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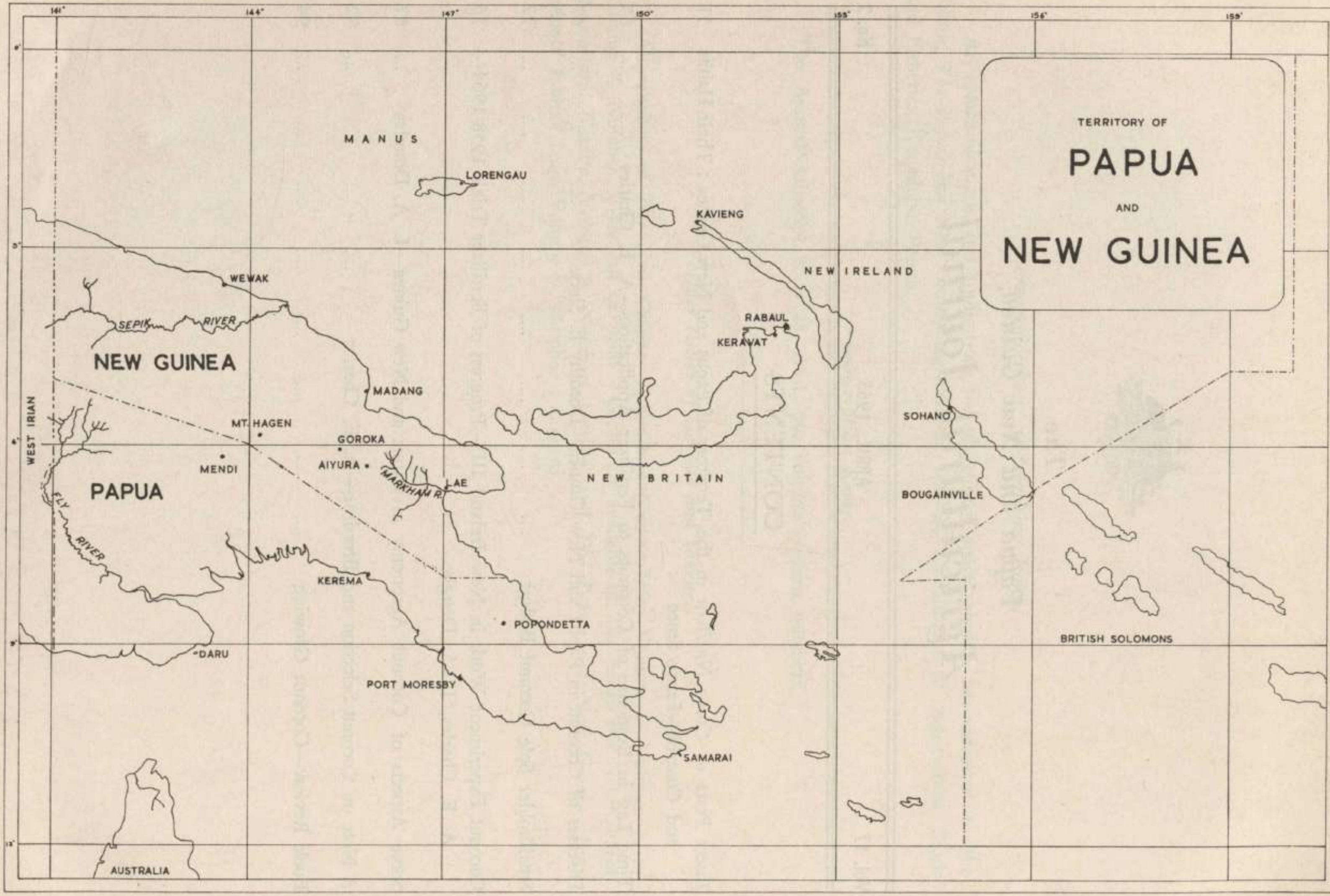
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Insect Pests of Cocos Nucifera In the Territory of Papua and New Guinea: Their Habits and Control.

LANCE SMEE.

Entomologist, D.A.S.F., Port Moresby.

MANY of the insects which attack coconuts are common to a large number of the coconut-growing areas throughout the world, whilst others are found only in one or two localities. However, even those which are confined to a relatively small area can cause serious damage. On the following pages the main pests of coconuts in the Territory of Papua and New Guinea are described; some, like the Asiatic rhinoceros beetle and the palm weevil are found in many of the coconut-growing areas of the world; others like *Brontispa* and '*Sexava*' are confined to the Western Pacific area. A description of these pests is given, together with their habits, the type of damage they inflict and a short resume of the control measures applicable to each.

The list includes :—

Rhinoceros Beetles.	*Oryctes rhinoceros* (L.).
	Oryctes centaurus Sternb.
	Scapanes Grossepunctatus Sternb.
	S. australis Boisd.
	Trichogomphus semilinki Ritz.
	Xylotrupes spp.
Palm Weevil.	*Rhynchophorus* sp.
Coconut Leaf Miner.	*Promecotheca papuana* Csiki.
Brontispa.	*Brontispa Longissima* Gestro.
Sexava (Coconut Treehopper).	Various species.
Lesser Spathe moth.	*Tirathaba rufivena* Walk.
Coconut Spathe moths.	*Batrachedra arenosella* Walk.
Amblypelta.	*Amblypelta* spp.
Axiagastus.	*Axiagastus cambelli* Dist.

RHINOCEROS BEETLES.

Oryctes rhinoceros (L.).
Oryctes centaurus Sternb.
Scapanes Grossepunctatus Sternb.
S. australis Boisd.
Trichogomphus semilinki Ritz.
Xylotrupes spp.

There are a number of beetles in the family *Dynastidae,* commonly known as "Rhinoceros Beetles", which attack coconuts. *Oryctes rhinoceros* (*Plate* I) is one of the most widespread pests of coconut palms in South-East Asia and the Pacific Region. It is indigenous to most of South-East Asia and has been introduced recently to Manus Island, New Ireland and New Britain as well as many other islands in the Pacific area. However, other species found in the Territory include *Scapanes australis* (on the New Guinea mainland). *S. grossepunctatus* (in the New Guinea islands, *Plate* VI), *Oryctes centaurus, Trichogomphus* and *Xylotrupes* spp. (also known as the Elephant Beetle, *Plate* VII.). *Oryctes Scapanes* and *Trichogomphus* have very similar habits, and cause similar damage.

The adults are generally 1½ inches to 2 inches in length, though *Xylotrupes* can be found up to 3 inches, the colour varying from light brown to black depending on age. The female *Xylotrupes* is quite distinct from the male, in the complete absence of any protuberances; the the females of the other species have horns though generally smaller than those found on the males. The larvae of all the species are very much alike (*Plate* II) being the common "white curl grubs" found in decaying vegetable matter.

Life History.

This description applies to *Oryctes rhinoceros,* though the other species are very similar. The eggs are laid in decaying vegetable matter, or

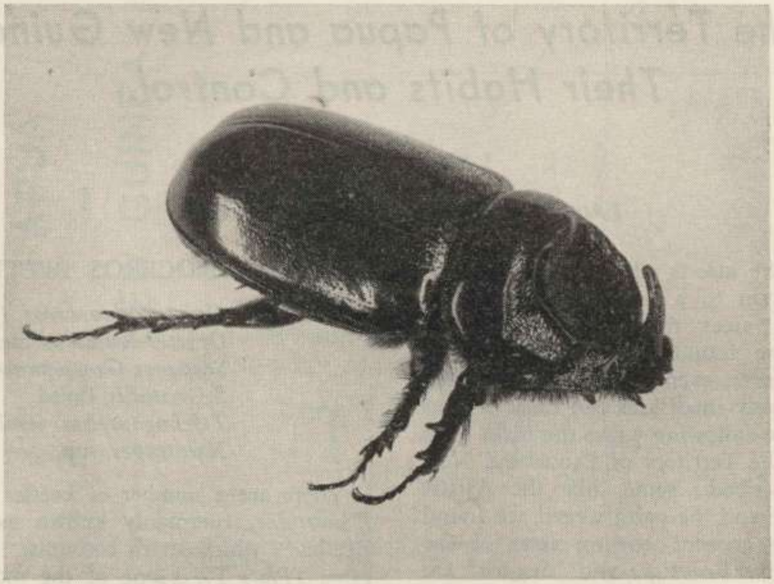

Plate I.—*Oryctes rhinoceros* L. (adult).

even soil rich in humus, and are often found in the decayed parts of living palms which have been attacked by the palm weevil (*Rhynchophorus*). The larvae emerge after an incubation period of 11 to 13 days, and are then about $\frac{1}{4}$ inch in length ; they eventually reach a length of some 3 inches before pupating. The larval period ranges from 74 to 191 days and pupation takes place in a cell which has been formed in the soil or vegetable matter in which the larva has developed. The adult emerges from the pupal shell after an average of 20 days but remains within the cell for a further period of up to three weeks, till the cuticle hardens and the dark colour is developed.

The adult has nocturnal habits, resting or feeding during the day and flying only at night. Their flight range is fairly closely restricted to the breeding site.

The total duration of the life cycle varies from five to nine months, with an average of seven months.

Host Plants.

Rhinoceros beetles attack many other plants besides the coconut palm. These include the African oil palm, sago palm, nipa palm, pandanus, sugar cane, bananas and pineapples.

Plate II.—*Oryctes rhinoceros* L. (larvae).

Damage.

The adults are the only stage to attack the coconut palm. *Oryctes* and *Scapanes* feed on the young unfolded leaves (*Plate* III) causing serious set-backs to the palms, as well as a loss of production caused by direct damage to the spathes. They do not ingest the solid plant material, but suck the juices that flow from the macerated cells. The older palms can generally survive the attacks by the beetles, though in some places, e.g., Palau Islands, up to 50 per cent. of the palms have been killed by the attacks of the rhinoceros beetle only. However young palms are much more susceptible and may often die from damage caused by the beetle. *Xylotrupes* adults feed on the underneath surface of the midribs of the fronds, and can cause the apical part to die or break.

The most serious aspect of rhinoceros beetle damage though, is the paving of the way for infection by other pests and diseases ; the most important being the palm weevil (*Rhynchophorus*) (see the section dealing with the black palm weevil and *Plate* IV).

Control.

1. *Mechanical.* Mechanical treatment to destroy breeding places and remove beetles from the palms has been given considerable attention in the various coconut-growing areas of the world where the pest appears. It involves burning and burying of plant debris, as well as collecting and destroying eggs, larvae and pupae, and removal of the adults from the palms by means of a hooked instrument.

Plate III.—*Oryctes* damage to a coconut palm.

Plate IV.—Young palm killed by combined attack of *Oryctes* and *Rhyncophorus.*

2. *Chemical.* The use of chemicals is replacing to a large extent the use of mechanical means in the control of rhinoceros beetle ; rather than actually collecting and killing the various stages, insecticides are being used with varying success. BHC has been found the most efficient of the different insecticides used ; 0.01 per cent. BHC used as a spray gives good control in the breeding places and can be used on the palms mixed with sand or sawdust to give some protection from the adults (5 per cent. BHC dust is mixed in equal proportions with sand or sawdust and placed in the axils of the central leaves ; this is most effective in dry weather).

Once the favourite breeding grounds have been eliminated, trapping should maintain control. The traps consist of attractive breeding materials such as split palm trunks treated with 0.1 per cent., BHC and covered with leaves.

3. *Biological.* Various insects (Plate V), notably the scoliid wasp (*Scolia ruficornis* F.), have been introduced into New Guinea in an attempt to find suitable predators or parasites for *Oryctes rhinoceros* and the other dynastid beetles which attack the coconut palm. This programme is being continued, with new possible predators or parasites being introduced as they are found.

However, biological control is a long term project, and it may be some time before these various predators can be evaluated.

PALM WEEVILS.

Rhynchophorus spp.

Palm weevils *Rhynchophorus* (*Plate* VIII) are probably the most destructive pests of coconut palms. They are unlike the rhinoceros beetle in that the adult itself does not cause any damage, but the juvenile stages are passed in the palm and the damage they inflict is often fatal. The adult weevil is black, 1 inch to 1½ inches long and sometimes has reddish stripes running down the pronotum. It has a typical elongated snout or rostrum with small, weak mouth-parts at the apical end.

Life History.

The eggs are laid only in the softer portions of the palm, usually where the palm has been injured in some way. However, there is some evidence that oviposition takes place in the crown of the young palms where the tissues are soft or amongst the exposed rootlets of young palms which have been incorrectly planted. Incubation of the egg requires two to five days, and the larva period varies from 36 to 78 days. Pupation takes place in the palm, in a cocoon which the fully developed larva has constructed from the fibrous strands. After the cocoon is finished the larva assumes the inactive stage known as the pre-pupa, which changes into the pupa after about three days. Pupation takes 12 to 20 days, the young weevil then remaining in the cocoon for a further period of a week or so before finally emerging as a mature adult.

The weevils are most active during early morning and late afternoon, with flight and crawling generally restricted to daylight, though some activity is carried on at night. These insects are strong flyers and are capable of long flights in seeking their host plants.

Both sexes live for two to three months, and in this time the female lays an average of 200 eggs.

Host Plants.

The palm weevil is commonly found on a number of palms including the sago palm and has been reported attacking the oil palm and other ornamental palms.

Damage.

After hatching, the larvae begin feeding toward the centre of the palm, ingesting only the softer parts and passing the fibrous strands to the rear where they eventually block the tunnel. Following the feeding of a number of larvae, a large cavity may be formed in the centre of the palm. The larvae may be found anywhere in the trunk of a young palm but are confined to the top few feet below the crown in older palms.

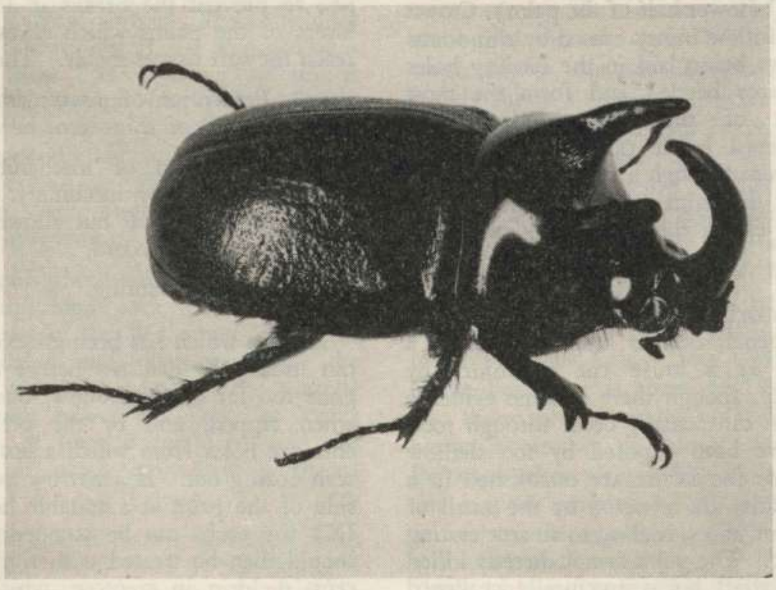

Plate V.—Scapanes Grossepunctatus.

