriction of the beetles' flight as well as a reduction in potential breeding sites. Flemingia is sometimes used in a mixture with Pueraria, especially if beetle damage is likely or regular weeding doubtful, but it should not be sown on or near harvesting paths. *Tephrosia noctiflora* has similar characteristics to Flemingia, but is quicker to establish, faster growing and less permanent.

Stylosanthes gracilis, as mentioned above, has had a fairly severe effect on palms, due apparently to a combination of moisture and nutrient stress, with the former more important on lighter soils and hilly ground, and the latter on the coastal clays. In most trials the seed was not inoculated with the approved *Rhizobium* strain, and much of the nutrient stress may be due to lack of nitrogen fixation. Stylo also puts down a deep taproot from the seed, and then more shallow roots from the nodes as it spreads, and propagation from cuttings may eliminate much of the moisture stress effect. It could be a valuable cover, as it is very easy to establish and maintain.

Upkeep in Mature Areas.

As mentioned, the cover crop is eventually shaded out, and a natural cover is usually maintained by hand or mechanical slashing with removal of undesirable species. A special point is made of eradicating lalang. The main method used was to spray sheet lalang with sodium arsenite, but the use of dalapon followed a few weeks later by paraquat is often recommended now. Small clumps can be eradicated by spot spraying, forking, or wiping with lalang oils. When harvesting starts, usually in the third year, paths are cut down alternate interlines, and these are kept clean weeded together with a circle around each palm about 8 ft. in diameter. Upkeep methods used are hand weeding, herbicides or both ; the decision as to which method to use being mainly based on costs. Herbicides are mainly used in Malaysia, and the principal one used in the past was sodium arsenite. This is very dangerous to users, and a newer method employing a combination of paraquat and amitrole is now being used on many estates (Headford 1965). The usual procedure is to spray amitrole first, at two pints per sprayed acre in about 20 gallons of water, and then two to four weeks later spray paraquat, at the same concentration. The formulations used of both these herbicides have 20 per cent. active ingredient. Two of these treatments per year should be adequate, and even just one double spraying and one or two single applications of one pint of paraquat may be enough in mature areas with fairly heavy shade.

CASTRATION.

The removal of male and female inflorescences on very young palms before they have matured or set fruit is a growing practice in Malaysia. The main reason why this is being done is that any bunches produced before about 30 months in the field are very small, have a low oil content and are expensive to harvest, as a large area must be covered to cut a few bunches. These bunches are also rarely pollinated properly, making the palm susceptible to attack by *Marasmius palmivorus,* a fungus which destroys bunches (see diseases section). Infrequent harvesting also encourages rats.

Palms are castrated monthly from about 14 to 26 months on many Harrisons and Crosfield estates, and thus the first crop comes in evenly at 31 to 32 months. Returns are most probably increased over the first few years, and at least little or no crop will be lost. Castrated palms also have sturdy vegetative growth, with a thickened trunk.

The effect of castration on commercial areas has been generally to produce a large number of female flowers after the treatment ceases, and hence increase the need for assisted pollination. Prolonged castration, when ceased suddenly, leads to a very large number of bunches in the first few months cropping which can in turn lead to over-stressing and the palm may enter an extended male phase. If prolonged castration is carried out, it seems that the palms should be allowed to come into production more slowly by partially castrating for a period, where only a limited number of bunches are allowed to develop.

While the need for assisted pollination may be increased by castration, the treatment is likely to be building a palm which, with an adequate nutrient supply, can stand up to the heavy early cropping that assisted pollination ensures, without undesirable effects on the sex ratio or later bearing life of the palm.

The case for relatively mild castration up to about 26 months seems well established, but more prolonged castration is probably only desirable on new estates. It is not usually economic to begin factory operations before the first year's planting is about four years old, and hence castration may be carried out up to 42 months if no alternate processing facilities are available.

Experimental work on castration has been limited, but a small Harrisons and Crosfield trial running since 1960 has shown no adverse effects on the palm. More critical experiments are just starting to produce results, and data on castration combined with assisted pollination and fertilizers should be forthcoming shortly.

ASSISTED POLLINATION.

The sex ratio of young palms up to about eight years old tends to be very high in Malaysia, which means a low rate of male flower production, causing low and uneven fruit yields. The reasons for this appear to be a combination of good environmental conditions and high yielding modern genetic material. The effect of the poorer climate in West Africa has been mentioned, drought particularly increasing the number of male flowers, and low sunlight inhibiting formation of female flowers. Soil fertility also has an effect and the problem in Malaya appears to be less acute on the poorer inland oils, though the increasing use of fertilizers is probably making pollen shortage a limiting factor on the yield of young palms there too. Generally it seems that some form of stress on the palm, such as that caused by low sunlight or soil moisture, less fertile soils, close pruning and heavy bearing, will produce a lower sex ratio.

Almost entirely female flowers are quite often produced initially on new estates or large new plantings in Malaya. Unless outside pollen is brought in, these bunches will be unpollinated and palms may produce female flowers indefinitely. Not only will no fruit be produced, but also an attack by *Marasmius* is likely, and this is expensive to eradicate and has a severe effect on the palm. If assisted pollination is carried out, fruit setting, which imposes a stress on the palm, takes place and quite quickly some male flowers are produced.

Gray (1966) discusses an experiment carried out to determine the effect of assisted pollination on yield and other palm characteristics. Unfortunately for the experiment, over the total five-year period male flower counts were not really low, and hence the yields over the whole period were not significantly greater with assisted pollination. Four, eight and twelve pollination rounds per month were compared with a natural pollination control, and commenced on three-and-a-quarter-years-old Deli palms. The main effect on bunch yields was to even out the large fluctuations over the year as obtained in the control treatment, a very desirable effect for factory and estate organization. When the peaks and troughs of yield in the control treatment were compared with male flower production five months earlier, a close correlation was obtained, indicating the direct effect of pollen availability on yield. Bunch weights in the pollination treatments were increased but a reduction in frond production and increase in inflorescence abortion gave a lower number of bunches. Pollination had a marked effect on the sex ratio, with the most intense treatment producing 40 per cent. more male flowers than the control over the whole period.

Several larger experiments with less danger of outside pollen masking the treatment effects, and sited in areas more liable to low male flower production are underway. It is hoped to more closely simulate estate conditions, where large areas of palms with really low male flower production occur, and where very substantial yield increases are obtained with routine assisted pollination.

Assessment of the need for Assisted Pollination.

The experiment referred to above indicated that male flower production at the time female flowers are receptive has a direct effect on yield. Actual pollen availability is then determined by male flower number and distribution, modified by weather conditions. This has been used for some years on estates in assessing the need for pollination, in conjunction with inspection of the actual fruit set obtained, and a number of ways of estimating male flower production are used. A commonly used ' rule ' is that pollination is necessary if less than 15 male flowers are produced per acre per month in areas over about five years old. Sometimes a higher figure is used for younger areas, with flowers close to the ground and more screening by fronds. Another rule used was that if all male flowers in an area, both ripe and pre-ripe, are counted at the one time, less than about 18 per acre may indicate a need for pollination. Of the 18, about six would be ripe and shedding pollen.

The number of palms producing male flowers may be a better guide to availability than just the number of flowers, since production can be all from a few palms, and the wind borne pollen apparently does not travel effectively more than about 100 ft. Distribution over the area rather than total quantity may be the problem. One figure quoted was that assisted pollination could probably be ceased when about 40 per cent. of palms are producing male flowers.

The characteristics of the aerial environment, namely windspeed, temperature, humidity and rainfall, modify pollen availability at any one time. The 100 ft. distance mentioned for effective pollen travel is under normal low windspeeds on the West Coast of Malaya, and more air turbulence will increase the range and effectiveness of pollen distribution. Diurnal pollen distribution, as measured with a Hirst Spore Trap, tends to follow the temperature curve directly and the humidity curve inversely. In other words, pollen is most available on warm sunny days, and least on rainy days, and at night. Some people claimed that best fruit set was obtained in the drier months, due to increased pollen availability rather than more male flowers.

If the relationships between male flower number, weather conditions and fruit set are known, an intelligent assisted pollination programme can be applied. The success of fruit set can be determined as early as two weeks after pollination, when the developing fruit has a squat, glossy appearance, whereas with initial parthenocarpic development, the unfertilized 'fruit' is narrower, and dull black.

On palms of five to eight years old, pollination may have to be done for eight months of the year or less, whereas younger palms may require it for the full 12 months. One estate on fertile volcanic soils has been regularly recording less than five male flowers per acre per month on three to four year old palms, indicating a need for year round pollination. These sort of levels are likely in Papua and New Guinea under similar conditions of good soil and climate.

Practical Application.

A number of trials have been carried out testing various devices for pollen distribution, but the simplest has so far proved to be the best. It consists of a small plastic bottle with some form of perforated lid, such as a piece of muslin stretched across the top. Pollen is dusted onto the receptive inflorescence by shaking or squeezing the bottle, and this is often called the 'pepperpot' method (*Plate* VII). When palms have grown too high for bunches to be reached, at about six years old, a variety of devices are used, such as one with an aluminium tube and rubber bulb.