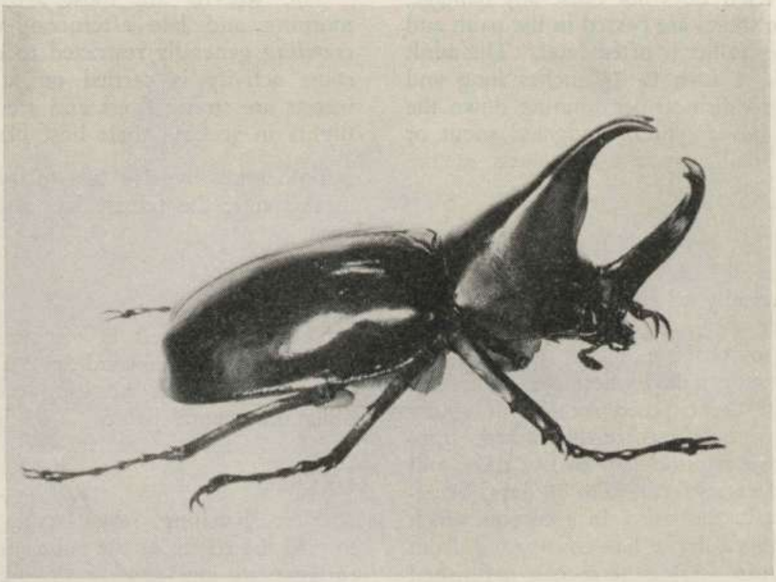

Plate VI.—*Xylotrupes* sp.

An attack may be initiated almost anywhere following injury to a young palm, though the type of damage may be generally classified as either " crown " (top half of the palm, see *Plate* IV) or " bole " (lower half of the palm). Crown attacks mostly follow injury caused by rhinoceros beetle (the eggs being laid in the feeding holes of the rhinoceros beetle) and form the most serious aspect of rhinoceros beetle attack, though the weevil larvae can penetrate to the trunk of the palm through a cut leaf petiole. In a crown attack the palm is usually killed by the larvae actually eating the growing point of the palm.

When the attack is in the lower half of the palm initial penetration is usually through a wound (such as a knife cut or injury by machinery, etc.), though there is some evidence that penetration can actually occur through rootlets which have been exposed by too shallow planting. Once the larvae are established in a palm, more adults are attracted by the smell of fermenting plant juices, leading to an accelerating rate of damage. The palm is not directly killed by this type of attack but is structurally weakened so that it eventually falls to the ground.

Control.

The first step to take in the control of this pest is to deny it oviposition places in the palms, i.e., to prevent the breaks in the outer fibrous layers of the palms which allow the weevils to reach the soft tissues inside. This is done by :—

1. Prevention of insect damage—mainly by control of rhinoceros beetle.
2. Prevention of mechanical damage—by knives or by machinery. Fronds should not be cut off but allowed to fall off of their own accord.
3. Correct planting.

A palm which has been attacked near the base can usually be detected before the damage has gone too far by the hollow sound of the trunk when tapped, and by the presence of small entrance holes from which a brown fluid can be seen oozing out. If a narrow hole is cut in the side of the palm at a suitable height (see *Plate* IX) the grubs can be scooped out. The hole should then be treated with a mixture of 2 per cent. dieldrin in creosote, which will kill any grubs remaining, and act as a repellant to prevent

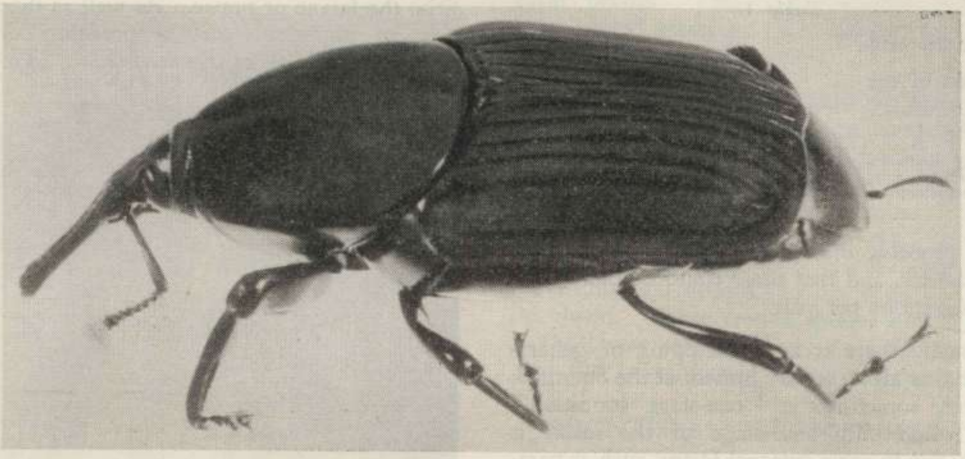

Plate VII.—*Rhynchophorus* sp.

re-infection. The use of a BHC/sand or sawdust mixture as for rhinoceros beetles has been found to have beneficial effect.

COCONUT LEAF MINER.

Promecotheca papuana Csiki.

The coconut leaf mining beetle, *Promecotheca papuana* Csiki. is a serious pest of coconuts only in some parts of New Britain. It occurs elsewhere in the Territory but is not recorded as a major pest in these areas. Other species of *Promecotheca* are found in New Guinea, mostly on pandanus, but do not attack coconuts. *P. papuana* is generally kept in check by natural enemies, but periodically appears in what is known as "one stage condition" when it can assume plague proportions.

In New Britain the most seriously affected areas are the Linga Linga area, the central north coast west and east of the Willaumez Peninsula, around Lindenhafen and other areas on the central south coast, and parts of the Gazelle Peninsula. Manus Island, the Duke of Yorks and other parts of New Britain have had less serious attacks at much more widely spaced intervals.

P. papuana is golden brown in colour, with the prothorax and distal third of the elytra a deep bluish-black and is about 1/3 inch in length.

Life History.

This beetle is closely associated with the coconut palm, all stages occurring in the palm crown, and with both adult and larvae feeding on the fronds.

The eggs are laid almost invariably on the underside of the leaflet and are covered with excrement by the female. They appear as a small oval mound, about 1/8 in. long, with a rough brown surface. Before ovipositing the female chews a furrow in the leaf surface, over which the eggs are laid. On hatching, the larvae penetrate directly into the inner leaf tissue by means of this furrow ; the larvae, young or old, cannot penetrate an unbroken leaf surface as their mandibles work only in a horizontal plane. The larvae feed inside the leaf, leaving the epidermis above and underneath the mine, through which they can be readily seen if the leaflet is held up to the light. The average number of larvae per mine is three (in the Lindenhafen area there are five) ; though if the infestation is heavy, a number of mines may run together. Pupation takes place within the mine and takes ten days to complete. Adults can live as long as five months, possibly even longer, and during this time, the female can lay 80 to 100 eggs. *Table* 1 shows the average length of each stage of the life cycle.

Table 1.

Stage of life cycle.		Days.
Incubation of egg	....	15 days.
Larval period	....	28 days.
Pre-pupa / Pupa / Post pupa	to emergence of adult	15 days.
Pre-oviposition	....	25 days.
Adult	....	160 days upwards.

It is probable that in nature these periods are much shorter, and that there could be more than five generations per year.

Normally there is an overlapping of generations so that all stages are present at the one time. However, sometimes a " one-stage condition " arises, when only one stage of the insect is present, due to some external factor, such as parasites, weather, or even incorrect insecticide application. When this occurs a rapid build-up of the *Promecotheca* population takes place, as the parasites lack suitable host material for oviposition, and many beetle generations are required before the parasites can gain the upper hand and reduce the beetle population again. Once the " one-stage " condition is reached it is maintained for a long period ; up to two years.

Damage.

In a severe infestation the palms can be damaged very badly ; the leaflets are completely destroyed, turning brown and giving the palms the appearance of being scorched. Sometimes the central shoot can be damaged so badly that the palm eventually dies. Recovery from severe infestation is slow, with the palm taking up to two years before nut production is resumed. With a less severe infestation, drying and curling of the tips of the leaflets is noticeable, together with the elongated patches due to the mining of the larvae within the leaflets.

Control.

No truly satisfactory artificial control measures against *Promecotheca* have been devised. In general it can be assumed that chemical treatment would do more harm to any parasites than to the beetle.

There are a number of parasites which are generally efficient in controlling *Promecotheca,* including a number of small wasps which parasitise the larvae or pupae. As well as these, ants play an important part as predators of both larvae and adults of *Promecotheca.* The most

Plate VIII.—Cutting a hole in a coconut palm to facilitate removal of *Rhynchphorus* larvae.

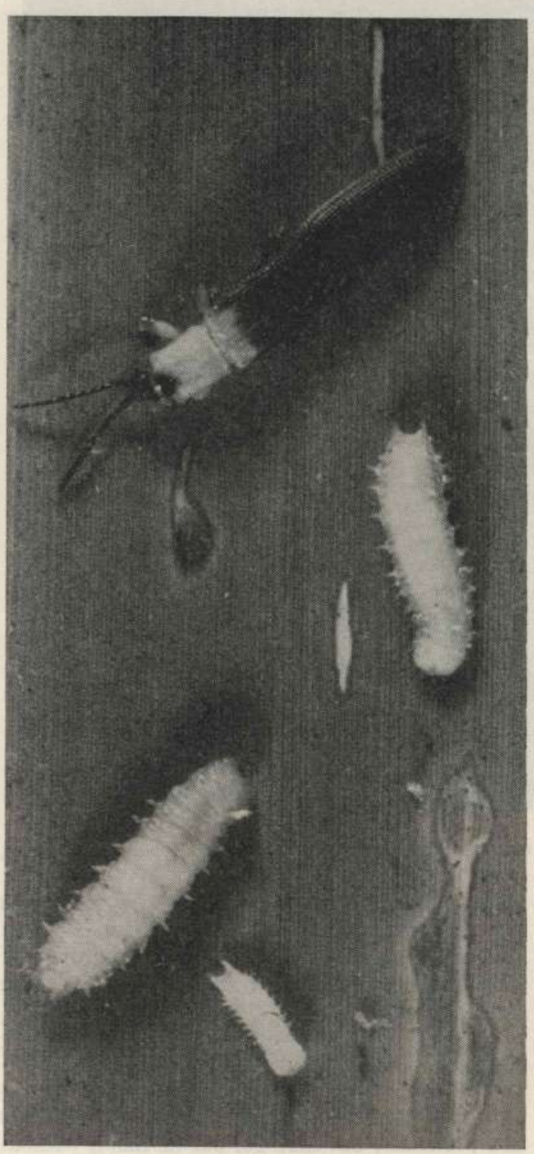

Plate IX.—Larvae and adults of *Brontispa.*

important of these predacious ants is the green tree ant, with others playing a less important part.

Vertebrates are often overlooked as predators of *Promecotheca.* Various lizards are abundant in plantations and presumably would feed on the adult beetles. Parrots (*Domicella* sp.) have been noted tearing open larval mines and apparently eating the larvae.

At the present moment, until the main factors contributing to an outbreak are understood, the only steps that can be recommended are the encouragement and protection of lizards, birds, ants, etc., and the periodic examination of random palms for detection of outbreaks. When an outbreak occurs insecticides can be used to kill the adults and fronds bearing eggs and larvae cut down. These fronds should not be burnt, as the larvae cannot mature once the frond has died and burning would only kill the parasites.

BRONTISPA (COCONUT HISPID).

Brontispa longissima Gestro.

The coconut hispid, *Brontispa longissima* (*Plate* X) is a small orange and black beetle which is an important pest of coconuts in the Solomon Islands and New Guinea. It attacks palms of all ages, but it is most severe in nurseries and young palms in the field. The adult is about ½ in. long by 1/8 in. broad, with the head and antennae black, and the thorax and a small portion of the elytra (wing cover) adjoining, yellow-brown. The remainder of the elytra is black.

Life History.

The eggs are laid between, and inside, the tightly- folded young leaflets, in groups of one to four. They are laid end to end in a furrow chewed by the female parallel to the axis of the leaf, and then covered with excreta. The larvae hatch after incubating for five days, and commence feeding between and inside the unopened leaflets. Pupation takes place between the unopened leaflets, where the adults also feed. *Table* 2 shows the average length of the different stages in the life history of *Brontispa.*

Table 2.

Stage of life cycle.	Days.
Incubation	5
Larva	36
Pupa	6
Pre-oviposition	74
Total, egg to egg	121

Plate X.—A young palm damaged by *Brontispa.*

This would give three generations per year. The shortest time for a generation is about 64 days.

Host Plants.

As well as the coconut, a number of palms serve as host plants to *Brontispa.* They include the sago palm, betel-nut, oil palm, as well as various other ornamental palms.

Damage.

Both larvae and adults feed amongst unopened leaflets. The larvae chew off the surface of the leaf, causing browning and eventual death of the tissue attacked. The adults chew the tissues in narrow lines parallel to the midrib of the leaflet, and probably cause more damage than the larvae, as they live much longer. A palm which has been damaged by *Brontispa* has a scorched appearance, with the fronds brown and curled at the tip. They retard the growth of the palms, and in cases of severe attack can cause death.

Control.

Brontispa is generally controlled by parasites and predators, but may get out of hand, particularly in large areas of young palms. A treatment which will give good control is to drench the central spike of the palm with 0.1 per cent. dieldrin in water. Equipment capable of delivering a fine low-volume spray controlled by an efficient trigger tap will use less than an ounce of mixture per palm up to three years old. Unnecessarily high volumes and concentrations should be avoided.

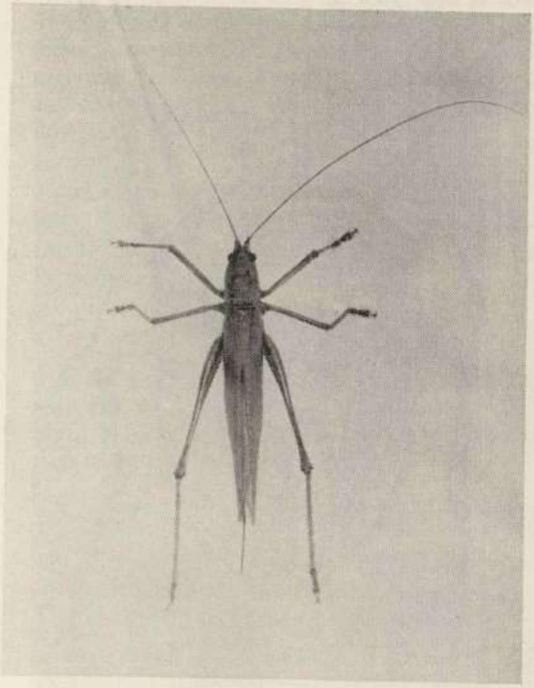

Plate XI.—*Sexava.*

Treatment should be repeated as required when damage to the palms can be seen.

'SEXAVA' (COCONUT TREEHOPPERS).

Family *Tettigoniidae,* sub-fams. *Mecopodinae* and *Conocephalinae.*

There are a number of species of treehoppers which are known under the name "*Sexava*". These are all rather similar in appearance (*Plate* XII) and habits. The colour of these treehoppers is generally green, though there are brown species. In appearance they are typical long-horned grasshoppers, with well-developed wings and jumping legs, and very long antennae.

Life History.

The eggs are laid either in the ground or in the accumulated debris around various epiphytes, etc. When the eggs hatch the young nymphs climb the palm and commence feeding on the leaves. All the nymphal stages, and the adult stage are passed in the top of the palm.

The life cycle of a typical tree-hopper is summarized in *Table* 3.

Table 3.

Stage of life cycle.	Days.
Egg	45-100 mean 78
Nymph (female)	90-124 mean 101
Nymph (male)	78-107 mean 101
Adult, pre-oviposition	33
Total, egg to egg	212

Host Plants.

Coconut treehoppers freely attack bananas, manila hemp, and oil palms as well as coconuts and are doubtless found on other plants also.

Damage.

The nymphs and adults of the coconut tree-hopper can completely strip the green leaves off the coconuts, causing a severe setback in growth, and loss of production.