Since the female flower is receptive for about three days, pollination rounds will have to be done this often if all bunches are to be fully pollinated, and where no natural pollination occurs. In practice about eight rounds per month is adequate, with less than five rounds usually of little value.

Pollen is usually obtained the previous day by cutting off male flowers, and drying either on a sheet of paper in the sun, or in a simple oven, with for example electric light globes to supply the heat. If in short supply, it can be diluted by using ten parts talc to one part of pollen. If pollen is likely to be in short supply for a programme, as on a new estate being planted up quickly, a 'pollen garden' can be established. An area of palms planted densely at about 15 ft. spacing, and pruned heavily, will produce mainly male flowers. If this source is relied on for all pollen supplies, about 3 per cent. of the estate area may have to be used, and the planting of at least a few acres has been recommended for some new estates.

With an efficient system, costs have dropped from about 8c per acre per round to less than 4c, which at eight rounds per month over the whole year is about $3.75. This is the total cost, including collection of pollen. One of the reasons for the cost reduction is that pulling back the sheaths surrounding the female flower was shown to be unnecessary, and now pollen is just dusted onto inflorescences which look to be receptive, without a close inspection. It does not matter if some are done twice. The usual practice is for the pollinator to scratch his initials and the date on the frond base subtending the pollinated flower, and this too can be omitted, though it does serve as a check on work.

An Alternative.

On a number of new Harrisons and Crosfield plantings, an alternative or at least addition to assisted pollination is being tried, and involves planting extra palms for the sole purpose of supplying pollen. An extra palm is planted 12 ft. in the row from every fourth palm in every fourth row, giving close to four extra per acre. The close spacing should encourage male flower production in both palms at each point, and the extra palm will be pruned heavily. Even if this treatment is not fully effective, it should at least cut down the amount of hand pollination required, and the extra palms can also be used as a source of pollen. Every palm will be within about 60 ft. of one of these 'pollinator palms'. After about eight years, or when the need for the extra palms is past, they can be cut out.

FRUIT RIPENING AND HARVEST.

The process of fruit harvesting and evacuation to the mill usually represents up to two-thirds of the annual field running costs on a mature estate, so the importance of an efficient system is obvious. The efficiency will be determined by the yielding characteristics of the palms as influenced by age and season, and by the estate layout, equipment and labour used.

Variation in Yield.

The yield variation due to age of the palm will follow a pattern such as that given below, based on figures for some of the early D x P material on average inland soils in Malaya (Chemara 1964), with estimates after the sixth year.

With more fertile soils and new D x P material, yields should be higher, and reach an earlier peak.

The effect of the environment on the sex ratio has been mentioned. Workers in Africa have generally shown that variations in sex ratio follow the seasonal trends at the time of sex differentiation, which is about two years before flowering there (Sparnaaij, Rees and Chapas 1963). High sunlight intensity particularly

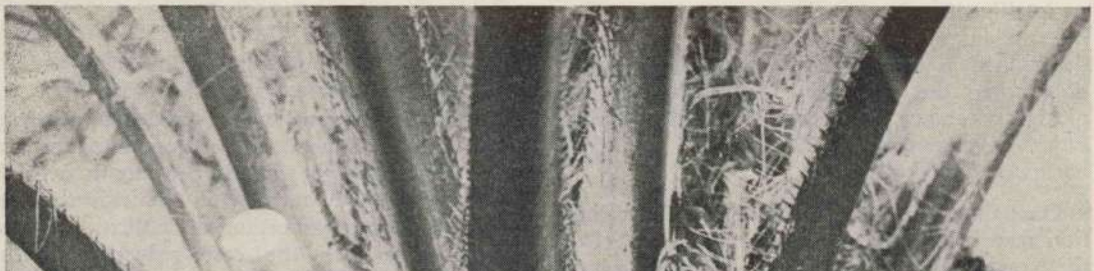


Plate VII.—Assisted pollination using a simple hand method. Such good fruit set on young palms may only be possible with assisted pollination.

Palm year in the field.	F.F.B./acre tons.	Per cent. Oil to F.F.B.	Oil/acre tons.	Kernels/acre tons.
3 (24-36 months)	0.5	14	0.07	0.02
4 (36-48 months)	3.6	16	0.6	0.16
5	6.3	17	1.1	0.28
6	8.7	18.5	1.6	0.42
7	9.2	20	1.8	0.46
8	9.7	21	2.0	0.48
9	10.0	22	2.2	0.50

appears to favour differentiation of female flowers. The effect of climate in the last 12 months before harvest on yield is also quite marked (Hemptinne and Ferwerda 1961), where drought tends to make inflorescences abort, and has an effect on pollination, fruit set and fruit development. A three-year-yield cycle is generally found in West Africa (Haines 1959), where peak yields occur when a high sex ratio in the palm coincides with optimum climatic conditions for fruit set and development.

Few studies of this type have been done in Malaya, but the climate produces a much higher sex ratio than in Africa and the limiting effect of climate is mainly in male flower production while the palm is young. Drought is a very minor factor in Malaya, on the coastal clays at least, and yield variation is generally very much less than in Africa. Whereas in Malaya 10 to 12 per cent. of the yearly crop may be in the peak month, and 6 per cent. in the lowest month, the corresponding figures in West Africa may be 15 per cent. and 3 per cent.

Fruit Ripening.

The fruit in the crown of the oil palm bunch usually ripens first, and the last fruit 8 to 18 days later, with the longest period for young palms. The oil content in the mesocarp of the fruit rises to about 52 per cent. when fully ripe, but may be only 30 per cent. in unripe fruit at the base of a bunch even when the top fruit are ripe.

After ripening, fruits tend to drop off the bunch, and any damage such as cutting or bruising will result in a rapid rise in free fatty acid (F.F.A.) content at the damaged surface, due to enzyme breakdown of the oil. Hence, the more fruits that are ripe at harvest, and the more damage a bunch is subject to in cutting and transport, the higher the F.F.A. content will be in the extracted oil. Since the price for palm oil is based on 5 per cent. F.F.A., with a premium or penalty for each 1 per cent. below or above this figure, it can be seen that a compromise between oil content of the bunch and F.F.A. of the product must be reached, as each bunch is harvested as a unit. Another compromise must be made between the value of the oil in the bunch and the cost of harvesting and transporting it. Each bunch would have its maximum oil value on a single day, but it is not possible to harvest the whole estate each day. On a weekly round, a fifth of the estate might be harvested each working day.

Once a harvesting round to give the desired quality has been worked out, a standard of minimum ripeness needs to be established for the cutters. Often, when a seven to ten day round is used, the standard may be at least as many loose fruit on the ground as the bunch weighs in pounds, for example 30 loose fruit for a 30 lb. bunch. Where the round is longer, or palms are younger the standard may be set at a smaller number of fruit. The evacuation system will also be taken into account, since more handling and a longer time in transit will mean increased F.F.A. An estate with a less efficient system may have to set their standard at a lower number of loose fruit to produce the same quality oil.

The Cutting Operation.

A chisel is normally used for harvesting young palms (*Plate* VIII), then often an axe until the bunches are out of reach from the ground (*Plate* IX), and then a curved knife on a bamboo pole (*Plate* X). A recent pruning experiment, referred to in "The Oil Palm in Malaya", has reinforced the general recommendation that at least the frond below the developing bunch should remain until the bunch is harvested. With young palms the removal of as few leaves as possible is probably desirable until the lowest bunch is about 3 ft. from the ground. This is best done with chisel harvesting. Fronds below the lowest bunch, not removed during the harvesting of mature palms, usually subtend a male flower or aborted female and can be removed by the harvesters or by a special pruning gang.

Plate VIII.—A chisel being used on a young palm, about four years old, in this case for light pruning.

The harvester usually cuts away any hindering fronds, and then cuts the ripe bunch, letting it fall to the ground. Normally he should be able to cut about 90 bunches per day in older areas or about 200 in young areas bearing well. He is usually paid a rate based on number of bunches and height of palms.

Fruit Evacuation.

This hotly debated subject was dealt with in a seminar recently (Sabah Planters' Association 1965). The estate layout, and method and equipment used, have a large influence on cost of oil production.

Most estates use teams of collectors, who carry the bunches and loose fruit in baskets to the nearest collection point where it is loaded for transport to the mill (*Plate* XI). The methods vary from a pair working together cutting and carrying fruit, to collection gangs separate from the cutters. One estate using teams of three women finds that each team can cover about 15 acres per day, or 24 in young areas. A typical arrangement might be with a harvesting path down every second interline, with an average distance of 15 to 20 chains between roads, to give a maximum fruit carry of 7 to 10 chains to the nearest road. Collection points are spaced along the roads ; for example one for each three harvesting paths.

Varying methods are used for transporting fruit from the collection point to the mill. The main ones are either a light railway network, or a complete road system employing combinations of trucks and tractors and trailers, or a mainline rail system supplied by tractors and trailers. Many other systems are found, for example on one estate where fruit is collected with a rail network and then loaded into trucks for road transport to the mill, which is some miles away on a separate estate.

It is rather unlikely that a railway would be used on a new estate now and most of those used in Malaya were established pre-war, when

Plate IX.—Axe harvesting can be started when the lowest bunch is more than about three feet from the ground.

[Photo : B. S. Gray]

Plate X.—Harvesting of a tall palm, about 35 years old, using a curved knife on a bamboo pole. Normally palms would now be cut out and the area replanted before this age.

costs were much lower. On the West Coast of Malaya, with flat land and heavy clay soils making roads difficult in wet weather, a rail system may be still economic and desirable, but the heavy initial capital cost will probably prevent their use in other areas. Quoted costs for laying a rail network were about $6,500 per mile. One estate has 52 miles of railway on 9,000 acres, another 190 miles on 21,000 acres. Good estate roads in Malaya, fully drained and surfaced with laterite, will usually cost between $700 and $2,400 per mile, depending on terrain. Fruit shells and boiler ash are widely used, although these are not usually available for initial road construction. Even if a rail system is installed, a road network is still needed for inspection purposes, transport of labour to work, and many other jobs where the railway is too slow and inflexible.

The layout of the road network is a most important factor to be considered in planning a new estate, as it can limit the efficiency of a collection system for at least 20 years. Improvements such as mechanized collection may not be used to full effect on a layout designed for a different system. Normally harvesting roads are spaced at an average distance of 15 to 25 chains apart, with main roads crossing them about every half mile to a mile depending on topography and factory location. A study was made of the variables involved in choosing the optimum harvesting road spacing (a paper presented at the seminar mentioned above). With the present hand collection system the data used gave an answer of between 17 and 27 chains, depending on whether the object was to achieve minimum costs per ton F.F.B. or maximum return on invested capital.

Prospects for mechanizing the bunch cutting operation seem slight, as quite a degree of skill and judgement is involved and an efficient job can be done if no carrying is done by the cutters. The main scope for mechanizing harvesting would appear to be in replacement of manual fruit carrying by vehicles, which can be loaded by hand as they pass down the interlines. For this to operate on a new estate, logs and stumps would have to be cleared out of every fourth interline, for example, to enable passage of a tractor and trailer. If other mechanized operations such as maintenance and fertilizer spreading are also envisaged, clearing of at least every second interline may be necessary. Where mechanized collection is intended or likely, it should be taken into account when planning the estate, as the optimum distance between roads will be increased considerably. An advantage of mechanized collection is that fruit handling can be reduced, enabling the cutting of more mature fruit without a decrease in oil quality.

NUTRITION.

The oil palm, being such a heavy yielder, will often respond very well to fertilizers, and large quantities are now being used on Malaysian oil palm estates. The palm makes particular demands on potassium, with magnesium, nitrogen and phosphorus also important among the major elements (Rosenquist 1962). Boron and some other minor elements are also important in many individual cases.

The techniques of leaf sampling and analysis, which are used as a guide to fertilizer requirements, were initially developed in Malaya (Chapman and Gray 1949) and Africa (Broeshart 1954), and have been widely applied since in most oil palm growing countries. Much of the fertilizing carried out in Malaya is based on recommendations made from leaf analyses, in conjunction with field experience, visual observations and experimental results where available. An outline of sampling and analysis techniques, critical levels used, visual symptoms of deficiencies and the requirements of the main Malayan soil types is given in " The Oil Palm in Malaya ". Most of the leaf analysis and fertilizer advisory work in Malaya has been done by Chemara, who run an advisory service for estates. Harrisons and Crosfield hope to provide a similar service in 1966.

Recommendations were noted, for individual fields, of up to 30 lb. of a fertilizer mixture per palm per year, and many areas were receiving at least 10 lb. per palm, particularly on the less fertile inland soils. Experiments mentioned in " The Oil Palm in Malaya " showed that 12 lb. of fertilizers could maintain yields economically at about nine tons F.F.B. per acre per year on granite derived inland soils.

To obtain true optimum leaf nutrient levels, other factors such as soil moisture, sunlight, drainage, pests and diseases would have to be non-limiting to growth and yield. Since this is the exception, optimum levels vary with different

Plate XI.—Counting fruit bunches, and loading them for transport to the mill.

areas, climatic conditions and soil types. The levels used in West Africa are usually lower than those used in Malaya, due mainly, no doubt, to the poorer climatic conditions (Ruer 1966). The levels used by Chemara have tended to rise in recent years, with improved management and planting material.

Levels vary with the age of the palm, and with the particular frond sampled. The standard procedure now used is to take a sample from the middle leaflets of frond number 17, taking the newest fully opened frond as number one. Frond 17 is in the second row of fronds, below frond one, and is normally about eight and a half months old. The sort of tentative optimum levels used are as follows (quoted in "The Oil Palm in Malaya") :—

Major element	N	P	K	Mg
Per cent. of dry matter	2.70-2.80	0.18-0.19	1.30-1.35	0.30-0.35

Optimum levels for boron are probably 16 to 25 parts per million of dry matter, based mainly on experience of the response of leaf symptoms to fertilizers, yield responses being ill defined. A manganese level below about 150 p.p.m. may indicate a deficiency under most conditions.

As well as the actual levels of individual nutrients, the balance between them must be carefully watched ; an example being that prolonged NPK fertilizing can bring on a gross magnesium deficiency. Antagonisms between a number of elements are also known.

Visual deficiency symptoms vary greatly in diagnostic value. Magnesium and potassium are of considerable value and fairly characteristic. The symptoms were first described and used in West Africa (Hale 1946, and Bull 1954). Magnesium deficiency usually appears as a bright yellow bronzing of the lower fronds, whereas potassium deficiency usually occurs as darker orange spotting on the fronds. Nitrogen deficiency is seen as pale green leaves, but only when the deficiency has become severe, and with a serious loss in yield. Boron deficiency (Bull and Robertson 1959) gives rise to a variety of symptoms readily seen in many areas, mainly due to brittleness of tissues and constriction of tissues in the bud. Such symptoms are hooking of leaflets tips, stunting of fronds and possibly tearing of leaflet lamina away from their midribs. These conditions are referred to as 'hook leaf', 'little leaf' and 'leaflet shatter' respectively.

Another common leaf condition is referred to as 'white stripe', and appears as a very pale yellow or white stripe down the leaflet lamina on both sides of the midrib. Indications at present are that the condition is a result of high nitrogen and low potassium levels in the palm, often where leaf nitrogen exceeds 3.0 per cent. and the N/K ratio exceeds 2.5. With severe white stripe, symptoms ascribed to boron deficiency can also occur, but this may be secondary.

With the very different soils of Papua and New Guinea, Malayan and African foliar diagnosis methods and results will need to be applied with care, and correlated with results of trials and field experience before fertilizer recommendations are made. Most of the foliar symptoms mentioned above have been seen on palms in this country, and it is expected that symptom surveys and foliar analysis will be just as valuable as in Malaya and elsewhere.

DISEASES.

Malaya has been comparatively free of certain serious oil palm diseases found in West Africa, such as Vascular Wilt and *Cercospora* leaf spot [Turner 1966 (*a*)], but several other diseases are of major or increasing importance.

Ganoderma infection, or Basal Stem Rot, has been known on old palms for many years, but only recently has the infection of young palms become widespread, particularly on the coastal clays. Turner [1966 (*a*) and (*c*)] gives a description of the disease, reviews experimental and survey work carried out, and recommends control measures.

Symptoms are similar to those of drought, namely wilting and failure of young fronds to open (*Plate* XII). This is due to destruction of water conducting tissue at the base of the palm, which may finally become almost a solid block of fungus producing typical bracket fungus sporophores on the outside. All major outbreaks have been on ex-coconut areas, and to a lesser extent ex-oil palm, with only a low incidence, usually less than 1 per cent. infection after 15 years, on areas developed from rubber or forest. An ex-coconut area on one estate seen had a field of six-year-old palms with 13 per cent. already lost, and probable infection over 50 per cent. Another area had 50 per cent. infection, measured by sporophore appearance, after 15 years, with almost 100 per cent. showing some foliar symptoms. Infection in ex-oil palm areas tends to be lower, 25 per cent. after 15 years.

The method of infection and spread of the disease has been fairly clearly established. Spores land on coconut stumps and logs which are then colonized by the fungus, in about two years for stumps, and one year for logs. An oil palm planted near the stump will become infected when its roots come into contact with it. The speed of infection and the length of time until symptoms are seen varies, probably mainly with the inoculum potential of the stump which is related to the volume of colonized tissue. A figure of 45 cu. in. has been put forward as a minimum sized piece of tissue to give infection under experimental conditions (Navaratnam 1965).

The only effective control method seems to be to remove all coconut and possibly oil palm logs and stumps before replanting. Provided that the main bole is removed small pieces of roots and other debris may not be important. In some areas coconut logs were buried for Rhinoceros beetle control, and these gave the worst infection of all. The cost of complete clearing of coconuts is much higher than normal clearing of forest or rubber, quoted as $75 to $90 per acre, against $48 and $36 to $54 respectively (B. S. Gray personal communication). At present the use of large bulldozers is recommended for clean clearing and stacking of coconut logs and boles. Poisoning with arsenite may not be necessary before felling, as good burns have been obtained with freshly felled coconuts.