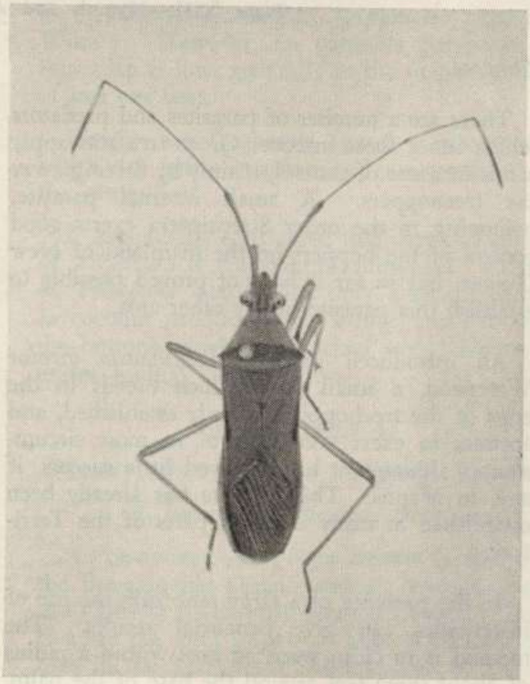

Plate XII.—***Amblypelta*** **(adult).**

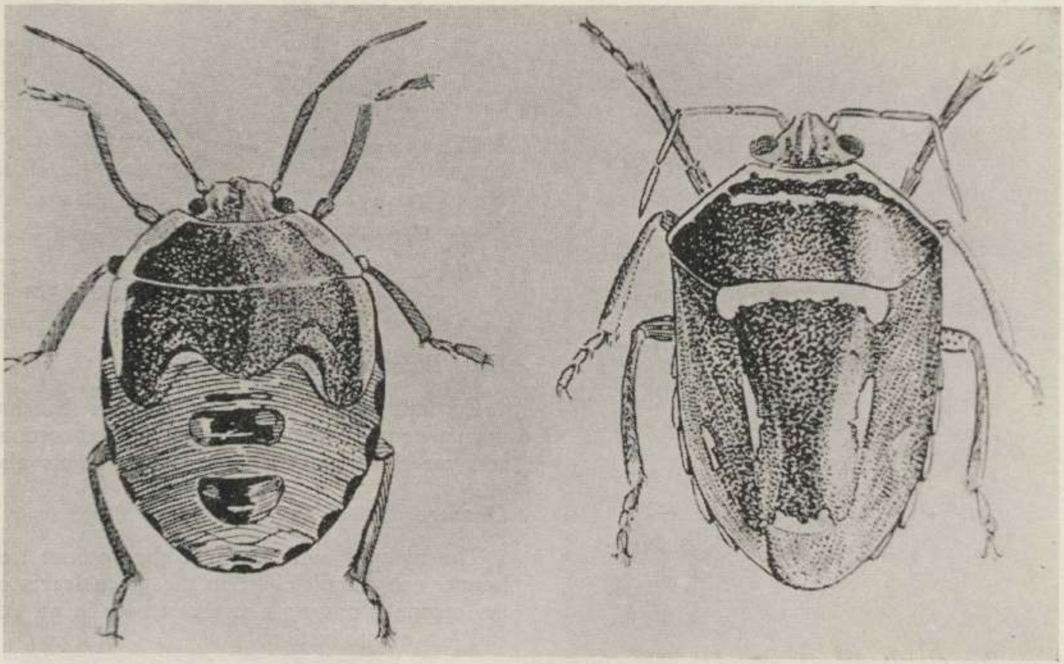

Plate XIII.—Nymph and Adult of *Axiagastus cambelli.*

Control.

There are a number of parasites and predators which attack these insects. Green tree ants apply a fair measure of control, mainly by driving away the treehoppers. A small internal parasite, belonging to the order Strepsiptera exerts good control of the hoppers on the mainland of New Guinea, but so far it has not proved possible to establish this parasite in any other area.

An introduced parasite, *Leefmansia bicolor* Waterston, a small wasp which breeds in the eggs of the treehopper, is easily established, and appears to exert good control in most circumstances although it has achieved little success, if any, in Manus. This parasite has already been established in many different parts of the Territory.

In the presence of a large outbreak, the use of insecticides can give beneficial results. The method is to clean weed an area within a radius of about three feet around the base of the palm, and then spray this area, plus the base of the palm to a height of about three feet with an 0.25 per cent. dieldrin in water mixture. This method is best in areas of low rainfall.

COCONUT SPATHE MOTH.

Tirathaba rufivena Walk.

Tirathaba rufivena Walk. is a small fawn coloured moth, with the veins in the wings clearly marked in a reddish colour, and is about $1\frac{1}{4}$ in. long. It is found from Ceylon to New Caledonia.

Betrachedra arenosella Walk. commonly known as the Lesser Spathe moth, is also quite common on coconuts. Its larvae bore in the male flowers only, and the damage caused is not of economic importance.

Life History.

The female oviposits on the coconut flowers as the bud is just opening, and the caterpillars feed on the newly opened buds. The mature larvae are about $\frac{3}{4}$ in. long, and are a dark grey with the head and prothorax brown.

The pupa is about 2/3 in. long, and is found in a cocoon which the larva has formed from debris, fragments of flowers and excreta, bound together by silken threads. The dried cocoons are often found in the accumulation of dead flowers in the bases of the fronds.

Table 4.

Stage of life cycle.	Days.
Egg	4-5
Larva	12-30
Pupa	7-14
Total	30

Each generation appears in time to coincide with the production of the new spathes. However, under the right circumstances the cycle can pass in only 15 days.

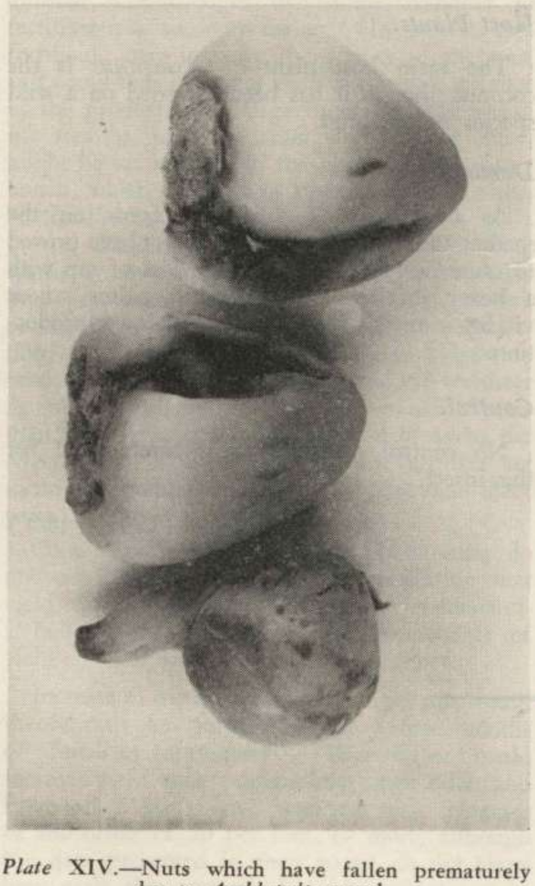

Plate XIV.—Nuts which have fallen prematurely due to *Amblypelta* attack.

The adult is nocturnal, and only the female is attracted to lights.

Host Plants.

Tirathaba attacks the following plants though it is best known from coconuts :—nipa palm, coconuts, oil palms, betel-nut, bananas and *Phaseolus*. It is thought that *Nipa fruticans*, the nipa palm, is the original host.

Damage.

The eggs are laid on the buds which have just begun to open. The caterpillars generally attack the male flowers, though occasionally the female flowers are attacked as well, and they often eat the peduncles (stalks) of the young buttons. In general *Tirathaba* causes a consistent but not serious fall of young nuts.

The damage caused by *T. rufivena* is most important on spathes which are defective in opening.

Control.

In the Solomon Islands, the caterpillars on the nipa palms are parasitized by a wasp belonging to the family Braconidae, (*Apanteles tirathabae* Wlkn.). However, on coconuts parasitism by this wasp is low, generally in the neighbourhood of one per cent.

Earwigs are frequently found in the spathes which are being attacked and are predators of the caterpillars.

It is generally considered that chemical control of *Tirathaba* is economically unsound. Control of *Tirathaba* would give only a small increase in coconut production, as a high proportion of the buttons which are attacked would fail to set under normal circumstances.

AMBLYPELTA.

Amblypelta cocophaga cocophaga Brown.

A. lutescens papuensis Brown.

A. cocophaga cocophaga Brown is found in the Bougainville District and *A. lutescens papuensis* Brown is found in Southern Papua. These two are the most important bugs attacking coconuts in the Territory. Other species of *Amblypelta* have been recorded on coconuts.

Amblypelta is a slender light brown to red insect slightly less than ½ in. long. It was first recorded as attacking coconuts in the Solomon Islands, where it causes extensive nutfall. In the Territory it occurs in isolated pockets only in Bougainville. *A. lutescens papuensis* causes extensive nutfall on the south coast of Papua and on the islands extending to the east.

Life History.

The life cycle of *Amblypelta* is short, only about six weeks, and all stages can be found on the coconut palm. The eggs are laid on the central spike, and hatch in seven to eight days ; the nymphal stages last 30 to 35 days.

Host Plants.

Amblypelta feeds on wild figs (*Ficus* species), poinciana, cacao, tapioca and various bush trees.

Damage.

Amblypelta feeds on the inflorescences and young nuts. When it feeds it injects salivary juices into the tissues, causing the death and distortion of quite a large area (of both cacao and coconuts), which can cause the nut to fall prematurely. Nuts which have fallen because of *Amblypelta* attack can be distinguished by the feeding scars (*Plate* XV).

Amblypelta has been known to cause 100 per cent. premature nutfall, so that production ceases altogether.

Control.

No satisfactory method of controlling this pest has been evolved, except by encouraging the tree ants which prey on it, and discouraging other ants which do not and which are antagonistic to the tree ants.

AXIAGASTUS.

Axiagastus cambelli Dist.

Axiagastus cambelli is a small brown and orange bug closely related to the " green vegetable bug " *Nezara viridula* L. (*Plate* XIV). It is often found in large numbers on the freshly opened spathes, however, it appears to feed mainly on the male flowers and has not been proved to cause nutfall.

Life History.

The various stages of the life cycle of *Axiagastus* cover about eight weeks (eggs 7 days, nymphs 46 days). The eggs are laid mainly on the dried spathes and fibrous stipules rather than on the leaves.

Host Plants.

The main host plant of *Axiagastus* is the coconut, though it has been recorded on a wild species of betel-nut.

Damage.

As noted above, *Axiagastus* feeds on the spathes and male flowers, and has not been proved to cause nutfall. However, the loss of sap with a heavy infestation can weaken palms whose vitality is already low, and possibly lower production.

Control.

No control measures are recommended for this insect.

(Received October, 1963.)

Time Lag in Response of Coconuts to Fertilizer Application.

A. E. CHARLES,
Economic Botanist, D.A.S.F., Port Moresby.

Statements in the literature on coconuts frequently imply that no improvement in yield of mature palms can be expected in less than two to three years from fertilizer application.

A typical statement is that "in the case of a plant like the coconut palm, an increase in yield as a result of fertilizer application is manifested only from two-and-a-half to three years after application" (Menon and Pandalai, 1958). This statement is supported by arguments presented by Copeland (1931), although Copeland himself acknowledges that some response to fertilizer may show up earlier. He suggests that fertilizing may improve the vitality of the tree, and could thus influence yield in the first instance by the production of larger nuts, perhaps within six months of application. A second effect might be an increase in the number of nuts per bunch, which could show up after nine months. A third effect could be the production of a greater number of bunches of nuts, or in other words a more rapid succession of bunches. He then proceeds to show that there is a time lag of about two years and nine months from initiation of leaf and flower primordia to harvesting of ripe fruit, and deduces that maximum fertilizer response could not show up in a period shorter than this. He concludes that "data as to the effectiveness of application of any fertilizer are incomplete unless carried on for more than three years after the application".

Copeland's arguments are sound, but they do not on their own warrant the conclusion that yield response will be evident *only* after two-and-a half to three years. Some components of yield could show a response much earlier.

Increase in the quantity of copra per nut would theoretically be possible within a few months of fertilizer application. This factor could increase yield quite substantially, since Ziller and Fremond (1961) have reported such increases of the order of 20 per cent. or more, although the data presented in their paper do not show how early this response became evident.

Increase in number of nuts per bunch should be possible in less than twelve months, since a proportion of shedding of fertilized female flowers seems always to occur in the first few months after setting. Menon and Pandalai (1958) review evidence as to whether fertilizing can reduce the proportion of button shedding, but information on this point is scanty. One report is quoted which indicated that fertilizer increased the number of female flowers per bunch rather than the proportion of fruit set. This report appears to have been based on observations some years after the commencement of fertilizing, when long-term effects would be established. It would therefore not preclude a short-term improvement in fruit setting during the period before flower numbers could be influenced.

Increase in frequency of bunch production might also be possible within a fairly short period. Trials on young palms shave shown increases in frequency of frond production resulting from cultural practices (Green and Foale, 1961 ; Ziller and Fremond, 1961). If the same effect occurred in mature palms it would be accompanied by increased frequency of bunch production.

Turning from theoretical considerations to practical results, there is substantial evidence that yield response can occur earlier than the third year after application of fertilizers. In experiments in Papua and New Guinea yield estimates have been made by six-monthly counts of maturing nuts on the palms, that is, of nuts which would fall and be harvested in the following six months. Some response to potassium fertilizing was evident in counts made twelve months after fertilizer application (Charles, 1959 ; Charles and Douglas, 1965) and the response reached statistical significance, and apparently its maximum level , in counts eighteen months after fertilizing. In experiments at Port Bouet (Ziller and Fremond, 1961) there was definite response in nut numbers in the second year after fertilizing, and possibly some response even in the first year, since all plots receiving potassium showed higher nut numbers than the unfertilized controls. In a series of experiments in the British Solomon Islands Protectorate (Green and Foale, personal communication) where fertilizers were applied in August or October, significant increases in quantity of copra per nut and total copra production occurred in the calendar year following application of nitrogen in two experiments, and in another experiment significant increases in quantity of copra per nut, number of nuts harvested and total copra yield occurred in the calendar year following NPK application. In other experiments, significant responses to nitrogen, phosphorus or potassium showed up in the second calendar year after fertilizer application.

It is therefore evident that coconuts can show appreciable yield response to fertilizer treatments as early as the second year after application,

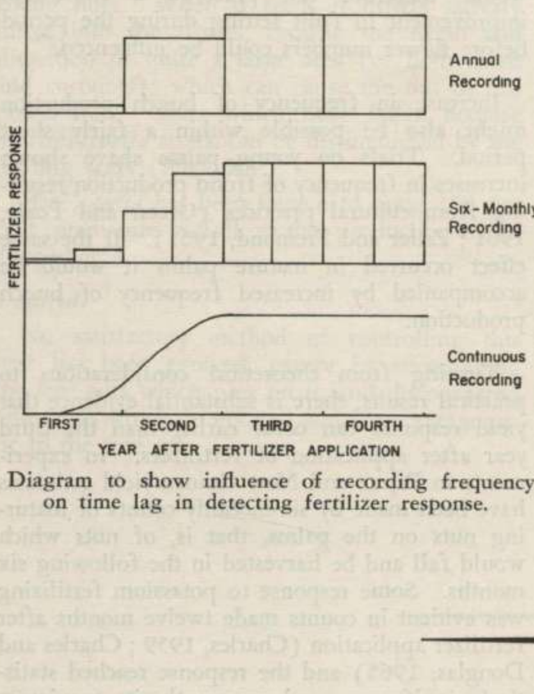

Diagram to show influence of recording frequency on time lag in detecting fertilizer response.

and there is some indication that response to a given level of fertilizer may reach its maximum by the end of the second year. In practice, the stage at which response is detected would depend to some extend on the method of yield recording used, as shown in the diagram.

From this it may be deduced that initiation of flower primordia must be of little or no importance in at least some cases of fertilizer response. For the producer, the significant aspect is that he can expect some return from investment in fertilizers in the second year after application.

Summary.

Evidence is presented that coconuts can and do show yield responses within two years of fertilizer application.

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(Received May, 1964)

Diseases of Coconut in Papua and New Guinea.

DOROTHY E. SHAW.

Principal Plant Pathologist, D.A.S.F., Port Moresby.

COCONUTS in Papua and New Guinea are free from serious diseases caused by organisms; the few diseases which do occur being of only minor importance. One of the factors which has contributed to this position is the prohibition against unrestricted importation and the rigorous quarantine measures in operation.

Coconuts in the Territory are affected by soil deficiency diseases with various leaf patterns, tapering of the stem, reduced yield and other symptoms, but these have been published previously, or are still under investigation by the chemistry section of the Department.

Diseases caused by organisms, or in which organisms play a part, are discussed below:

WHITE THREAD BLIGHT.

This disease is caused by the fungus *Corticium penicillatum* Petch, and the known Territory distribution is New Guinea mainland, New Hanover, New Ireland, New Britain, Bougainville and Papua.

Plate I.—White thread blight. Large white area on leaflets caused by *Corticium penicillatum.*

The disease usually occurs on the older leaves and can be distinguished from the ground by the presence on the upper surface of the leaves of large dead patches, mainly circular in outline, comprising all or part of several to many leaflets,

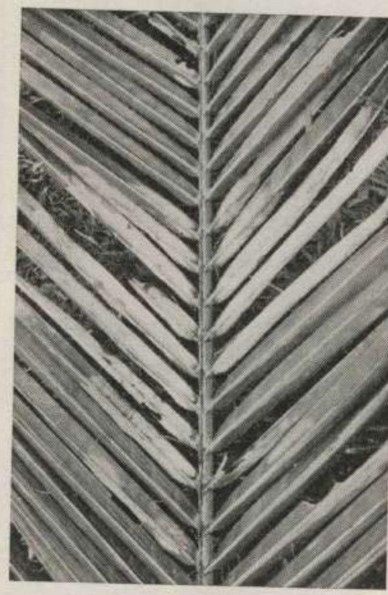

Plate II.—White thread blight. White appearance of upper surface of leaflets caused by *Corticium penicillatum.*

sometimes several feet in diameter, and usually pale tan at first but later becoming bleached to pale buff. (*Plates* I and II.)

On the under surface of the leaves, white fungal threads in strands run along the midrib and these and finer threads spread lengthwise over the under surface forming a white film. The advance threads spreading towards the tip of the leaflets resemble fans of white cotton. (*Plate* III.) The fungus kills the leaf tissue, forming the conspicuous bleached spot visible on the upper surface; the tissue below the advancing edge of the fungus is usually green. The spores of the fungus, if present, occur on the white mass of threads.

The disease is usually found on the older leaves, and therefore does little damage. For some time after the disease was described 40 years ago, it was recommended that affected leaves be removed and burnt, but now such measures are rarely necessary.

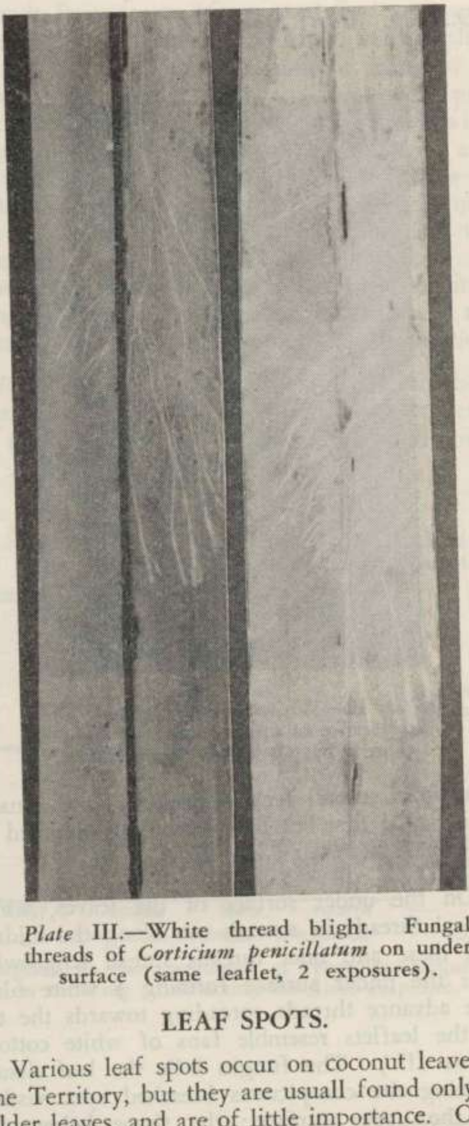

Plate III.—White thread blight. Fungal threads of *Corticium penicillatum* on under surface (same leaflet, 2 exposures).

LEAF SPOTS.

Various leaf spots occur on coconut leaves in the Territory, but they are usuall found only on older leaves, and are of little importance. Occasionally they do occur on young leaves of palms in the field, and can be controlled if good conditions are provided, such as soil balanced in nutrients, and without competition from weeds and grasses. Occasionally the spots build up on young palms in nurseries, and in this case can be controlled by fungicides.

The main fungi associated with leaf spots are described below :—

Pestalotiopsis palmarum (Cooke) Steyaert (often given as *Pestalotia palmarum* Cooke).

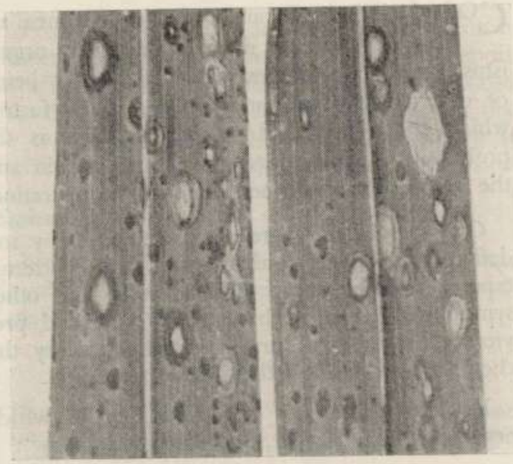

Plate IV.—Leaf spots. Young and old spots, mainly caused by *Pestalotiopsis palmarum.*

This fungus is the one most commonly found on leaf spots of coconut in the Territory. The spots are oval in shape, reaching ½ in. x ¼ in. in size, tan coloured when young, later nearly white or pale grey on the upper surface, with a distinct edge, and small black bodies about the size of a small pin's head scattered over the surface ; these are the fruiting bodies which contain masses of spores. Young and old spots are shown in *Plate* IV. Inoculation tests reported by several workers gave negative results, and the workers concluded that weakening of the plant is necessary for infection.

Pestalotiopsis theae (Saw.) Steyaert.

This fungus has been found on large leaf spots, as shown in *Plate* V, and has also been isolated from the edge of the lesions. The spots are light brown in colour, with a definite edge, often with a concentric pattern, and with the fruiting bodies bearing the spores scattered over the centre. The lesions can reach 4 in. and more in length, and often take up the whole width of the leaf, although occasionally a lesion is stopped by the midrib. Only a few collections of this disease have been found to date in the Territory. No pathogenicity tests have as yet been reported with this species on coconut.

Pestalotiopsis spp.

Other species of *Pestalotiopsis*, viz. *P. japonica* (Syd.) Steyaert, *P. papposa* Steyaert and *P. stictica* (Berk. and Curt.) Steyaert have also been recorded on leaf spots on coconut in the Territory but at present no pathogenicity tests with these organisms have ben reported on coconut, and it is not known whether they are primary or secondary invaders.

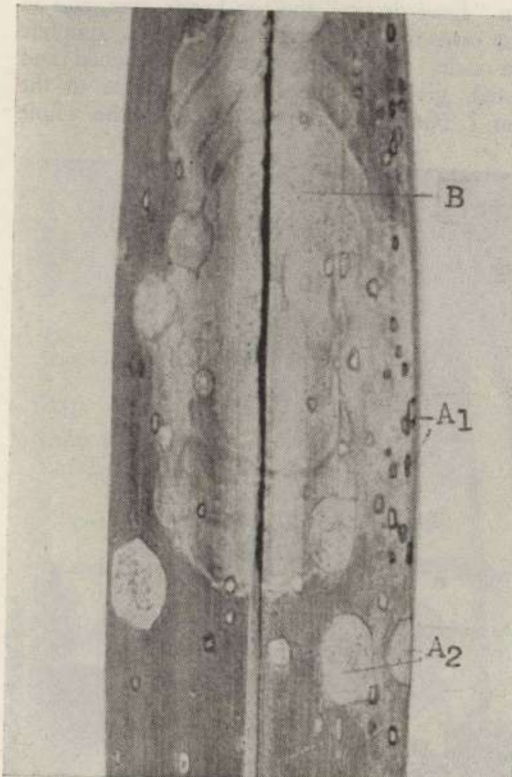

Plate V.—Leaf spots. A1 and A2, young and old spots caused by *P. palmarum* ; B, large leaf spot caused by *P. theae*.

Melanconium palmarum Cooke.

This fungus has been found occurring on large leaf spots very closely resembling those described above for *P. theae*, but on one collection only to date. Again, it is not known under what conditions this fungus occurs on leaf spots, and its relation to the spot.

Epicoccum cocos Stevens.

This fungus has also been found on leaf spots in the Territory. The spots on which it occurs are oval in outline, usually dark tan in colour, and often smaller than the spots with *P. palmarum*. The spores occur in black masses the size of a pin's head, scattered over the surface of the spot. Stevens, who first described the fungus, stated that "infection often occurs through wounds caused by insects, though often also such injuries are not evident." No pathogenicity tests have been reported to the author's knowledge.

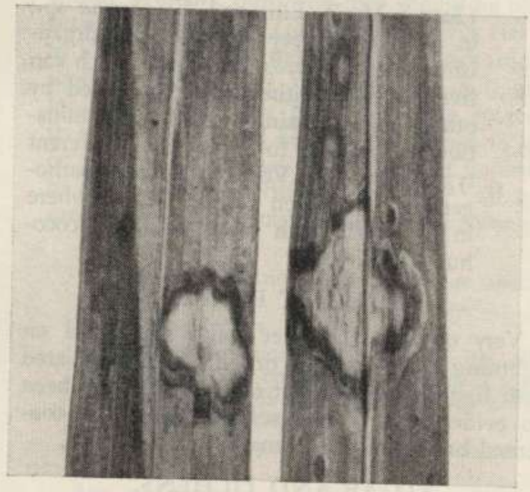

Plate VI.—Leaf spots, caused by ***Helminthosporium incurvatum***.

Helminthosporium incurvatum Bernard.

Very occasionally this fungus is found on spots on coconut leaves in this Territory. The spots are less regular in outline than those of *P. palmarum*, but they have a distinct border. (*Plate* VI.) The spores are not borne in masses as are the spores of the fungi mentioned above, but are borne on stalks which rise from the leaf surface. The spores cannot be seen with the naked eye unless conditions for sporulation have been extremely good, in which case the spores and their stalks may appear as a fine black dust on the surface of the lesion.

In considering the leaf spots of coconut in this Territory, the following should be emphasized :—

1. It is often difficult to distinguish the different types of spots, and the only sure means of identfying the fungi at present is by microscopical examination.
2. Often more than one type of spot occurs on the same leaf, as shown in *Plate* V.
3. As well as those listed above, other species of fungi are found on healthy and diseased coconut leaves.* In some cases they are sooty moulds living on insect honey dew on the leaf surface, or black moulds on the leaf surface, such as *Clasterosporium cocoicola* M. B. Ellis and D. Shaw, *Sporidesmium macrurum* (Sacc.) M. B. Ellis and *Xylohypha* sp.; in other cases they are secondary organisms such as *Gloeosporium* sp. which can live on tissue either dying or killed by other fungi. Again, microscopic examination is necessary to identify the different types of spores. Very few tests for pathogenicity have been carried out anywhere in the world with fungi found on coconut leaves.

BRACKET FUNGI.

Very occasional bracket fungi are found on lightning struck palms, or on palms associated with lightning strike, but to date there has been no evidence in these cases that the fungi concerned have been the primary cause of death.

ALGAE AND LICHENS.

Species of these organisms occur on leaves and trunks, particularly on palms immediately adjacent to the coast. As damage either does not occur or is quite negligible, they are not discussed here in detail.

UNCONFIRMED DISEASES.

Since the present pathological service commenced in 1955, there have been no confirmed records of the following :—

1. Bud rot of coconut caused by *Phytophthora palmivora* ; (Dwyer, 1953)
2. Bacterial leaf blight ; (Dwyer, 1937)
3. Stem bleeding disease. (Dwyer, 1937)

Information and specimens of any condition thought to resemble the three mentioned above would be welcome.

PALMS WITH ABNORMAL HABITS.

Occasionally palms are found with abnormal growth habits, such as " corkscrew ", often called " head droop " or " strangle disease ", the " head droop " condition being a stage of the corkscrewing.

In " head droop " the top bends over, and in many cases the whole stem may form a complete semi-circle, while the leaves are bunched and twisted, giving a one-sided appearance to the palm (*Plate* VII). In some cases the whole stem may form a distinct loop, or in others become " S " shaped. Occasionally the stem continues to " corkscrew " for many feet (*Plate*

Plate VII.—" Head droop ", a stage of " corkscrewing ", showing one sided appearance of cabbage.

* The fungi and other conditions recorded on coconuts in Papua and New Guinea, as well as the relevant literature, have been recorded by Shaw (1963).

Plate VIII.—Palm with "corkscrew" trunk, resuming normal growth and symmetrical cabbage.

VIII), and there is usually failure to bear nuts while the condition persists. The cause of the condition is unknown.

LIGHTNING STRIKE.

Death of palms struck by lightning, and the slow death of surrounding palms over a period of up to 18 months after the strike, still occurs in parts of the Territory. The precise cause of the slow death of the surrounding palms has not been elucidated.

Notification of any lightning strike, together with the exact time of the strike, will be welcomed. The site will be visited by the Pathologist or Agricultural Officers, who will plan the position of the struck palms and the surrounding ones, and keep a check on the position and time of death of any surrounding palms, over a period of months.

SPECIMENS.

Specimens of fungi collected in the Territory are lodged in the Fungal and Pathology Herbarium at the Department of Agriculture, Stock and Fisheries at Port Moresby. Portion of most of the collections are also sent to various institutions overseas, for additional lodging and study.

Collections are welcomed from all areas of the Territory, at all times. If specimens are received continually in this way, there is a constant check on both the distribution and degree of severity of the various diseases, as well as on the appearance in the Territory of hitherto unrecorded diseases.

Specimens of coconut leaves should be sent wrapped in plastic if they can reach Headquarters within 24 hours. otherwise they should be placed between newspaper, (to keep the leaves flat and to help dry out the moisture) and forwarded as soon as possible. If specimens are in transit a long time, i.e., over three days, the spores of secondary fungi and bacteria commence to grow on the surface, so that it is sometimes impossible to distinguish the primary organism. All specimens should be accompanied by a note stating :—

Collector's name.

Locality of collection (e.g., Plantation and District.)

Date of collection.

Degree of infection (e.g., whether the disease occurs on only one or several leaves of a palm, or whether it is widely spread over hundreds of palms.)

Colour of the palms (e.g., older leaves very yellow, etc.)

Any additional notes such as type of ground cover (legumes or kunai), or interplanted cacao, or cattle grazing, are most helpful and often necessary for a complete understanding of the disease.