Marasmius palmivorus infection of the developing bunch is one of the main causes of direct crop loss in Malaya (the other being rat damage). This disease appears to be of increasing importance on the coastal clays and peats, and is discussed by Turner (1965). The fungus is normally a saprophyte living in debris accumulating in leaf axils and other places in the crown, but when a large mass of dead material accumulates, usually in the form of unpollinated bunches, the fungus can become a parasite, with the build up in inoculum potential. White mycelium spreads from the unpollinated bunches to healthy ones, causing them to rot. The

Plate XII.—A palm showing the external symptoms of *Ganoderma* infection. Another to the right and behind has been completely killed by the fungus.

disease is most severe on young bearing palms, with the likelihood of these carrying unpollinated bunches.

The main control measures recommended are palm hygiene, involving removal of unpollinated bunches and possibly close pruning, and effective pollination, which usually means an assisted pollination programme. Normally any good bunches becoming infected must be removed, but trials to find an effective fungicide are being carried out. Antimucin at 0.12 per cent. has given good results on partially infected unripe bunches (P. D. Turner 1966, personal communication). Under normal conditions with healthy palms the disease should only arise with bad palm hygiene, but with rather weak palms on acid peat soils, the disease appears to be rampant in spite of control measures, and a fungicide programme may be necessary.

Crown Disease is the name applied to a condition which is often seen in young palms up to about three years old, and is most likely physiological in origin. It normally occurs only on vigorously growing palms ; and may be due to an excess nitrogen supply or imbalance in other nutrients. A dark wet patch appears in the middle of unopened fronds leaving an area bare of leaflets on the rachis which usually bends at this point. All fronds can be affected, and all bent over in a different direction. The condition has been likened to 'growing pains', and normally palms recover by the third year.

Blast is a serious root disease in nurseries in West Africa (Robertson 1959), and occurs during the dry season when soil moisture drops below about 10 per cent. and soil temperature rises above 29 degrees C. Light textured soils appear to be worse for blast. A *Pythium* sp. invades the root primarily, enabling *Rhizoctonia lamellifera* to invade aggressively, and cause a dry rot to spread rapidly up the cortex. The external symptoms are those of drought, the outside leaves browning and drying first. Little of this has been seen until very recently in Malaysia when large outbreaks were found in two polythene bag nurseries [Turner 1966 (*b*)]. The disease can be prevented fairly readily by shading, mulching or particularly by heavy watering, all playing some part in increasing or conserving soil moisture and lowering soil temperature.

All the above-mentioned diseases may occur in Papua and New Guinea under similar conditions, and *Ganoderma* infection particularly will need to be carefully considered if old coconut areas are to be replanted. Blast disease is almost certain to occur, with polybag nurseries and light soils, unless preventative measures (mainly heavy watering) are taken.

PESTS.

Oryctes rhinoceros, the Asiatic rhinoceros beetle, is the major insect pest of oil palms in Malaya. Young palms are vulnerable, and must be protected by application of the known control methods, which mainly involve destruction or hiding of breeding places, mainly rotting logs, stumps and other debris. Experiments carried out by Chemara have shown the advantage of a thick legume cover over bare ground, where the latter gave a tremendous build up in larvae and pupae. Some cover crop experiments of Harrisons and Crosfield have also indicated this, where bare ground, slashed grass, creeping legumes and bushy legumes in that order gave a decreasing amount of beetle damage on palms in these plots. *Flemingia congesta*, as already noted, gave particularly good protection if allowed to grow to about 5 ft., apparently restricting flight as well as breeding.

Infestation coming from village coconuts on the outside of oil palm estates is very common, and palms close to these may require special attention such as hooking out beetles, and dusting crowns with an insecticide such as B.H.C. Generally on estates, though, effective control is obtained with good cover crops combined with regular inspection of possible breeding sites and collection of larvae. Secondary infestation of damaged palms by the palm weevil, *Rhynchophorus* sp., does not seem to be as common in Malaya as in Papua and New Guinea, but appears just as destructive in the isolated cases when it does appear.

The occurrence of *Metisa plana* Wlk., and other bagworms as major pests in Malaya has served to emphasize the importance of predators and parasites of a pest species in tropical agriculture. Wood (1965) describes how large scale use of residual contact insecticides such as dieldrin and endrin have induced severe outbreaks of caterpillars on three estates in Malaya. One of these suffered a 30 per cent.

crop loss when the whole 6,000 acres was repeatedly sprayed. This estate has since ceased spraying, and pest attacks are decreasing rapidly as parasitization builds up. The use of more selective insecticides such as lead arsenate, a stomach poison, is now recommended if outbreaks are really serious, otherwise no artificial control measures at all should be used.

Rats are the main mammal pests in Malaysia, and cause considerable damage to young palms newly planted out, and later to fruit bunches. 'Rat collars', made of strong wire mesh, may be necessary if palms are planted in the field before they are 12 to 14 months old. The main problem is protection of fruit bunches, which are very attractive to rats. A regular and systematic poisoning campaign is the only really effective control measure, based on either the use of acute poisons such as zinc phosphide, or the newer warfarin based poisons which are probably the best. A variety of bait formulations are used, the requirement being that the bait is more attractive than the fruit. One apparently successful bait was made from warfarin, coconut cake, fish heads and palm oil, mixed with melted wax for setting into small blocks.

Birds, porcupines, pigs and elephants can also cause considerable damage, the last being in the habit of kneeling on young palms, and pulling them up by the roots to chew the soft tissues inside.

PROCESSING.

Small scale processing methods are almost universally regarded as undesirable in Malaysia, especially when producing oil for export. The generally quoted minimum acreage to support an efficient mill is 2,000 or preferably 3,000, with any size over 5,000 acres being regarded as close to optimum. Most of the large oil palm factories in the world today have been made by Gebr. Stork and Company of Holland (*Plate* XIII). Twitchin (1955 and 1956) discusses palm oil machinery and processing, and an outline is also given by Newton (1961). Various brochures of the Stork Company are also available.

Briefly, the process involves reception of fruit from the field, steam sterilizing to prevent further enzyme breakdown of the oil, and stripping of the fruit from the bunch. After digestion of the fruit, the oil is extracted from the mesocarp in a press, and then clarified and stored in bulk, ready for shipment. The press cake after oil has been extracted is broken up, and fibre removed in the 'depericarper'. Fibre is blown off through a 'cyclone' to the boilers, where it is used as fuel. Nuts are then dried, graded and cracked. After separation from shell pieces, the kernels are dried and bagged for shipment. The empty bunches after stripping are sometimes incinerated, the ash making a valuable fertilizer with a high potassium content. Shells can be used as extra fuel if necessary, or for surfacing estate roads.

Many new features are now being incorporated in mills being built in Malaysia by Stork and others. Steam turbines are being used to drive electric generators, individual electric motors power each item of machinery, and more automation is used, such as automatic hydraulic presses, kernel separation and fuel feed to the boilers.

Mills are usually built in stages, to correspond with rising production from areas being planted up and coming into bearing. The final capacity is calculated from expected total yields, and must be able to handle production during the peak months, usually by running about 22 hours per day. Mills will normally be operating about 300 days per year. The capacity of a mill will be between about two and three tons F.F.B. per hour for each 1,000 acres of palms. For a 5,000 acre estate, a mill of 10 to 15 tons per hour capacity would be needed, depending on the expected total yields and seasonal variability.

Storage and transport of oil.

Oil is usually stored at the factory in heated tanks of between 200 and 500 tons capacity, and then moved out in rail or road tankers to the nearest port, where heated bulking installations are available. The very good rail and road system in Malaya enables the shipping of almost all oil through either Singapore, Port Swettenham or Penang.

The case of two estates on an isolated part of the Sabah coast may be more pertinent to likely conditions in Papua and New Guinea. These estates will supply oil to a bulk installation and shipping jetty a few miles from both mills. A seven-and-a-half-ton road tanker will be used for transport since a pipeline is normally regarded as impractical over about a quarter of a mile and, as oil is best pumped at 135 degrees F., would need to be heated along its length. The estates, of about 6,000 acres each, will eventually be producing about 2,000 tons of oil per month between them, most of which will be stored at the mills. When a ship calls, usually to collect between 500 and 1,000 tons, oil will be pumped from one or both of the 500 ton tanks, through a 6 in. diameter pipe rising to a height of 30 ft. at the end of the jetty, and into the ship via a flexible hose.

COSTS.

An indication of the likely range of costs for establishing and running an efficient estate in Malaysia is given below, based on figures given by estates and research stations in Malaya and Sabah, and in "The Oil Palm in Malaya". Figures have been converted from Malaysian currency, usually rounded off, to Australian currency, and hence may not be meaningful to the full number of significant figures given. Labour cost and efficiency will influence the figures given. The base wage in Malaya is about $0.90 to $1.05 per day, and in Sabah, $1.20 to $1.35, though many jobs such as harvesting are done on a piece work basis.

Establishment Costs.

(*a*) *Direct field costs* up to bearing at three years in the field, per acre.