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Smallholder Sole Coconut Budget.

THE following sole coconut budget has been used in Papua and New Guinea by the Native Loans Board as a guide for smallholder indigenous development. It should not be regarded as an unalterable and final budget as many of the assumptions and data will need to be adjusted and corrected in the future as more factual information becomes available.

This model budget is based on family labour, with the borrower commencing operations on an unimproved leasehold block without established subsistence gardens or any capital. The loan repayment programme is calculated to allow a steadily rising net income which the borrower may use to improve his standard of living and/ or further development of his property.

PHYSICAL DATA.

Labour—Family units of labour available, 1.5.

Annual number of working days—290.

Annual labour units available—435.

Units per operation—

	labour units per acre.
Felling, etc.	60
Nursery (12 units per year)	4 (per acre planted)
Line, hole, plant	9
Maintenance—ring weed and pest control	
Years 1, 2, 3 and 4—9 times per year	3
Years 5, 6 and 7	4.5
Harvest—heap, cut and carry	15
Construction of dryer—28 units	
Subsistence	80

Yields—

Bearing Year	cwt. per acre.
Year 7	3
Year 8	4
Year 9	5
Year 10	6
Year 11	7
Year 12	8

Planting density 27 feet. 70 trees per acre.

Bagging—Average weight per bag—160 lb.

Bags per year per acre—related to yield.

Year 7	2
Year 8	3
Year 9	3
Year 10	4
Year 11	5
Year 12	6

Dryer—Ceylon type 4-bag capacity—constructed in Year 6. Replaced every 6th Year.

Pest Control—Brontispa—spraying of palms until 4 years old.

DEVELOPMENT PROGRAMME.

Year 1.

Clear, etc., 4½ acres—60 units per acre	270
Nursery—4 units per acre	16
Line plant, etc.—4 acres—9 units per acre	36
Maintain—4 acres—3 units per acre	12
Subsistence—½ acre garden	40
Planted—4 acres	374 (+ 61)

Year 2.

Clear, etc.—4 acres	240
Nursery—4 acres	16
Line, plant, etc.—3½ acres + ½ acre (garden)	36
Maintain—8 acres	24
Subsistence—½ acre	40
Planted—8 acres	356 (+ 79)

Year 3.

Clear, etc.—acres	240
Nursery	16
Line, plant, etc.,—acres	36
Maintain—12 acres	36
Subsistence—½ acre	40
Planted—12 acres	368 (+ 67)

Year 4. Increase garden area to 1 acre.

Clear—3½ acres	210
Nursery—3 acres	12
Line, plant, etc.—2½ acres + ½ acre	27
Maintain—15 acres	45
Subsistence—1 acre	80
Planted 15 acres	374 (+ 61)

Year 5.

Clear—1 acre for garden	60
Maintain—4 acres at 4.5 units	18
Maintain 11 acres at 3.0 units	33
Subsistence—1 acre	80
Planted—15 acres	191 (+ 244)

Year 6.

Clear, etc.—1 acre for garden	60
Maintain—8 acres at 4.5 units	36
Maintain 7 acres at 3.0 units	21
Dryer Construction	28
Subsistence—1 acre	80
Planted—15 acres	225 (+ 210)

Year 7.

Maintain—12 acres at 4.5 units	54
Maintain 3 acres at 3.0 units	9
Harvest—15 units per acre—4 acres	60
Subsistence—1 acre	80
Planted—15 acres	203 (+ 232)

Sufficient labour to operate the dryer, to clear new land for garden in Year 6 onwards.

Full Production.

Maintain—15 acres at 4.5 units	68
Harvest—15 acres at 15.0 units	225
Subsistence—1 acre	80
	373 (+ 62)

FINANCIAL DATA

	£
Rations—first six months	70
Cash Allowance—£4 per month to Year 5 (Then £12 per annum to end of Year 7). Per annum	48
Tools and Equipment, etc.—first year	20
Replacement at £2 per annum from Year 2	2
House Material—galvanised iron and water tank	60

Seed nuts—3d. per nut.

Assume—150 nuts planted in nursery per acre £2 per acre

Pest Control—Spray equipment	3
Dieldrin—assume 25 per cent. of palms infested—cost 15s. per acre	15s.
Dryer—Ceylon type	30

Assume life—5 years.

Bags—4s. each new

Twine, ink, etc.—10 per cent. of bag cost.

15 bags per ton.

Bags Cost per Year	£
Year 7	2
Year 8	5
Year 9	8
Year 10	11
Year 11	14
Year 12	16
Year 13	18
Full production—15 acres	20
Stencil—heavy gauge	£4

Selling price of copra—sold direct to C.M.B. Net return to grower.

Income—Net return to grower £45 and £50 per ton.

	£	£
Year 7—4 acres at 3cwt. per acre	27	30
Year 8—4 acres at 4 cwt. per acre 4 acres at 3 cwt. per acre	63	70
Year 9—4 acres at 5 cwt. per acre 4 acres at 4 cwt. per acre 4 acres at 3 cwt. per acre	108	120
Year 10—4 acres at 6 cwt. per acre 4 acres at 5 cwt. per acre 4 acres at 4 cwt. per acre 3 acres at 3 cwt. per acre	155	173
Year 11—4 acres at 7cwt. per acre 4 acres at 6 cwt. per acre 4 acres at 5 cwt. per acre 3 acres at 4 cwt. per acre	189	210
Year 12—4 acres at 8 cwt. per acre 4 acres at 7 cwt. per acre 4 acres at 6 cwt. per acre 3 acres at 5 cwt. per acre	223	248
Year 13—8 acres at 8 cwt. per acre 4 acres at 7 cwt. per acre 3 acres at 6 cwt. per acre	248	275
Year 14—12 acres at 8 cwt. per acre 3 acres at 7 cwt per acre	263	293
Full production—Year 15	270	300

ESTABLISHMENT COSTS.

COPRA 15 ACRES. PRICE—£50 PER TON.

	Year 1.	Year 2.	Year 3.	Year 4.	Year 5.	Year 6.	Year 7.	Year 8.	Year 9.	Year 10.	Total end of Year 8
Subsistence—Rations	70	—	—	—	—	—	—	—	—	—	70
Cash Allowance	48	48	48	48	48	12	12	—	—	—	264
House Material	60	—	—	—	—	—	—	—	—	—	60
Tools, etc.	20	2	2	2	2	2	2	2	2	2	34
Seed Nuts	8	8	8	6	—	—	—	—	—	—	30
Spray Unit	3	—	—	—	—	—	—	—	—	—	3
Pest Control, spray	3	3	4	5	4	4	3	3	3	2	29
Dryer—depreciation, etc.	—	—	—	—	—	30	6	6	6	6	42
Stencil	—	—	—	—	—	4	—	—	—	—	4
Bags, etc.	—	—	—	—	—	—	2	5	8	11	7
Total Annual Outflow	212	61	62	61	54	52	25	16	19	22	543
Income	—	—	—	—	—	—	30(*a*)	70	120	173	—
Debit Balance	212	61	62	61	54	52	25	16			543
Interest—4¾ per cent.	10	3	3	3	3	3	1	1			27
Total Annual Debit	222	64	65	64	57	55	26	17			570
Cumulative debit b/d	—	222	296	375	457	536	616	671			—
Interest on cumul. debit	—	10	14	18	22	25	29	32			150
Total cumul. debit	222	296	375	457	536	616	671	720			720

(*a*) In lieu of cash allowance Year 8.

REPAYMENT OF LOAN.

COPRA AT £45 PER TON.

Year	Gross Income.	Gross Income less operating expenses. (a).	Repayments.	Loan and Interest less repayments brought down.	Net Income.
9	108	108 — 14 = 94	25	720 + 34 — 25 = 729	69
10	155	155 — 17 = 138	50	729 + 35 — 50 = 714	88
11	189	189 — 20 = 169	75	714 + 34 — 75 = 673	94
12(*b*)	223	223 — 46 = 177	75	673 + 32 — 75 = 630	102
13	248	248 — 24 = 224	120	630 + 30 — 120 = 540	104
14	263	263 — 26 = 237	125	540 + 26 — 125 = 441	112
15	270	270 — 26 = 244	125	441 + 21 — 125 = 337	119
16	270	270 — 26 = 244	125	337 + 16 — 125 = 228	119
17	270	270 — 26 = 244	125	228 + 11 — 125 = 114	119
18(*b*)	270	270 — 50 = 220	119	114 + 5 — 119 = 0	101

(*a*) Operating expenses limited to dryer depreciation and bags.

(*b*) Years 12 and 18—construction of new dryer.

REPAYMENT OF LOAN.

COPRA AT £50 PER TON.

Year	Gross Income.	Gross Income less operating expenses. (a).	Repayments.	Loan and Interest less repayments brought down.	Net Income.
9	120	120 — 14 = 106	25	720 + 34 — 25 = 729	81
10	173	173 — 17 = 156	50	729 + 35 — 50 = 714	101
11	210	210 — 20 = 190	75	714 + 34 — 75 = 673	115
12(*b*)	248	248 — 46 = 202	100	673 + 32 — 100 = 605	102
13	275	275 — 24 = 251	125	605 + 29 — 125 = 509	126
14	293	293 — 26 = 267	125	509 + 24 — 125 = 408	142
15	300	300 — 26 = 274	125	408 + 19 — 125 = 302	149
16	300	300 — 26 = 274	125	302 + 14 — 125 = 191	149
17	300	300 — 26 = 274	125	191 + 9 — 125 = 75	149
18(*b*)	300	300 — 50 = 250	79	75 + 4 — 79 = 0	171

(*a*) Operating expenses limited to dryer depreciation and bags.

(*b*) Years 12 and 18—construction of a new dryer.

Coconut Experiment Work in New Ireland. III.—Progress of Fertilizer Trials 1958-1964.

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INTRODUCTION.

In an earlier paper (Charles 1959 a) a description was given of the condition of coconut palms on the east coast of New Ireland where extensive production decline had occurred over the previous ten to twenty years. A survey had indicated that the condition of the palms was related to variations in the type of soil developed from coral parent material.

Comprehensive fertilizer trials were laid down on the two most important soil types, yellow-brown clay-loams and red-brown clay-loams. Yield records up to May, 1958, showed a response to potassium on the yellow-brown clay-loam, and no significant response to any element tested on the red-brown clay-loam (Charles 1959 b).

Further progress in these trials, and in new trials initiated following the evidence of potassium response, will be reported in this paper.

COMPREHENSIVE FERTILIZER TRIALS. YELLOW-BROWN CLAY-LOAM.

Methods and Results.

This commenced as a comprehensive fertilizer trial in November, 1955, when the first fertilizer applications were made. Similar fertilizer dressings were repeated in November, 1957, with the exception of sulphate of ammonia, which was applied every six months between November, 1955, and May, 1959.

The only significant response recorded was to potassium. From May, 1957, to June, 1960, palms fertilized with potassium showed an increase of 12 to 14 nuts per year over control palms. This increase represented a return of 1.8 tons of copra for 1 ton of fertilizer applied.

By 1959 it appeared that the response to potassium had reached a steady level, and the possibility that any further deficiencies would become evident was remote. Hence from November, 1959, the applications of all fertilizers except potassium were discontinued. Also, this fertilizer was now applied to the group of palms which had previously received molybdenum (to which there had been no response). This new arrangement gave four groups of 32 palms each, with respect to the application of potassium chloride :—

(*a*) Palms fertilized continuously since 1955 ;

(*b*) Palms fertilized in 1955 and 1957, but not after 1957 ;

(*c*) Palms fertilized from November, 1959, but not previously ; and

(*d*) Palms not fertilized at all.

A further observation was that fertilized palms, though improved in appearance relative to the controls, were in 1959 still far from a condition of full vigour. It was therefore decided to increase the rate of potassium chloride application to 8 lb. per palm every two years.

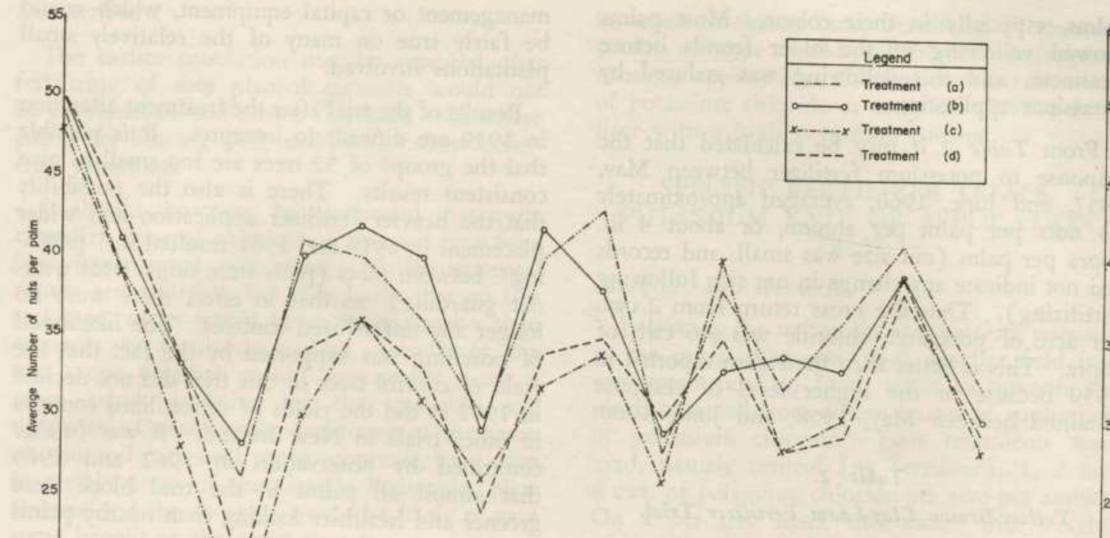

Figure 1.—Yellow-Brown Clay-Loam Fertilizer Trial. Estimates of nut numbers at six monthly intervals. For details of treatments, see Table 1.

Fertilizer was applied at this rate in November, 1959, and November, 1961. The 1959 application, being larger than earlier applications, was spread in a circle extending further from the bases of the palms. By 1961 there was evidence from another trial that wide placement was better than close placement, and the fertilizer was broadcast over a larger area still, extending eight to ten feet from the palm bases.

A summary of the quantities of potassium chloride which have been applied to the four groups of palms, is given in *Table* 1.

Table 1.

Yellow-Brown Clay-Loam Fertilizer Trial.

Weights of Potasium Chloride applied in the four Treatments.

	Nov. 1955	Nov. 1957	Nov. 1959	Nov. 1961	Jan. 1963
Treatment (*a*)	4.5 lb.	4.5 lb.	8 lb.	8 lb.	8 lb.
Treatment (*b*)	4.5 lb.	4.5 lb.	—	—	—
Treatment (*c*)	—	—	8 lb.	8 lb.	8 lb.
Treatment (*d*)	—	—	—	—	—

Yield estimates for the four groups between November, 1955, and May, 1963, are shown in *Table* 2 and *Figure* 1.

As explained in the earlier paper (Charles 1959 b) yield estimates were based on six monthly counts of older immature nuts on the palms. In the earliest counts, a larger proportion of the immature nuts was counted than in later years. Hence the decline in yield over the period of recording is exaggerated. From 1958 onwards, the technique of counting was stabilized, and the count at each date would represent a fairly accurate estimate of the number of nuts to fall in the following six months.

Discussion.

Results in this trial prior to the change in treatments in 1959 were quite clear. *Figure* 1 shows the definite yield response which occurred after application of potassium chloride. Analysis showed this response to be statistically significant. This yield increase was accompanied by an improvement in the appearance of fertilized palms, especially in their colour. Most palms showed yellowing of the older fronds before treatment, and this yellowing was reduced by potassium application.

From *Table* 2 it may be calculated that the response to potassium fertilizer between May, 1957, and June, 1960, averaged approximately 13 nuts per palm per annum, or about 4 lb. copra per palm (nut size was small, and records did not indicate any change in nut size following fertilizing). Thus the gross return from 2 cwt. per acre of potassium chloride was 3.6 cwt. of copra. This is better than the return reported in 1959 because of the higher level of response obtained between May, 1958, and June, 1960.

Table 2.

Yellow-Brown Clay-Loam Fertilizer Trial.

Nut Numbers per palm (Average of 32 *palms).*

Date of Recording	TREATMENTS * (*a*)	(*b*)	(*c*)	(*d*)
Nov. 1955	49	50	48	50
May 1956	39	41	39	43
Nov. 1956	33	33	28	33
May 1957	26	28	17	20
Nov. 1957	41	40	30	34
May 1958	40	42	36	36
Nov. 1958	36	40	31	33
May 1959	30	29	26	24
Nov. 1959	40	42	32	34
May 1960	43	38	34	35
Nov. 1960	28	29	26	30
May 1961	38	33	40	35
Nov. 1961	32	34	28	28
May 1962	36	33	30	29
Nov. 1962	41	39	39	38
May 1963	32	30	28	29

* For details see *Table* 1.

At a copra price of £60 per ton, the gross return from one ton of fertilizer would be approximately £108. At fertilizer cost of £45 per ton and an estimated cost of £12 per ton for harvesting, transporting, and drying the copra, the extra cost involved would be £75. Net return would be approximately £33 for each ton of fertilizer applied. This is the most favourable estimate of return, and assumes that fertilizer could be transported from wharf to plantation at no extra cost as back-loading on vehicles carrying copra. It also assumes that the increased production could be processed without increasing management or capital equipment, which would be fairly true on many of the relatively small plantations involved.

Results of the trial after the treatment alteration in 1959 are difficult to interpret. It is possible that the groups of 32 trees are too small to give consistent results. There is also the possibility that the heavier fertilizer application and wider placement in 1959 and 1961 resulted in "poaching" between plots (plots were single trees without guarding), so that in effect there were no longer any unfertilized controls. The likelihood of poaching was supported by the fact that the yield of control trees in this trial did not decline in 1962 as did the yields of unfertilized controls in other trials in New Ireland. It was further confirmed by observation in 1962 and 1963 that almost all palms in the trial block were greener and healthier looking than nearby palms on the same soil type.

Because the precision of the experiment was low, in the light of uncertain copra prices and a lag of 1½ to 2 years between fertilizer application and production increase, it was not felt that the results of this experiment alone warranted a general recommendation for fertilizer use on this soil type. Nevertheless the trial was of value in diagnosing the primary soil deficiency and serving as a guide to further experiment. The design was a satisfactory compromise in that it permitted reasonable replication of a large number of treatments without having to use an unmanageable number of palms.

RED-BROWN CLAY-LOAM.

Method and Results.

As reported in the earlier paper (Charles, 1959 b) no response of significant magnitude was evident up to May, 1958. Fertilizer applications were repeated, and nut counts were continued until November, 1959 with nothing more substantial than a hint of response to nitrogen in May, 1959. A nut count which was carried out in November, 1959, indicated that this response, if real, was not sustained. Another nut count made in November, 1960, again failed to show that a response was occurring to any treatment and therefore the experiment was discontinued.

Discussion.

The earlier conclusion may be repeated, that fertilizing of sole planted coconuts would not be economic on red-brown clay-loam soils where palms are bearing well, and do not show deficiency symptoms.

It should, however, be mentioned that quite extensive areas of coconuts on this soil type have been interplanted with cacao. No experimental results are available, but it is likely that on this soil type, cacao would be more responsive than coconuts to fertilizing. Also, growth of the two crops together would presumably cause a more rapid depletion of the available soil nutrients. Consequently, fertilizing of the cacao on this soil may well prove economic, as it does in certain areas of the Gazelle Peninsula, New Britain, and the coconuts would be likely to gain some benefit at the same time.

Any application of fertilizer would need to be related to whether *Leucaena glauca* is also planted, and detailed recommendations would have to be based on an examination of the particular locality. The only generalization that can be made is that a cacao fertilizing programme on this soil type should probably include frequent nitrogen applications, and less frequent dressings of potassium chloride or complete (NPK) fertilizer with a high potassium content.

SPECIFIC FERTILIZER TRIALS.
POTASSIUM RATE OF APPLICATION TRIAL.

Methods and Results.

Following the indication of potassium response in the initial diagnostic trial, another field trial was commenced in June, 1958, to compare the yields obtained from different rates of application of potassium chloride. Four treatments were used, namely control (no fertilizer), 1, 2 and 4 cwt. of potassium chloride per acre per annum. On a per tree basis, this meant that weights of fertilizer applied to palms in the different treatments were 0, 2.5, 5.0 and 10.0 lb. per year.

Design of the trial was a randomized block with four replications. Plots were nominally of 16 trees (4 x 4), separated by a single common untreated guard row. Fertilizer was broadcast

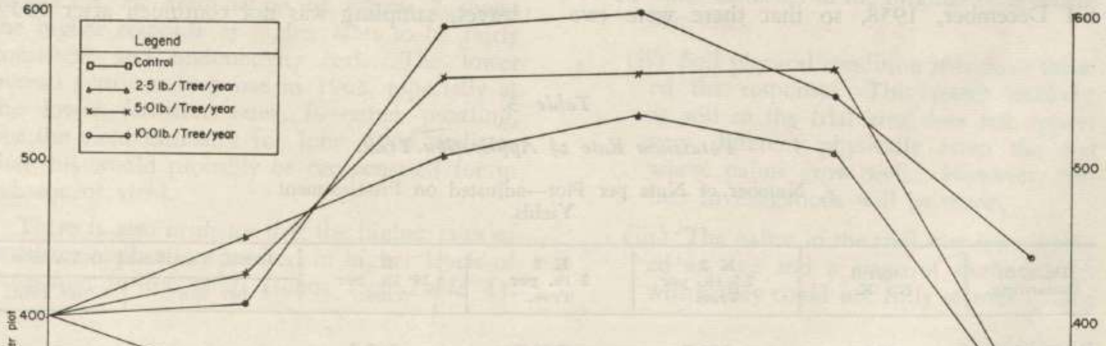

Figure 2.—Potassium Rate of Application Trial. Estimated nut numbers, adjusted for pre-treatment yields (May and November counts combined).

over a circle 20 to 24 feet in diameter around the base of each palm. Grass and cover crop were cut back prior to fertilizing.

The site selected was a typical yellow-brown clay-loam soil, where the growth of palms had been very variable. Palms were over 40 years old at the date of commencement of the trial, and in general were of poor appearance.

Many palms were missing in the stand, and because of this the actual number of palms in the plots averaged only 12. By 1963 this average had decreased to 11, through the death of a further 12 palms. The number of missing palms in the stand was even greater than the 25 per cent. indicated by the plot average, as gaps had to be left between some plots and some replicates where large groups of palms were missing.

Before the trial commenced, *Leucaena glauca* was planted in the coconut lines. Cacao was planted under this shade in 1958. The growth of the cacao trees has been very variable.

The trial was marked out and nut counts commenced in June, 1958. Fertilizer was not applied till December, 1958, so that there were two pre-treatment yield estimates. Fertilizing has been repeated in November or December each year.

There was very great variability between plot yields, as is indicated by pre-treatment totals, where the total nut number for the poorest plot was 71, while for the best plot the total was 440. Variation was great within, as well as between, replicates, and the four treatments started off at different levels. Average numbers of nuts per palm in the pre-treatment counts were : Control—17.3 ; K1—15.0 ; K2—15.1 ; K4—22.6. Results have therefore been adjusted by covariance analysis, and adjusted yield estimates are shown in *Table* 3. To reduce random fluctuations, a further analysis was made on annual yield figures (combined May and November counts), and the adjusted yields so obtained are shown in *Figure* 2.

In addition to estimates of yield, in the first two years of the experiment leaf samples were taken from one tree in each plot for analysis of the potassium content. A summary of the results of these analyses is shown in *Table* 4. Because of practical difficulties in collecting leaves, sampling was not continued after 1959.

Table 3.

Potassium Rate of Application Trial.

Number of Nuts per Plot—adjusted on Pre-treatment Yields.

Date of Recording.	Control No K.	K 1 2.5 lb. per Tree.	K 2 5 lb. per Tree.	K 4 10 lb. per Tree.	Least Significant Difference	
					5 per cent.	1 per cent.
Pre-treatment*	200.7	200.7	200.7	200.7	—	—
June 1959	182	222	197	196	42.1	61.2
Dec. 1959	178	231	233	214	56.5	82.2
July 1960	167	273	270	284	82.3	119.7
Nov. 1960	132	234	285	305	55.1	80.1
May 1961	168	259	284	274	63.3	92.1
Nov. 1961	174	275	276	324	95.8	139.3
May 1962	150	266	290	292	92.8	135.0
Jan. 1963	148	255	282	273	71.5	104.0
June 1963	125	185	183	227	72.2	105.0
Nov. 1963	126	157	164	217	54.5	79.2
June 1964	169	293	291	271	107.6	156.4
July 1960-June 1964	1359	2197	2325	2467	—	—

* Average of June and December, 1958, counts.

Table 4.
Potassium Rate of Application Trial.

Quantity of Potassium Chloride applied (lb. per annum).	Percent Potassium in Palm Fronds.		
	December, 1958.	June, 1959.	December, 1959.
0	0.62	0.68	0.70
2.5	0.67	1.02	1.09
5.0	0.66	1.01	1.32
10.0	0.64	0.96	1.69

To assess the return from each treatment the average annual yield response has been calculated for the period June, 1960, to December, 1963 (see *Table* 5). Estimates of gross return and costs shown in *Table* 5 are based on nut size of 6,800 nuts per ton of copra, and as before, on a price of £60 per ton for copra, a cost of £45 per ton for fertilizer and production cost of £12 per ton.

Discussion.

From the results shown in *Table* 3 it can be seen that yields from the three positive levels of fertilizer were all significantly higher than control yields. Although differences between these three levels were not generally statistically significant, an examination of *Figure* 2 shows the higher response at higher rates to be fairly consistent and undoubtedly real. The lower overall fertilizer response in 1963, especially at the lower fertilizer rates, is rather puzzling, but the yield estimates for June, 1964, indicate that this would probably be compensated for in subsequent yield.

There is also evidence that the higher rates of fertilizer application resulted in higher levels of potassium in the palm fronds (see *Table* 4). By twelve months after the initial application, foliar potassium levels were more or less proportional to the amount of fertilizer added.

The most important conclusion to be drawn from the trial is that the lowest rate of fertilizer (2.5 lb. per palm of potassium chloride) gave the most economic response, and at higher rates the net return diminished rapidly. On the basis of these results, application rates greater than 1 cwt. per acre per annum could not be recommended.

A curious feature of the trial was that even when palms received a large and uneconomic application of fertilizer each year they were not brought to anything like a condition of full health, as indicated by the general appearance of the palms and the yields obtained from them.

Possible explanations of this are :—

(i) The soil may be low in nutrients other than potassium, and these become limiting once potassium has been supplied. This seems unlikely in view of the absence of any interaction between potassium and other elements in the original comprehensive trial.

(ii) Soil physical condition may have limited the response. This seems unlikely, as soil in the trial area does not appear very different physically from the soil where palms grow well. However, further investigations will be made.

(iii) The palms in the trial may have reached an age and a stage of decline from which they could not fully recover. This

Table 5.
Potassium Rate of Application Trial.
Estimated Extra Returns and Costs per Palm per Annum.

Quantity of Potassium Choloride applied (lb. per annum).	Extra Nuts per tree.	Extra Gross Return.	Extra Production Costs.	Fertilizer Cost.	Extra Net Returns.
		s. d.	*s. d.*	*s. d.*	*s. d.*
2.5	15.5	2 9	0 6½	1 0	1 2½
5.0	17.9	3 2	0 8	2 0	0 6
10.0	20.5	3 7	0 9	4 0	—1 2

was probably an important factor, as the palms were in many cases very debilitated and all were quite old.

(iv) The method of application may not have been satisfactory. While it is standard practice in some countries for fertilizer to be turned into the soil in some way, there seems no obvious reason why this should prove more efficient than surface broadcasting, under local conditions where, even in the absence of rain, dew is heavy enough to dissolve the fertilizer within a few days and carry it into the soil.

To investigate the two last, a new trial has been commenced on younger palms, including a cultivation treatment at the time of fertilizer application.

Results of a long term fertilizer experiment in Ceylon (Eden, Gower and Salgado, 1963) are of considerable interest in respect of the influence of age and condition on palm responsiveness to fertilizer. In this trial, in the first 15 years there was a marked decline in yield of unfertilized control palms, while fertilized palms maintained their yield. After 15 years the control palms were fertilized, but although this arrested the decline in yield it did not restore them to normal health. This may indicate that the effects of potassium deficiency in coconuts are to some extent irreversible, and the subject is worthy of further investigation.

POTASSIUM METHOD OF APPLICATION TRIAL.

Methods and Results.

In the original diagnostic trials, the fertilizer was placed in a narrow band extending only three to five feet from the base of the palms, as a precaution against inter-plot "poaching". It was observed that this concentrated fertilizing caused severe burning of grass and cover crop species, and it was surmised that some burning of palm roots might occur, possibly inhibiting fertilizer uptake.

It was therefore desired to compare the narrow placement with broadcasting over a larger area. Also, it was thought desirable to study frequency of application, since leaching rate is high, and two-yearly applications may not be frequent enough.

A trial was therefore laid down with four treatments, as outlined below :—

1. Control—no fertilizer.
2. Biennial application of 2 cwt. of potassium chloride per acre, broadcast over a narrow band (a circle 6 to 10 ft. in diameter around the base of each palm, as in the original diagnostic trial).
3. Biennial application of 2 cwt. of potassium chloride per acre, broadcast over a broad band (a circle 20 to 24 ft. in diameter around the base of each palm).
4. Annual application of 1 cwt. of potassium chloride per acre, broadcast over a broad band.

Design was a randomized block with six replications. Plots were nominally 10 trees (5 x 2) separated by a common untreated guard row. The trial was superimposed on the original cultivation trial, in which there had been no treatment responses (Charles, 1959 b). Fertilizer treatments were rearranged, where necessary after randomization, so that all were represented equally on the old cultivation treatments. Palms were over 40 years of age and in poor condition, with many missing. Actual numbers of trees per plot averaged only eight, and out of an original 196 there were six deaths between 1958 and 1963.

Nut counts on these palms had been maintained since November, 1955. The first fertilizer applications were made in November, 1958, and these were repeated annually or biennially as required.

As in the Rate of Application Trial, there was high variability between the plots, although there was not as great a difference between the initial yields of the four treatments. In the pre-treatment period, 1956-1958, plot yields ranged from 56 to 277 nuts ; average numbers of nuts per tree were approximately 20, 23, 16 and 22 for treatments 1, 2, 3 and 4, respectively.

Results have been adjusted by covariance analyses, and these adjusted yield estimates are shown in *Table* 6. Similar covariance analyses have been carried out on annual yields, and the adjusted figures are shown geographically in *Figure* 3.

Table 6.

Potassium Method of Application Trial.

Number of Nuts per Plot—adjusted on Pre-treatment Yields.