Operation.	Cost ($A)	
Clearing and burning	39-48	Depends on forest density.
Lining and holing	3-9	Depends on soil type.
Planting	6-7.50	
Nursery costs—		
85 pregerminated seed @ 18 to 21c		
64 final seedlings @ 21 to 24c		
Total Nursery	29-33	Polybag nursery.
Fertilizers	6-30	Depends on needs and policy.
Cover crop seed and planting	4.50-7.50	
Cover crop fertilizers	0-9	Depends on needs and policy.
Weeding of covers and palm circles—		
Year 1	18-24	Depends on vigour of covers and weed species, and policy.
Year 2	12-21	
Year 3	6-18	
Roads .008 to .014 mile per acre at $1,800 per mile	14-25	Road building costs may vary widely.
Drains. A full system on coastal clays may cost $18 to $24	0-24	Many areas need no draining at all.
Pests and diseases (years 1 to 3)	3.60-18	Very variable.
Castration—		
14 to 26 months at $0.30/acre/month	3.60	Length depends on policy.
Total direct costs—very approximate	180-240	May be more if developed on ex-coconut area.

(*b*) *General estate establishment costs.*

	$A per acre.
Factory	160
Staff housing	30
Labour and general buildings	60
Vehicles and mechanical equipment	50
Total	300

RUNNING COSTS.

(*a*) *Maintenance*, bearing palms.

	$A/acre/year.
Selective Weeding, hand slashing	2.70-6.00
or Mechanical slashing (no logs)	1.80
Weeding of paths and circles—	
6 rounds hand weeding	3-5.50
or 2 rounds herbicides	1.50-2.40
Fertilizing, with 2 to 15 lb. of mixture, assumed 3c/lb.	4-27
Assisted pollination (up to eight years old) eight rounds per month at 3.5 to 7.5c/round	3.50-7.50
Pruning—	
1 round per year....	1.20-1.80
Diseases and pests—	
arbitrary figure, with no serious outbreaks	0.90-1.80
Road maintenance—	
Low cost if properly surfaced	0.90-2.40
Drain maintenance—	
normal range on coastal clays $1.20 to $1.40	0-1.40

(*b*) *Harvesting and processing.*

Harvesting. $2.10 to $4.50 per ton F.F.B., depending on height and yield of palms. Usually a minimum at about seven years old.

Processing. $7.50 to $12 per ton of oil, depending on size and efficiency of mill and extraction rate of oil to F.F.B., which is low with young palms.

$5.10 to $7.50 per ton of kernels.

(*c*) *General running costs* on an estate, including salaries, insurance, rents, repairs, labour welfare, etc., may be about $15 to $24 per acre per year.

SUMMARY.

With large areas of land possessing suitable climate and soils, and with the world market for fats and oils in a sound position, the prospects for an oil palm industry in Papua and New Guinea appear bright. High yields, of the order of two to three tons of oil per acre per year, and a relatively stable price of approximately $200 per ton mean that the oil palm is one of the most attractive and profitable tropical crops. The industry in Malaysia is expanding very rapidly at present, with a combination of favourable climate, both physical and economic, and improved management techniques and planting material. It would appear that Papua and New Guinea can benefit greatly from the knowledge and experience of oil palm cultivation gained there.

Large scale processing is needed for efficient production of high quality oil. This means that large amounts of capital are required, of the order of $2.5 million to bring a 5,000 acre estate and factory into production. Smallholder production, where fruit is sold to a central factory, should be a feasible addition to estate production.

Some of the important developments in oil palm cultivation recently include the breeding of high yielding *tenera* planting material, improvement of the germination characteristics of the seed using the 'dry heat' method, and development of superior nursery procedures, particularly using polythene bags.

The very favourable Malaysian climate tends to induce a shortage of male flowers, and hence pollen, in young palms, and this is likely in Papua and New Guinea also. The practice of assisted pollination is quite widespread, particularly on fertile soils, and under these conditions is necessary to obtain high yields from young palms. Castration, or removal of inflorescences before they set fruit, is a growing practice on very young palms. It is claimed to bring palms evenly into production, make early harvesting more efficient, and reduce disease susceptibility. The treatment probably builds a palm able to cope with the heavy bearing ensured by assisted pollination also.

Leguminous cover crops are usually grown in young areas for a variety of reasons, including weed control, effect on soil fertility, erosion prevention and pest control. The various species

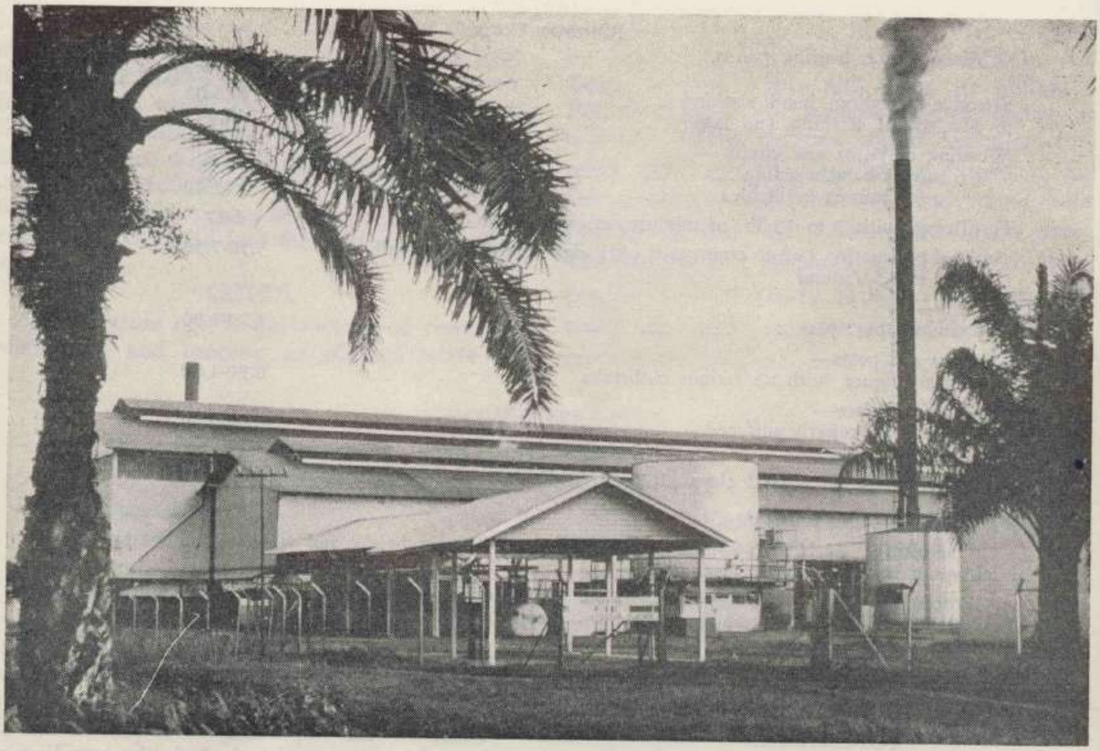


Plate XIII.—A typical oil mill. The weighbridge is in the foreground, with the horizontal sterilizers directly behind. To the right are bulk oil storage tanks.

and establishment methods are discussed. Covers are shaded out in mature areas, and upkeep then involves slashing, elimination of noxious weeds, and clean weeding of palm circles and harvesting paths by hand or herbicides.

The high yielding oil palm makes heavy fertilizer usage necessary on most soils, at least after a few years bearing. Magnesium, nitrogen, phosphorus and particularly potassium are in heavy demand, with deficiencies of a number of minor elements being found on some soils. Fertilizer recommendations are usually based on leaf analysis, in conjunction with leaf symptoms, experimental results and field experience.

The principal disease in Malaya is *Ganoderma* Basal Stem Rot, which is mainly a problem on ex-coconut and ex-oil palm areas, and the main control measure is removal of the infection sources, old coconut or oil palm stumps. *Marasmius* bunch infection, and a number of nursery diseases such as Blast are also important. The main insect pest is the Rhinoceros beetle, and control measures are based on elimination of breeding sites. Use of non-selective insecticides has led to severe caterpillar outbreaks on some estates. Rats are the main mammal pests, and are usually controlled by poisoning.

Methods of fruit harvesting, and the factors affecting choice of these, are discussed. Fruit must be harvested about every seven to ten days, and, with the very heavy fruit yields (10 tons per acre per year for example), the operation usually represents between one-third and two-thirds of the field running costs of an estate. The main scope for improvement would appear to be in elimination of manual fruit collection, and in streamlining evacuation systems.

(Received August, 1966.)

ACKNOWLEDGEMENTS.

With the rising interest in oil palms as a commercial crop for Papua and New Guinea, a study tour was made of oil palm areas in Malaysia in late 1965. The author would like to thank the estate groups and government organizations who made the tour possible, and the estate and research staff who provided information and assistance. Most of the experimental work mentioned has been carried out by either Harrisons and Crosfield Oil Palm Research Station, Banting, Selangor, or Chemara Research Station (Guthrie Agency), Layang Layang, Johore, and the Author's debt to the staff of these two is particularly acknowledged.

REFERENCES.

BEVAN, J. W., FLEMING, T. AND GRAY, B. S. (1966). Planting Techniques for oil palms in Malaysia. Incorporated Society of Planters, Kuala Lumpur.

BROESHART, H. (1954). The use of foliar analysis in oil palm cultivation. *Trop. Agriculture Trin.*, 31 : 251-60.

BULL, R. A. (1954). Studies on deficiency diseases of the oil palm. 1. Orange frond disease caused by Magnesium deficiency. *J. W. Afr. Inst. Oil Palm Res.*, 1 (2) : 94-129.

BULL, R. A. AND ROBERTSON, J. S. (1959). The problem of 'little leaf' of oil palms—a review. *J. W. Afr. Inst. Oil Palm. Res.*, 2 : 355-75.

CHAPMAN, G. W. AND GRAY, H. M. (1949). Leaf analysis and nutrition of the oil palm. *Ann. Bot. N.S.*, 13 : 415.

CHEMARA (1964). Oil palm planting material, Ulu Remis (D x P). Unpubl. notes, Planting Material Unit, Chemara Research Station, Layang Layang, Johore.

DEPARTMENT OF AGRICULTURE, Malaya (1966). The Oil Palm in Malaya. (In press.)

GRAY, B. S. (1963). The potential of the oil palm in Malaya. *J. Trop. Geography*, 17 : 127-32.

GRAY, B. S. (1964). *In* Harrisons and Crosfield (Malaysia) Ltd., Research and Advisory Scheme, Oil Palm Research Station Annual Rep. 1963.

GRAY, B. S. (1966). The necessity for assisted Pollination in areas of low male flower production, and its effect on the components of yield of the oil palm (*Elaeis guineensis*) *Trop. Sci.* (In press.)

GUNN, J. S. AND SHELDRICK, R. D. (1963). The influence of the age and size of oil palm seedlings at time of transplanting to the field on their subsequent growth. *J. W. Afr. Inst. Oil Palm Res.*, 4 : 191-200.

HAINES, W. B. (1959). The significance of cyclical peak yields in Nigerian oil palms. *Emp. J. Exp. Agric.*, 27 : 1-9.

HALE, J. B. (1947). Mineral composition of leaflets in relation to the chlorosis and bronzing of oil palms in West Africa. *J. Agric. Sci.*, 37 : 236-44.

HEADFORD, D. W. R. (1965). A new system of herbicide use for the control of perennial grass weeds in plantation crops. *The Planter, Kuala Lumpur*, 41 : 334-6.

HEMPTINNE, J. AND FERWERDA, J. D. (1961). Influence des precipitations sur les productions du palmier a huile. *Oleagineux*, 16 : 431-7.

INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT (1965). The economic development of the Territory of Papua and New Guinea. The John Hopkins Press, Baltimore.

MICHAUX, P. (1961). Les composantes climatique du cycle annuel de productivite du palmier a huile, *Oleagineux*, 16 : 523-8.

NAVARATNAM, S. J. (1965). *In* a paper presented at an oil palm diseases symposium, held at the University of Malaya, 20 November, 1965.

NEWTON, K. (1961). Notes on the botany, breeding and establishment of oil palms and production of palm oil. *Papua and New Guinea agric. J.*, 14 : 53-77.

NULL, W. S., ACTON, C. J. AND WONG, I. F. T. (1965). Reconnaissance soil survey of southern Johore. Malayan Soil Survey Report 1/1965, Soil Science Division, Dept. of Agric. Kuala Lumpur.

PANTON, W. P. (1964). The 1962 soil map of Malaya. *J. Trop. Geography*, 18 : 118-24.

REES, A. R. (1959). Germination of oil palm seed : large scale germination. *J. W. Afr. Inst. Oil Palm Res.*, 3 : 83-95.

REES, A. R. (1960) (*a*). The germination of oil palm seeds—a review. *J. W. Afr. Sci. Assoc.*, 6 : 55-62.

REES, A. R. (1960) (*b*). The effect of high temperature pretreatment on germination of oil palm seed. *Nature*, 189 : 74-5.

ROBERTSON, J. S. (1959). Blast disease of the oil palm : its cause, incidence and control in Nigeria. *J. W. Afr. Inst. Oil Palm Res.*, 2 : 310-30.

ROSENQUIST, E. A. (1962). Fertilizer experiments on oil palms in Malaya. Part 1. Yield data. *J. W. Afr. Inst. Oil Palm Res.*, 3 : 291-301.

RUER, P. (1966). Relations entre facteurs climatiques et nutrition minerale chez le palmier a huile. *Oleagineux*, 21 : 143-8.

SPARNAAIJ, L. D., REES, A. R. AND CHAPAS, L. C. (1963). Annual Yield variation in the oil palm. *J. W. Afr. Inst. Oil Palm Res.*, 4 : 111-25.

TROPICAL PRODUCTS INSTITUTE (U.K. Ministry of Overseas Development), Oil Palm Conference, 3-6 May, 1965.

TURNER, P. D. (1965). *Marasmius* infection of oil palms in Malaya—a review. *The Planter, Kuala Lumpur*, 41 : 387-93.

TURNER, P. D. (1966) (*a*). Infection of oil palms by *Ganoderma* in Malaya. *Oleagineux*, 21 : 73-6.

TURNER, P. D. (1966) (*b*). Blast disease in oil palm nurseries. *The Planter, Kuala Lumpur*, 42 (3) : 103-8.

TURNER, P. D. (1966) (*c*). *In* "The Oil Palm in Malaya".

TWITCHIN, J. F. (1955 and 1956). Palm oil machinery. *The Planter, Kuala Lumpur*, 31 and 32.

WONG PHUI WENG (1964). Evidence for the presence of growth inhibitory substances in *Mikania cordata* (Burm. f.) B. L. Robinson. *J. Rubb. Res. Inst. Mal.*, 18 : 231-42.

WOOD, B. J. (1965). Severe outbreaks of caterpillars on oil palm estates in Malaya induced by the use of residual contact insecticides. *Proc. 12th Int. Congr. Ent.*, London, 1964 : 575.

*Aircraft Disinsection Procedures.**

G. P. KELENY.†

ABSTRACT.

The increasing volume and speed of international air services has greatly increased the risk of disseminating insect pests and vectors of diseases, including agricultural pests and diseases. It is the responsibility of national plant quarantine services to institute the necessary control measures. Methods of disinsecting aircraft are discussed and it is recommended that spraying by aerosols be carried out upon the arrival of the aircraft at the airport of entry, and before the disembarkation of passengers and crew. Aerosol formulations used for aircraft disinsection should contain a concentration of the active principles of not less than that contained in the "Standard Reference Aerosol" recommended by W.H.O. Attention is drawn to the possibilities of vapour fumigation.

THE ever-increasing volume of international air traffic, the constantly increasing speed and range of aircraft and the development of insecticide resistant pests and disease vectors create considerable problems for plant quarantine services. This increasing air traffic places a heavy responsibility on the authorities charged with preventing the dissemination of insect pests or diseases affecting plants. Relatively few studies have been made of the effect of aircraft movements on the dissemination of insect pests ; the outstanding example being that of Campbell carried out in the Cocos-Keeling Islands (1952).

The F.A.O. Regional Plant Protection Committee at its fourth meeting in Manila drew attention to the risk of spreading diseases and pests by aircraft and recommended to member countries that appropriate steps be taken to reduce the risk to an absolute minimum. Considerable developments have taken place in aircraft treatment methods during recent years.

The standard procedures previously recommended were : (*a*) Pre-flight disinsection, i.e., treatment of the aircraft prior to the embarkation of the passengers and crew ; or (*b*) in-flight disinsection carried out prior to landing at airport of entry. These methods, though included in the recommended practices contained in previous editions of Annex 9 to the Convention of International Civil Aviation, were often found to be less than fully efficient. The following remarks in the Eleventh Report of the Expert Committee on Insecticides of the World Health Organization (1961) illustrate the position :

"The Committee reviewed the evidence that has accumulated since its seventh report in which recommendations were made against in-the-air disinsection of aircraft with aerosols. Notable examples were the report that during the year ending 30th June, 1957, out of 1,592 mosquitoes found aboard aircraft arriving at Miami International Airport following in-the-air treatment with aerosols before arrival, 305 were still alive, and the more recent advice from the Philippines Government that although its quarantine regulations specify in-the-air disinsection for incoming aircraft, collections made following landing, over a five-year period, showed that 87 per cent. of the mosquitoes were still alive.

"Replies to Circular letter 15 indicated that despite the ineffectiveness of in-the-air disinsection with aerosols, approximately 30 per cent. of the 111 countries replying require or accept this method of aircraft disinsection (6 per cent. with some reservations), while about 10 per cent. refuse to accept it in all or some instances.

"The Committee reaffirmed the previous recommendation that in-the-air disinsection of aircraft with aerosols should not be recognized as complying with the requirements of the International Sanitary Regulations."

"The Committee noted that, discounting those governments that have no disinsection requirements of any kind, some 60 per cent. of the remainder of those replying to the circular letter make provisions for post-arrival disinsection. The Committee also considered the frequent opportunities for vectors aboard aircraft to escape after the plane has landed and before disinsection could be accomplished (e.g., through open cockpit windows, from the wheel wells or through the cabin door as it is opened to admit the Airport Health Officer or his representative)."