Time of Recording.	Treat. 1.	Treat. 2.	Treat. 3.	Treat. 4.	Least Significant Difference	
					5 per cent.	1 per cent.
Pre-treatment *	163	163	163	163	—	—
May 1959	151	155	166	168	33.4	46.3
Dec. 1959	136	154	179	183	45.8	63.5
July 1960	127	174	201	176	36.4	50.5
Nov. 1960	135	219	223	219	46.6	64.5
May 1961	129	181	219	216	49.8	69.1
Nov. 1961	140	155	192	195	41.5	57.6
May 1962	118	139	188	175	28.0	38.9
Jan. 1963	118	177	210	158	38.7	53.3
June 1963	90	154	203	179	38.3	53.2
Nov. 1963	97	161	201	190	44.5	61.8
June 1964	106	192	216	224	61.9	85.9

* Average of seven counts between November, 1955, and November, 1958.

Discussion.

While all fertilizer treatments showed a significant yield response, results shown in *Table* 6 and *Figure* 3 strongly suggest that the biennial narrow band placement (Treatment 2) was less effective than the biennial broad band placement (Treatment 3). There was no indication that annual application was superior to biennial application when both were spread over a wide band, and in fact the biennial treatment may have been more effective than annual treatment.

The apparent difference in response, when the same weights of fertilizer were applied, may perhaps be explained in terms of a concentration effect concerned with fertilizer application. Where the concentration is too great, roots may be damaged, and uptake slowed down. Thus greater losses through leaching might occur. Where the concentration is too low, as perhaps was the case with the annual application, there may be significant losses to competing grass and cover crop.

The yield response obtained to the annual application of 1 cwt. per acre of potassium chloride in this experiment fully supports the results obtained for the similar treatment in the Rate of Application Trial. In this trial, the average annual yield increase was 17.4 nuts per palm, while in the rates trial it was 15.5 nuts per palm, a small difference in relation to the precision of the two trials.

The results of this trial indicate that biennial fertilizer application is as effective as annual, while all the trials described combine to indicate that a worthwhile profit may be expected from the application of potassium chloride at the rate of 4 to 5 lb. per palm every second year, on yellow-brown clay-loam soils.

FERTILIZER TRIAL WITH SEEDLINGS.

Method and Results.

This trial was superimposed on a Replanting Trial (to be discussed fully in a later publication) in New Ireland. The soil type was a yellow-brown clay-loam, but the mature palms were better than average for this soil.

For a measure of potassium response, each of the twelve plots of the replanting trial was split, and fertilizer was applied to seedlings in one half while the other half was left as a control. Measurements were made on 18 seedlings in each sub-plot.

The seedlings were transplanted in January, 1959, after about six months in the nursery. Potassium chloride was applied to the treated plots at the rates given in *Table* 7. The fertilizer was broadcast over a circle around the base of each seedling, the diameter of the circle being increased from about three feet in the first year to about 10 feet in the fourth year.

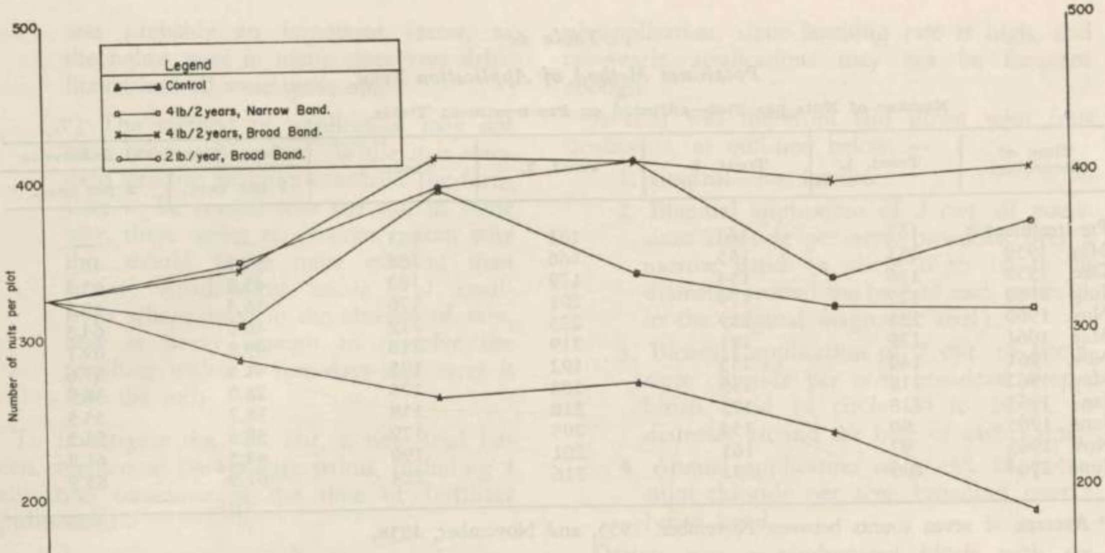

Figure 3.—Potassium Method of Application Trial. Estimated nut numbers, adjusted for pre-treatment yields (May and November counts combined).

Table 7.

Fertilizer Trial with Seedlings.

Potassium chloride applications.

Date of Application.	Quantity Applied per Seedling.
June, 1959	4 oz.
December, 1959	6 oz.
December, 1960	8 oz.
December, 1961	8 to 16 oz. according to seedling size.

Unfortunately it became evident as the trial progressed that it was sited in a bad locality. It was on the boundary of the plantation, close to a swamp, and as the seedlings reached a susceptible size (beginning in 1961) they were severely damaged by dynastid beetles (*Scapanes* sp.) followed later by palm weevils (*Rhynchophorus* sp.). Because of such damage, and in the interests of the Replanting Trial as a whole, it was decided in June, 1962, to discontinue the fertilizer trial as such and to apply potassium to all surviving seedlings and replants.

Leaf samples for chemical analysis were collected at regular intervals. The sample taken consisted of two central leaflets from the youngest fully opened frond of six seedlings in each sub-plot. Results of such analyses are given in *Table* 8.

Growth measurements were made on the seedlings at six-monthly intervals. Leaf production, leaflet weight and seedling height were taken as criteria on which to base growth comparisons. In this paper, results for these measurements are given only for the period from transplanting to May, 1961, when damage to the seedlings was not excessive. After this date, records are considered to be unreliable, especially as dynastids showed a preference for the more vigorous fertilized seedlings (as discussed below).

Table 8.

Fertilizer Trial with Seedlings.

Potassium Content of Leaves (averages from 12 sub-plots).

Sampling Date.	Treatment.	
	No K.	K.
	per cent.	per cent.
December, 1959	0.98	1.79
December, 1960	0.99	1.65
December, 1961	1.18	1.68

The mean number of leaves produced by relatively undamaged seedlings, from transplanting to May, 1961, is given in *Table* 9. The mean weights of leaflets sampled in May, 1961, are also given in this table.

Table 9.

Fertilizer Trial with Seedlings.

Mean Number of Leaves Produced and Mean Weights of Leaflets (averages from 12 sub-plots).

Treatment.	Mean No. Leaves June, 1959-May, 1961.	Mean Weight of Leaflets May, 1961.
No K	13.4	7.2 gm.
K	14.3	11.8 gm.

The "seedling height" originally recorded was the distance from the ground to the tip of the tallest leaf, when this leaf was straightened out. However, in May, 1961, many seedlings were too tall for this technique to be carried out satisfactorily, and so the height was recorded by standing a scale beside the leaf without straightening it. The average heights are shown in *Figure* 4. In interpreting this histogram it is necessary to remember the change in method of measurement in May, 1961. Whereas one would expect the palms to increase rapidly in height after eighteen months in the field, this is not indicated in *Figure* 4, due to the alteration in technique.

Discussion.

Results given for potassium content and mean weight of leaflets (see *Tables* 8 and 9) and seedling height (see *Figure* 4) indicate that seedlings growing on yellow-brown clay-loam benefit substantially from applications of potassium fertilizer. Figures given in *Table* 9 suggest that the application of fertilizer did not significantly affect the rate of leaf production by seedlings during the period June, 1959, to May, 1961. Therefore, it seems that the increased rate of tissue production which resulted from the improvement in potassium status of fertilized seedlings was reflected mainly in the production of larger leaves.

From *Figure* 4, it can be seen that in May, 1961, at 2.5 years of age, fertilized seedlings were 30 per cent. taller than were controls. But for dynastid beetle damage, this response would undoubtedly have been greater, as fertilized palms were more severely affected than were controls. In November, 1961, numbers of beetle damaged seedlings amounted to 5 per cent. of the total in the control sub-plots and 8 per cent. in fertilized. The difference between treatments was even more marked in June, 1962, when the percentages were 6 and 15, respectively. This is not thought to be a direct effect of the fertilizer, but simply a preference on the part of the beetles for large seedlings. This suggestion is supported by the fact that the only plot where damage was substantially greater on control than on fertilized seedlings was an exceptional plot where control seedlings were larger than fertilized.

Considering results of this trial in conjunction with the trials on mature palms, a general recommendation can confidently be made for potassic fertilizing of coconut seedlings planted on yellow-brown clay-loam soils. In fact, it would be unwise to plant on this soil type without fertilizing.

The rate of application should be related to the size of the seedlings, progressing from 8 oz. per seedling in the first year after transplanting up to 4 lb. every two years at maturity. In the

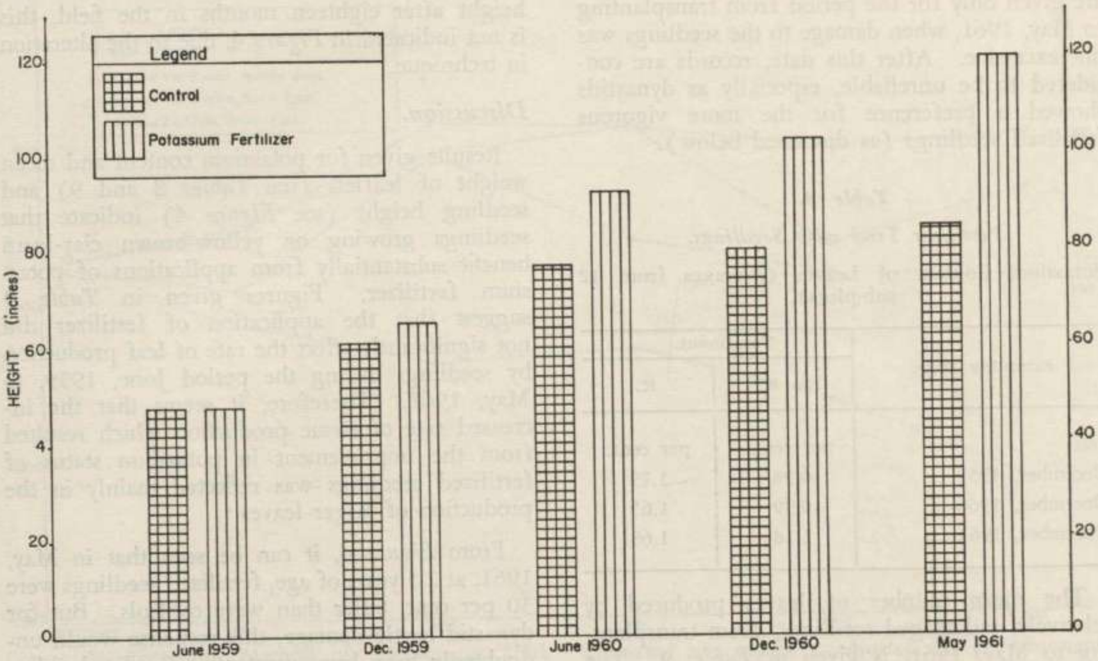

Figure 4.—Potassium Fertilizer Trial on Seedlings. Heights of seedlings.

first two or three years it would be desirable to split the annual application and apply every six months.

SUMMARY.

Comprehensive fertilizer trials on mature coconuts in New Ireland indicated response to potassium on yellow-brown clay-loam soils. Further trials showed a more economic response from 2½ lb. potassium chloride per palm per annum than from higher rates ; as good a response from biennial application as from annual ; and better response from broadcasting over a circle 20 to 24 feet in diameter around the base of the palm than from placement in a smaller circle. Good growth response was obtained from potassic fertilizing of seedlings.

ACKNOWLEDGEMENTS.

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Some Aspects of Coconut Agronomy in Papua and New Guinea.

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INTRODUCTION.

The export earnings from Coconut Products in Papua and New Guinea amount to approximately £7,000,000 annually. As this is 40 per cent. of the total value of exports from the Territory each year, the position of the coconut is clearly one of great importance to the economy of the country.

With increasing costs, it is imperative that all operations on the plantation be performed as efficiently as possible. This paper deals with several aspects which are of interest to the owner-manager. Articles of a more specialized nature will be found in this, and other editions of the *Journal*.

NURSERY PRACTICE.

It has been clearly shown by Liyanage (1955) that improvements in future plantation productivity can be achieved by selection of seedlings in the nursery. Therefore, the practice of planting nuts directly in the field is not recommended as this severely restricts the efficiency with which seedling selection can be carried out. Some important aspects of nursery practice are outlined in the following discussion.

Seed Selection.

In the past, it has been the practice for some individuals to regard high yielding palms as "mother trees" from which all nuts for the nursery were obtained. Thus Sampson (1923) advocated the selection of certain high-yielding trees for this purpose.

Recently, some questions regarding the effectiveness of mother palm selection have been asked. Charles (1961) critically reviewed evidence on the subject, and concluded that there was no evidence to support the practice of mother palm selection of coconuts. He further stated that all that could be recommended was that seed for planting should be taken from blocks of well-grown, healthy palms, from which any markedly abnormal types had been removed. This is in fact the usual method of obtaining seed nuts in the Territory.

All nuts collected for planting must be approximately the same age. If this is not so, then the effectiveness of nursery selection is considerably reduced (as explained in "Seedling Selection" of this section). Therefore, to ensure that nuts of a uniform age are collected, areas from which seed nuts are to be taken should first be harvested, and then the next fall of nuts is taken for planting.

Location.

The nursery should if possible, be established on level soil which is well drained. As a dry period may seriously retard the growth of the seedlings, it is an advantage to have a supply of water nearby, so that supplementary applications can be made when necessary. A light overhead shade may be provided for the nursery, although where this is not done the plants will still grow satisfactorily if an adequate supply of water is available.

Planting.

Nuts are normally planted in long rows in the nursery. A distance of 18 inches between the rows and 12 inches along the rows should enable each seedling to be removed together with a large proportion of the roots.

The depth of planting should be such that the nuts are almost covered by the soil. Placing the nuts horizontally has been shown to result in a higher percentage germination than when they are placed vertically. (Report, Coconut Industry Board, Jamaica, 1961-62). However, Piggott (1964) states that in British Guiana, where the insect *Strategus aloeus* L. is a serious pest of seedlings, vertical planting is favoured, as this allows the pests to be readily detected and controlled. In the Territory, where no similar pest is present, horizontal planting is recommended.

Seedling Selection.

Liyanage, (1955) suggested three criteria on which to base selection of seedlings in the nursery :—

(i) *Early sprouting*—In Ceylon, all seed nuts that have not germinated within 20 weeks of planting are rejected. This however fails to allow for the retardation in germination which occurs during a period of dry weather. Therefore, as Charles (1959) states, a more satisfactory criterion might be the rejection of all ungerminated nuts as soon as the first 70 per cent. have shot.

(ii) *Seedling vigour*—The age of the seedlings determines the efficiency with which selection on this basis can be performed. It is easy to detect differences in vigour with older seedlings, but on the other hand, these will be more severely set back at transplanting than will younger ones. A compromise must therefore be reached, and under conditions of adequate rainfall, the four-leaf stage is recommended as the stage at which the final selection should be carried out, and the seedlings transplanted to the field.

(iii) *Resistance to pests and diseases*—Any seedlings which are badly attacked by pests and diseases in the nursery should be rejected. If they were transplanted, it is doubtful whether they would survive, and further, their genetic constitution may render them more susceptible to future attacks than is the case with other seedlings.