The deliberations of the World Health Organization Committee led to the development of the 'blocks away' disinsection method. This

* Paper presented at the meeting of the F.A.O. Regional Plant Protection Committee for the South-East Asia and Pacific Region, held at Canberra, December, 1964.

† Plant Introduction Officer, Department of Agriculture, Stock and Fisheries, Port Moresby.

method was incorporated in the Fifth Edition of Annex 9 (containing recommended practices) to the Convention on International Civil Aviation dated April, 1964.

The new recommended procedures are :—
Section 2.21

When disinsecting is required by a Contracting State as a public health measure, that requirement shall be deemed to have been met by discharging into those portions of the aircraft which may carry insects from one area to another, an insecticide of a strength, formula and method of dispersal recommended by World Health Organization and acceptable to that State, such insecticide to be effectively discharged :—

(*a*) into the flight deck and into those portions of the aircraft which cannot be reached when the aircraft is moving, as near as possible to the time of the aircraft's last departure before entering the State and in sufficient time to avoid delaying such departure ; and

(*b*) into those portions of the aircraft which can be reached when the aircraft is moving, after the time of the aircraft's last departure before entering the State, either—

(i) by means of an aerosol spray, or any equivalent system, while the aircraft is taxying from the ramp to the runway for takeoff ; or

(ii) if the aircraft is suitably equipped, by means of an automatic dispersal of vapour while the aircraft is flying, but as far in advance as possible and at least thirty minutes prior to first landing ; or

(iii) by other equally effective means.

The above procedures, as adopted, overcome the previous objections by airlines to the 'blocks away' method, namely that the introduction of an aerosol into the cockpit just prior to takeoff might affect the judgement of some pilots, who might be allergic to the spraying compounds, and thus endanger the safety of the aircraft.

However, until such time as automatic spraying equipment is installed in aircraft the 'blocks away' method is open to the same objections as the in-flight treatment, namely that it is applied by airlines personnel who are likely to be more concerned with passenger reaction than thorough disinsection and pest control.

Under present circumstances the most reliable aircraft disinsection method is the post-arrival treatment by aerosol of all parts of the aircraft (including passenger, crew, cargo and baggage compartments) by a government inspector prior to the disembarkation of the passengers or crew. It is recommended for adoption by all member countries. It is emphasised that the provision of Annex 9 are only recommendations and all countries are free to register their disagreement and alternate requirements.

The following disinsection procedures are recommended.

Upon arrival of the aircraft at the first airport of entry and before the disembarkation of the passengers and crew, all passenger and crew compartments should be lightly sprayed with an aerosol by the responsible quarantine official. This is the so called 'knock down' spray and the aircraft should be kept closed up for five minutes. Immediately after the disembarkation of the passengers and crew the aircraft should be closed up again and all compartments thoroughly disinsected, the aircraft remaining closed up for seven minutes. Concurrently with the above procedures the cargo and luggage compartments should be sprayed with an aerosol, then closed again for a period of seven minutes before unloading operations are authorized.

Pre-flight disinsection is still widely practiced in many countries. The certificates stating this treatment may be a useful additional safeguard, but the possession of such a certificate should not exempt an aircraft from post-arrival disinsection at the first airport of entry. Similarly in-flight disinsection should not be accepted as an alternate to thorough spraying by government personnel.

Aerosol formulations.

The next consideration is the formulation of aerosols best suited for aircraft disinsection, i.e., type and concentration of the active principles (both knock down and persistent), solvents, propellants, etc. It is understood that in most countries ordinary household aerosol preparations are being used for aircraft disinsection. It is submitted that household formulations are not altogether suitable for plant quarantine purposes. Pests of agricultural importance are usually more resistant to insecticides than flies or mosquitoes, therefore, it is considered that for plant quarantine purposes an aerosol should contain a higher percentage of the active principles than is customary in commercial household preparations.

The following formula, called standard reference aerosol, is recommended for use in aircraft by the Expert Committee on Insecticides of World Health Organization :—

	Per cent. by weight.
Pyrethrum extract (25 per cent. pyrethrins)	1.6
D.D.T. technical	3.0
Xylene	7.5
Odourless petroleum distillate	2.9
Dichlorodifluoromethane	42.5
Trichlorofluoromethane	42.5

As compared with the above standard, a widely used commercial aerosol contains :—

Gamma isomer BHC (Lindane)	0.3 per cent. w/v
Pyrethrins	0.1 per cent. w/v
Piperonyl butoxide	0.5 per cent. w/v

Other formulations recommended by U.S.D.A. are :—

	Per cent. by weight.
G-651	
Pyrethrum extract (20 per cent. pyrethrins)	6.0
D.D.T.	2.0
Aromatic petroleum derivative solvent	8.0
Dichlorodifluoromethane (Freon 12 or Genetron 12)	84.0
G-1029	
Pyrethrum extract (20 per cent. pyrethrins)	6.0
D.D.T.	2.0
Aromatic petroleum derivative solvents :—	
Velsicol AR 60 or Socony Vacuum 544 G	6.0
Velsicol AR 50 or Socony Vacuum 544 C	2.0
Trichlorofluoromethane (Freon 11 or Genetron 11)	25.2
Dichlorodifluoromethane (Freon 12 or Genetron 12)	58.8

Information seems to indicate that there are technical difficulties in connection with aerosol formulation in increasing the D.D.T. content above 3 per cent. The solvents and propellants used have been tested and do not cause undue passenger discomfort, nor do they cause damage to the perspex or other parts of the aircraft.

The use of aerosols is the only treatment generally acceptable for aircraft disinsection but the method has some weaknesses such as :—

(*a*) relative ineffectiveness of aerosols applied in airborne aircraft ;

(*b*) difficulty of ensuring that treatment has been carried out.

The main reason why in-the-air aerosol treatments are not very effective are :—

(*a*) they are rapidly removed from the aircraft through ventilation ;

(*b*) they impact on various objects in the aircraft ; and

(*c*) they fail to penetrate into many parts of the aircraft where insects may be resting.

Most of the above difficulties could be overcome by a vapour disinsection method. In contrast to aerosol particles, vapour follows the laws for the dispersion of gases. The vapour will penetrate to all portions of the aircraft and, if an adequate concentration is maintained for a sufficient period of time, will exert the required insecticidal effect.

Experiments indicate that DDVP (0, 0-dimethyl 0-2, 2-dichlorovinyl phosphate) is a compound which appears to meet all the foregoing requirements and satisfactory systems have been developed in the United States for the vapour disinsection of aircraft. Commercial sprays containing DDVP for household use are already on the market, thus it is confidently expected that it would be approved for use in aircraft in the near future. The present tests are understood to be on the possible toxic effects to humans of concentrations required for effective insect control.

In view of the fact that the initial spray is only for knock down purposes it is thought an aerosol containing pyrethrins only might be suitable for the purpose, leaving the formulation with the persistent insecticide for the second application.

Summarizing the position and the recommendations.

1. The increasing volume and speed of international air services has greatly increased the danger of disseminating insect pests and vectors of diseases.

2. Pre-flight and in-flight disinsection, practiced by many countries, are ineffective.

3. Aircraft disinsection is the first line of defence against the incursion of introduced pests.

4. The treatment recommended by the International Civil Aviation Organization is the 'blocks away' method developed by the World Health Organization.

5. The reliability and effectiveness of the 'blocks away' method depends on the installation of mechanical means of aerosol dispersion.

6. Pending the installation of such equipment in aircraft, it is recommended that post-arrival disinsection be applied by the quarantine authorities on arrival of the aircraft at the airport of entry. Procedures recommended are :—

(*a*) a light knock-down spray immediately on arrival of the aircraft and prior to the disembarkation of passengers and crew ;

(*b*) a thorough spraying following the disembarkation of passengers and crew ;

(*c*) the aircraft to be kept completely closed up during both treatments ; and

(*d*) the cargo and luggage holds should be disinsected concurrently with the main compartments.

7. The aerosol formulation used for aircraft disinsection should contain a concentration of the active principles, both knock down and persistent, of not less than that contained in the 'Standard reference aerosol' recommended by W.H.O.

8. Attention is drawn to the latest developments using vapour fumigation methods, such as DDVP, for aircraft disinsection. Vapour fumigation is reported to be the most effective method of treatment ensuring complete dispersal of the fumigant.

(Received December, 1965.)

REFERENCES.

BUSVINE, J. R. (1952). Disinfestation of aircraft by aerosols, *Pyrethrum Post*, March.

CAMPBELL, T. G. (1952). Entomological survey of Cocos-Keeling Islands. *Aviation Medicine Memorandum No.* 14, Dept. of Civil Aviation (Australia).

KELENY, G. P. (1964). Plant Quarantine in Papua and New Guinea, *Australian Territories*, 4 (1) : 26-32.

RASMUSSEN, W. A., JENSEN, J. A., STEIN, W. J. AND MAYES, W. J. (1963). Toxicological Studies of DDVP for Disinsection of Aircraft, *Aerospace Medicine*, 34 (7) : 593-600.

SULLIVAN, W. N., KEIDING, J. AND WRIGHT, J. W. (1961). WHO studies on aircraft disinsection at 'blocks away'. World Health Organization, *Insecticides*, No. 128.

SULLIVAN, W. N., AZURIN, J. L. WRIGHT, J. W. AND GRATZ, N. G. (1963). Studies on aircraft Disinsection at 'blocks away' in tropical areas, World Health Organization, *Vector Control*, No. 19.

TEW, R. P., DAVID, W. A. L. AND BUSVINE, J. R. (1951). Factors affecting the efficiency of aircraft disinsectisation procedures, *Monthly Bulletin of the Ministry of Health and Public Health Laboratory Service*, pp. 30-38.

WORLD HEALTH ORGANIZATION (1961). Aircraft Disinsection. 11th Report of the Expert Committee on Insecticides W.H.O., *Technical Report Series*, No. 206.

Since the preparation of the above paper for the FAO Conference at Canberra, a number of articles were noted, all confirming the safety of the use of DDVP (Dichlorvos or Vapona) in aircraft disinsection and on the development of mechanical disinsection systems for aircraft :

CASSIDA, J. E. (1965). Toxicology and pharmacology of 'Vapona' insecticide. *Shell Agricultural Chemical Bulletin*, ADB : 872/Da, 28.

HAYES, W. J. (1961). Safety of DDVP for the disinsection of aircraft. *Bull. World Hlth Org.*, 24 : 629-633.

JENSEN, J. A., PEARCE, G. W. AND QUARTERMAN, K. D. (1961). A mechanical system for dispensing known amount of insecticidal vapours. *Bull. World Hlth Org.*, 24 : 617-622.

SCHOOF, H. F., JENSEN, J. A., PORTER, J. E. AND MADDOCK, D. R. (1961). Disinsection of aircraft with a mechanical dispenser of DDVP vapour. *Bull. World Hlth. Org.*, 24 : 623-628.

WITTER, R. E., GAINES, T. B., SHORT, J. G., SEDLAK, V. A. AND MADDOCK, D. R. (1961). Studies on the safety of DDVP for the disinsection of commercial aircraft. *Bull. World Hlth. Org.*, 24 : 635-642.

SHELL CHEMICALS, (1965). Vapona in slow release strips. *Safety Use Manual*, No. 2/V.

U.S. DEPT. OF HEALTH, EDUCATION & WELFARE (1966). The Dichlorvos aircraft disinsection system. Public Health Service, Communicable Disease Center.

Termite protection that lasts!

STOP TERMITES

and timber borer too with

dieldrin concentrate (15%)

Termites have a taste for timber and their ability to live on it is unique among insects. If you let them set tooth on your buildings you'll soon be faced with expensive repairs. "Dieldrin" is being used throughout the world today to stop both termites and timber borers by big pest control operators and it has proved its long lasting effectiveness on both new and old dwellings. Just add water to dieldrin and apply to the soil around foundations. An impregnable barrier will remain for years. For timber borer "dieldrin" is applied with kerosine, by brush or spraying. Ring Shell Chemical or write for an illustrated folder on termite control with dieldrin.

SC5836/24R

SHELL

AGRICULTURAL CHEMICALS

SHELL CHEMICAL

(AUSTRALIA) PTY. LTD. (Inc. in Victoria)
Melbourne - Sydney - Brisbane - Adelaide - Perth - Hobart
An Affiliate of the Shell Co. of Aust. and registered user of its trade marks.

SPECIFIED FOR THESE COMMONWEALTH DEPT. OF WORKS PROJECTS:

New Guinea
Housing for Papuan Infantry Regiment.
Taurama Army Barracks.
Commonwealth Banks.
Reserve Banks Honiara, Port Moresby.
Lae Army Barracks.
P.M.G. Station, Rabaul.

Australian Capital Territory
Orroral Valley Tracking Station.
2CA Canberra.
Tidbinbilla Tracking Station.
Bureau of Mineral Resources.
The Secretariat Building.
Royal Military College—Duntroon.
Dept. of Navy—H.M.A.S. Harman Barracks.

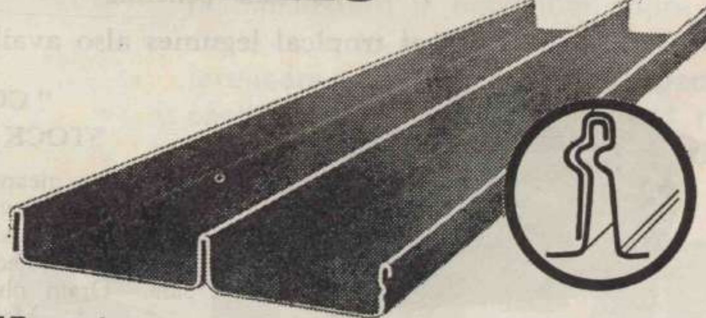
Northern Territory
Darwin Hospital.
Reserve Bank.
Commonwealth Education Dept.
R.A.A.F. Hangars.

New South Wales
Holsworthy Army Camp.
R.A.A.F. Base, Richmond.
Kapooka Army Camp.
D.C.A. Buildings, Mascot.
Atomic Energy Commission.

... and similar projects in other States.

Fiji
Derrick Technical Institute, Suva.
Suva Post Office.

Brownbuilt the strong roof!



Brownbuilt's unique button-punching process.

Here's proof:

Tests supervised by the Department of Civil Engineering, University of Melbourne, proved the ability of the Brownbuilt decking system to withstand upward suction loads equivalent to winds of cyclonic force.

POSITIVE CONCEALED FIXING.

Brownbuilt's great strength lies in its deep rib profile, concealed fixing method and exclusive, proven button-punching process for sheet interconnection. The combination of all three results in a completely secure, weatherproof, maintenance-free roof unaffected by heat expansion.

Note these other features:

1. Greatest span strength permits economical roof frame designs.
2. Most versatile—adaptable to all roof designs . . . flat skillion, steep pitch, up-and-over and radial pitch.
3. Wide selection of materials—galvanised steel, copper, aluminium, stainless steel, pre-coated "COLORARMOR."
4. Unmatched service—qualified technical representation coupled with smooth-running shipping facilities through our Export Division. Prompt and complete documentation—we take care of the details.

Brownbuilt LIMITED

METAL SECTIONS DIVISION

499 Princes Highway, Kirrawee, Sydney 2232.
Cable: Metform.

Local Distributors

Morobe Constructions Pty. Ltd., Saraga Street, 6 Mile, Port Moresby.
D. C. Watkins Ltd., Angau Drive, Boroka, Port Moresby.
John Stubbs & Sons (Papua) Ltd., Lawes Road, Port Moresby.
Madang Building Supplies, Madang.
Lae Plumbing Ltd., Lae.
Reddy Constructions, Suva, Fiji.

BB:P18

Coffee planters
Shell can end your weed problems

The full range of proven Shell weedicides gives you more economical, long-term control of weeds and grasses right through your plantation.

Shell research and field work throughout the world has produced selective weedkillers for special application: others for long-lasting 'blanket' eradication. The range includes:

- GRAMEVIN* — for positive, selective control of grasses. Its systemic action kills grass roots.
- KARMEX* — for long-lasting weed control on plantations. Safe on coffee at recommended rates.
- HYVAR X* — for effective long-term weed control on non-crop areas.
- NONIDET* WK — the economical wetting agent, with 100% active ingredient.

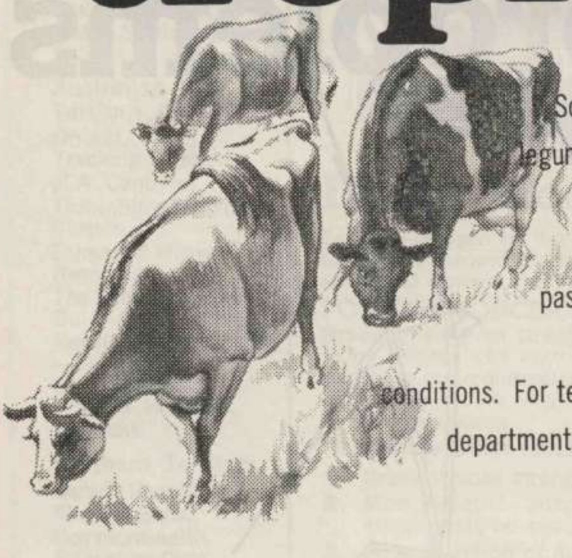
Your Shell agent or one of our trained field representatives will be glad to advise you on a Shell weed control programme to meet your needs. Contact him now, or write to P.O. Box 169, Port Moresby.

*Registered Trade Marks.

SPI 104

Shell Company (Pacific Islands) Ltd.

Terranova best tropicals



Sow Terranova 'calculated' mixtures of tropical legumes and grasses for maximum Spring, Summer and Autumn production — under all seasonal conditions. Save your established temperate pastures for winter grazing. There are Terranova 'calculated' mixtures for all soil types and conditions. For technical details contact your seed merchant or departmental agronomist or consult Andersons Seeds Ltd.

for price, purity, productivity and profit.

ANDERSONS
Terranova®
TROPICAL PASTURE SEED
PEDIGREED

are sold and recommended by your local seed merchant

ANDERSONS SEEDS LTD.,
68 BOUNDARY ST., BRISBANE TOWNSVILLE AND BILOELA, QLD., COFFS HARBOUR, N.S.W.

AT 1