By selecting in this manner, the cost of planting material will be considerably increased. However, this is a minor item when the total costs of planting, and the advantages to be gained by such selection, are considered.

MARKING OUT AND PLANTING.

Spacing.

Different spacings for coconuts have been adopted in the various coconut growing countries. Menon and Pandalai (1958) report that spacings adopted in different countries are :—

India 7.5-9.0 m. ; Ceylon 8.0-8.7 m. ; Malaya 9.0-10.0 m. ; Indonesia 10.0-11.0 m. ; Seychelles 9.0-10.0 m. ; Trinidad 10.0-11.0 m. ; British Guiana 9.0 m.

In Papua and New Guinea, coconut palms have been most commonly planted a distance of 30 feet apart. Planting on the triangle is recommended, as this allows 55 palms per acre compared with 45 per acre when palms are planted on the square.

Unfortunately, there is little experimental evidence to indicate which is the optimum spacing distance. Results from Jamaica (Report Coconut Industry Board Research Dept. 1961-62) suggest that under the conditions on that island, the maximum yield is obtained from palms planted on a 22-foot square. However, it is thought that planting at this close spacing in New Guinea would lead to an increase in Threadblight disease (*Corticium* sp.) and therefore the wider spacings are preferred. In this regard, the author recently noted on Bougainville that Threadblight was more prevalent on palms planted at 25 and 27 feet triangle spacings than it was on palms planted on 30 feet triangle.

Planters establishing coconut palms on fertile, well drained soil should keep in mind the possibility of a later interplanting with cacao. Where a 30-foot triangle spacing is used, there should be little need for the provision of extra shade for the cacao, while competition between the two species should not be too severe.

The location for each palm should be carefully determined, as any trees out of line may hinder maintenance in the future. A measuring tape should therefore be used when marking out and stakes should be used to mark the positions determined.

Dimensions of Planting Hole.

The size of the holes necessary for the coconut seedlings varies according to the type of soil which is present. Menon and Pandalai (1958) state that in some districts in India, where very coarse material known as " laterite " is present, holes of dimensions 3 ft. 6 in. x 3 ft. 6 in. x 3 ft. 6 in. are dug. Layers of mulch are placed in the bottom of such holes, the purpose of this being to provide nutrients for the seedlings which the laterite has in insufficient quantities.

Where a soil of reasonable physical and chemical properties is present, as is the case in most coconut growing areas in the Territory, the planting hole is usually 10 to 12 inches deep and measures 12 inches square at the top.

Transplanting.

Transplanting from the nursery to the field should be done as quickly as possible, so that seedlings are not left out of the ground for any appreciable length of time. Further, it is best to transplant during wet weather, when the sky is overcast, as this will ensure that a ready supply of moisture is available to the plants over a period when mortalities due principally to lack of water, may occur.

Following planting, attention should be given to fertilizer requirements for the particular soil type involved. For example, Charles and Douglas (1965) found that to maintain satisfactory growth on yellow-brown clay-loam soils on New Ireland, an application of 10 oz. potassium chloride per plant was necessary in the first year after transplanting. It was also necessary to increase this rate of application as the tree grew larger.

Aspects of pest and disease control, and plantation maintenance, in connection with seedlings, are discussed in the following sections.

GENERAL PLANTATION MAINTENANCE.

To ensure that production does not decline, adequate attention should be given to all aspects of plantation maintenance. The following discussion is limited to the more important of such maintenance considerations.

Grass and Cover Crop.

Of particular importance is the control of grass and leguminous creepers such as *Pueraria* sp. If these plants are allowed to grow unchecked, many nuts may be lost, and seedlings may be smothered. (*Plate* 1.)

Plate I.—Leguminous creeper smothering seedling.

In the past, all grass on the plantation was cut by labourers using sarifs. Today, rotary mowers and large rollers which are pulled by tractors are used for this purpose where the terrain is not too uneven. When labourers are employed to cut grass, it is usually found most satisfactory to set a minimum daily task per man, and to pay a bonus for any work done in excess of this.

Roads.

If tractors are to have access to all parts of the plantation, the roads must be kept in good condition. Where gravel or coronous pits are nearby, this material should be used on the roads, as the vehicles are then not liable to get bogged in wet weather.

Pests and Diseases.

All areas of the plantation should be regularly inspected so that any outbreaks of pests or diseases can be noted in their early stages. If this is done, then the expense involved in controlling such outbreaks should be reduced to a minimum. Control measures to be adopted are discussed in the next section, and in other papers in this *Journal*.

Plate II.—*Oryctes* damage on coconut palms.

Fertilizer.

From production records, and the general appearance of the palms, it should be possible to determine whether yield is below what might be expected. If production is low, or is declining, advice on the problem can often be obtained from D.A.S.F. Officers. Thus Charles and Douglas (1965) found that palms growing on yellow-brown clay-loam soil, New Ireland, required applications of potassium fertilizer in order to maintain production. Such applications must of course result in an increase in net income for the plantation if they are to be considered by the manager. Therefore, it is important that experiments be carried out to determine the optimum rate of fertilization, when net return is taken as the criterion for comparison of treatments.

Cultivation.

Cultivation is regularly carried out on plantations in some countries. Menon and Pandalai (1958) report that in India, intercultivation has been shown to increase yields substantially. Such increases have not been shown to occur following cultivation in the Territory. For example, in an experiment on a plantation on the Papuan Coast, no significant yield increases following cultivation were noted. (D.A.S.F. Annual Report 1962-63). A trial recently started on New Ireland has similarly failed to show any evidence of yield increases due to cultivation. Therefore this practice is not recommended as under conditions in the Territory it does not result in an increased net profit.

Replacement of Dead Palms.

The replacement of dead trees with seedlings is an almost continual task in some areas of the Territory. This applies particularly to Bougainville plantations, where lightning strikes frequently occur, and result in the death of up to 30 palms per strike.

Machinery.

As the use of machinery on plantations is being extended wherever possible, it is necessary that the manager should be able to service all such equipment satisfactorily. Further, it is an advantage if repairs can be carried out by the manager, thus avoiding the costs involved when outside labour has to be called in for this purpose.

Buildings.

All buildings on the plantation require regular maintenance, firstly to keep them looking respectable, and secondly to promote the longevity of the structures. Labourers with slight injuries can often be assigned to such tasks, as much of this work, though tedious, is not hard. The annual expense involved in building maintenance eventually proves less than the costs incurred when a poorly maintained structure must be replaced after relatively few years of service.

INSECT PESTS OF COCONUTS.

Control measures to be adopted against insect pests are discussed in a paper by L. Smee in this issue of the *Journal*. (pp. 51-64). However, it is desired to add some recent observations on a coconut pest, and on developments in the biological control of dynastid beetles in the Territory.

Aspidiotus destructor Signoret.

This scale, though present in the Territory, has never caused severe damage in this country. However, it has appeared in various other areas as a pest of *Cocos nucifera.* Stephens (personal communication) reported that a very serious outbreak occurred recently on the Island of Efa in the New Hebrides. Leaves were almost completely covered by the scale insects, and a severe decline in production was noted. Several palms died after this insect attack.

Fortunately, control of this insect is now being effectively carried out by the coccinellid *Lindorus lophantae* Blaisd. which was an accidental introduction into the New Hebrides, as was *Aspidiotus.*

Dynastid Beetles.

Major pests of the Coconut Palm in the family Dynastidae are *Oryctes rhinoceros* L., which was accidently introduced into the Bismarck Archipelago (see typical damage to a young palm in *Plate* II) and two indigenous species : *Scapanes grossepunctatus* Sternb. which is restricted to the Bismarck Archipelago and Bougainville and *Scapanes australus* Boisd. which is found on the mainland of New Guinea.

Reference is made in Smee's paper (pp. 51-64) to current biological control experiments carried out in the Territory against dynastid beetles. The most promising of these involves the large reduviid *Platymerous rhadamanthus* Gerst. which has been released in large numbers at several locations. This reduviid can kill an adult dynastid beetle in a few minutes, death being caused by the predator inserting its proboscis into the soft tissue behind the head and the body liquid being sucked out. (Dun, personal communication).

DISEASES OF COCONUTS.

This subject is adequately covered in a paper by Dr. D. E. Shaw, Principal Pathologist, in this edition of the *Journal.*

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A Note on Coconut Selection and Breeding.

A. E. CHARLES,

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THE approach adopted by the Department of Agriculture, Stock and Fisheries of Papua and New Guinea to genetic improvement of coconuts has been reviewed in earlier publications (Charles 1959a, b, 1961). Briefly, it was felt that the case for selection of mother palms on the basis of their copra yield had been overstated, and available evidence indicated that such selection was largely ineffectual. Mother palms could only be reliably selected after progeny testing which would ensure that the parents were able to transmit high yield to their progenies. A different approach, considered more likely to bring early results of benefit to the Territory, was the comparison in " variety " trials of strains of palms growing in different localities in the Territory to determine whether any local strain was above average in yielding ability and could be recommended for general planting. Until such trials produced results, the recommendation was that seed nuts should be selected carefully for size and shape and seedlings subjected to careful selection in the nursery.

In 1957, a progeny testing trial was commenced in Papua and in 1958-59, a " variety " trial was planted at the Lowlands Agricultural Experiment Station, Keravat. Early performance of seedlings in both trials indicated that worthwhile differences between progenies and between strains probably existed. Unfortunately, both trials encountered severe difficulties in establishment and it was not possible in either of them to bring enough palms through to maturity to make valid comparisons of yielding ability. Details of these trials have been published in Annual Reports of the Department of Agriculture, Stock and Fisheries from 1959 to 1963.

It was decided in 1964, to commence a new " variety " trial at Kapogere Agricultural Station in Papua where, in the past, coconuts have been raised successfully without undue difficulty. The scope of this trial was to be broadened to include " varieties " from other countries as well as from Papua and New Guinea. Caution is necessary in introduction from overseas, since there are serious coconut diseases of unknown cause in several countries. Consequently no introductions were to be made unless an officer of the Department first inspected the palms in the locality of collection and found them free of serious disease.

In 1964, officers of the Department, with the assistance of local agriculturalists, collected seed nuts for this trial from Bougainville, New Ireland, New Britain, Madang, Karkar, Markham, and East Papua and, outside the Territory, from the New Hebrides, British Solomon Islands Protectorate, Singapore and Ceylon. Collections in Singapore and Ceylon were made in conjunction with the attendance of the Economic Botanist at the Second Session of the Food and Agricultural Organization Technical Working Party on Coconut Production, Protection and Processing held in Colombo in December, 1964.

At this meeting, aspects of selection and breeding were discussed and some new findings were reported, and some reappraisal of the Department's approach has resulted. Liyanage (1964) presented results of a progeny trial in Ceylon which showed convincingly that definite genetic improvement can be achieved by selection of mother palms on the basis of their yield. Comparing yields of progenies with yields of parents (the latter comprising 104 palms taken at random from a block of 292 palms) it was found that selection of the best 5 per cent. of parent palms, on the basis of four years' records of yields of husked nuts, would have given progenies yielding 15 per cent. above the average yield of all progenies.

Under Papua-New Guinea conditions, the requirement of four years' yield records for accurate selection of mother palms is a major practical limitation on the use of this method. Nevertheless, growers undertaking new planting might profitably commence recording yields of promising parent palms on their plantations. It would be beyond the resources of the Department to attempt selection of sufficient mother palms to make a significant contribution to Territory seed requirements, but mother palm selection may be used in conjunction with other breeding methods for the establishment of seed gardens.

The desirability of establishing " variety " trials in main producing countries was stressed at the Colombo meeting by Charles (1964) who pointed out that detection of a local superior strain would make improved seed immediately available in quantity, at a substantially lower cost in money and time than required for most other methods of improvement. He also recommended inclusion of sufficient introduced strains to link trials in different countries. There was general agreement that detailed study is needed to differentiate the strains growing in different countries, and an international committee is to be set up to examine the subject. The basic problem is that all commercial strains of coconuts contain within them a wide range of variability and many of the commercial characters are subject to environmental influence. The proposed international exchange of information and planting material should ultimately be of benefit to Papua and New Guinea coconut producers.

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Book Review.

Coconut Growing.

This latest addition to the series of Oxford Tropical Handbooks presents a concise coverage of coconut agronomy for the plantation owner. The book does not pretend to be an authoritative text on the subject, and in fact other publications of a more technical nature are recommended in the Bibliography, for those who wish to read further.

The subject matter for the ten chapters in the book has been well chosen. Sub-headings are used to advantage, as are photographs and diagrams related to topics discussed in the text.

As the publication is very concise, it has been necessary to severely limit detail in certain sections. This applies particularly to chapters on soil fertility and pests and diseases. However, the author has, on the other hand, made valuable attempts at costing for many operations, and this information should prove most interesting to plantation owners.

It is stressed that while returns per acre obtained from coconut plantations were quite high in the past, such is not the case today. Various aspects of management aimed at achieving the maximum net return are discussed, and the advantage of adopting improved cultural practices is emphasised.

Unfortunately, the author's experience has been limited, and certainly has not encompassed the Territory of New Guinea. Therefore, the reader has to make allowances at times for what may seem erroneous statements. Thus, for example, while in the Seychelles it may take three years for the coconut palm to show a yield response to fertilizer application where soil is deficient, in New Guinea a definite response to such treatment is noted after two years.

A brief coverage of the Botany of the Palm is given, with illustrations being used to advantage. Factors concerning the establishment of a plantation are discussed, with the author stressing the high capital outlay which is necessary to establish a plantation today. This is indeed a major problem for undeveloped tropical countries, where money is not readily available.

Copra drying has been discussed in a fairly informative chapter. Different aspects of sun, smoke, and hot-air drying are introduced, with preference being given to the last method.

The author has striven to keep his language simple, and may in fact be criticised for at times using terms which are far from technical. Thus the description of viruses as " minute organisms even smaller than germs " is below the standard desired in a publication of this nature. Nevertheless, the book should be a useful text for planters, who should regard it as a junior companion to the larger monograph by Menon and Pandalai.

C. J. PIGGOT.

OXFORD UNIVERSITY PRESS, LONDON, 1964. 109 pp. £A.1 6s. 6d.

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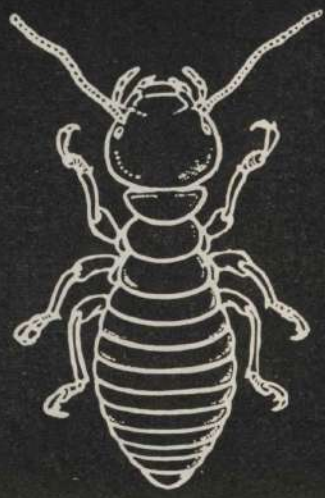

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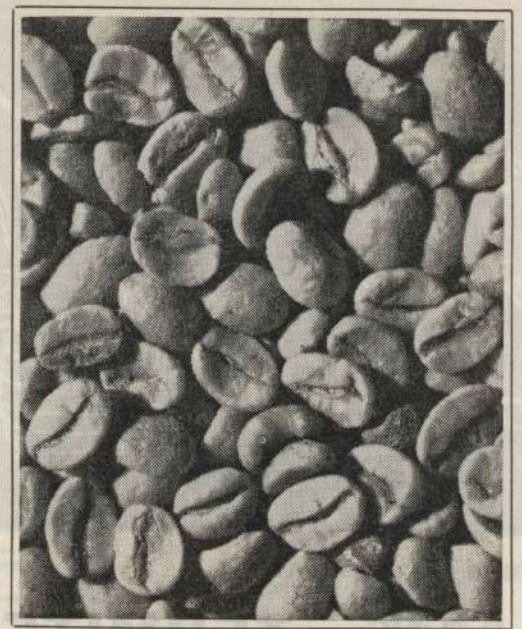

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