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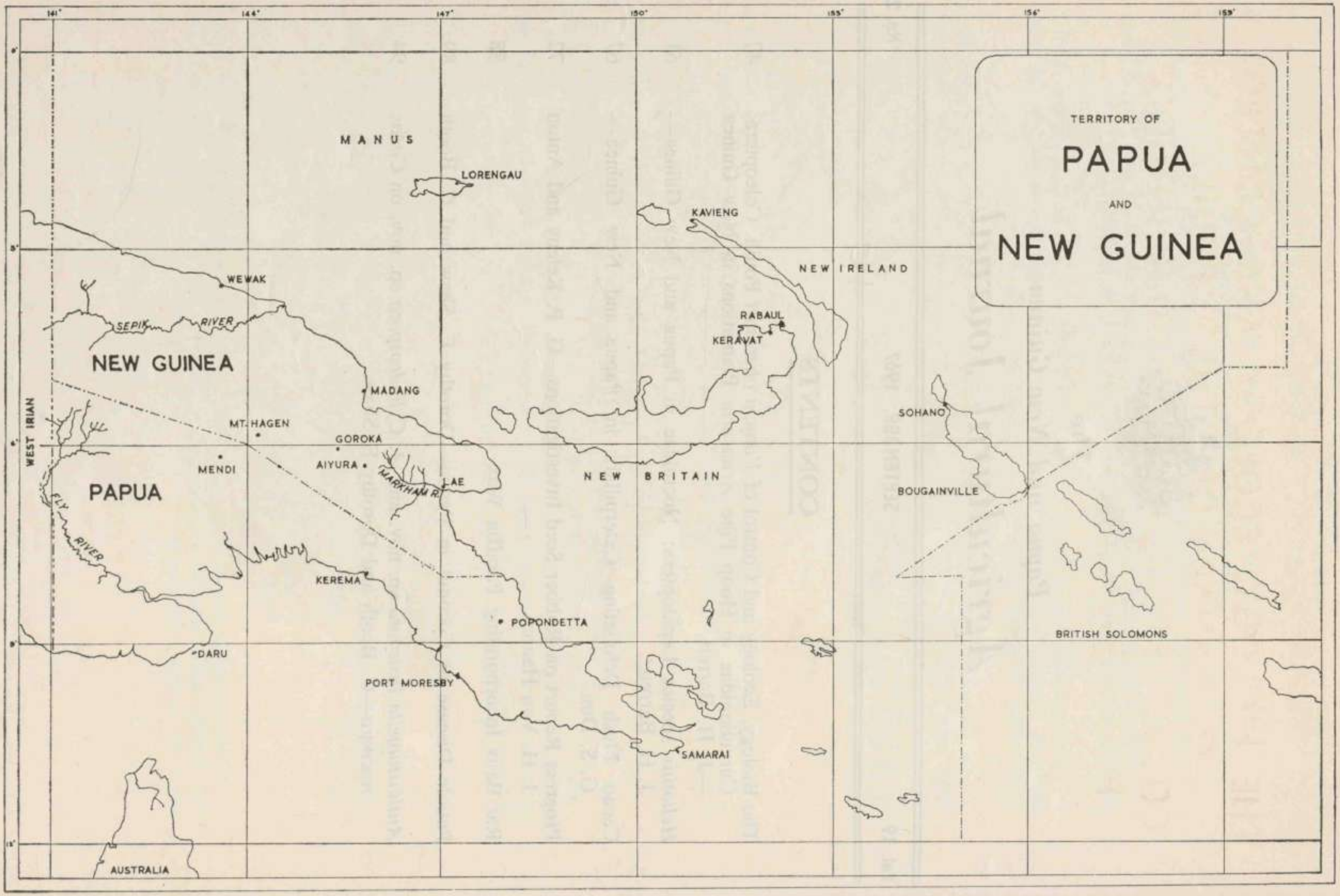

TERRITORY OF
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NEW GUINEA
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MANUS
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WEST IRIAN
MT. HAGEN
GOROKA
MENDI
AIYURA
LAE
MARKHAM R.
NEW BRITAIN
BOUGAINVILLE
PAPUA
FLY
RIVER
KEREMA
POPONDETTA
BRITISH SOLOMONS
DARU
PORT MORESBY
SAMARAI
AUSTRALIA

THE BIOLOGY, ECOLOGY AND CONTROL OF VANAPA OBERTHURI POUILL. COLEOPTERA; CURCULIONIDAE IN HOOP PINE ARAUCARIA PLANTATIONS IN NEW GUINEA

J. H. BARRETT*

ABSTRACT

Vanapa oberthuri *causes serious damage in plantations and also in some native stands of* Araucaria cunninghamii. *The adults fly and appear host specific. The life cycle lasts approximately six months. Galleries are produced in the inner bark by larval feeding. The effect is similar to that of 'ring-barking' and the tree dies in six months to one year. Successful attack appears to be associated with poor resin flow in the bark. Control is based on the early detection and removal of infested trees. Associated insects are discussed briefly.*

INTRODUCTION.

NATURAL stands of Hoop pine, *A. cunninghamii,* are widely scattered at elevations between 2000 and 7000 feet on the mainland of New Guinea. Mixed stands of Hoop pine, *A. cunninghamii,* and Klinkii Pine *A. hunsteinii* (=klinkii) are also found, particularly in the Bulolo Valley. Many thousands of acres in this valley have been progressively logged and burned during the last fifteen years and planted to Hoop pine. Small areas of this species have also been planted in both the Eastern and the Western Highland Districts.

The black pine weevil, *Vanapa oberthuri* Pouill. has been known as a pest of Hoop pine since 1949, and observations on its habits were made at Aiyura in 1950. Since 1957, opportunities have been taken by the author to do further work at the Highlands Agricultural Research Station (Aiyura), and at Kainantu. An increase in incidence was reported at Bulolo in late 1961, and entomological studies were formally requested. As a result the scope of the investigations at Aiyura was widened to include laboratory work, and surveys were undertaken at Goroka and Kainantu in the Eastern Highlands District, and at Bulolo and Wau in the Morobe District.

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HISTORY AND DISTRIBUTION.

Vanapa oberthuri was described by Pouillaude (1915) from specimens collected by Oberthur late in the last century from the upper Vanapa river area in Papua. It was also captured by Pratt in the Angi Lakes area. In 1949, this insect was found to be damaging Hoop pine in plantations at Aiyura. Damage was also found on the Anderson Plantation, a few miles to the east of Wau, in 1951 (a natural stand of Hoop pine had been cut out on the ridges below the present McAdam Park). Replanting was commenced here in 1940.

Attacks were noted in the main plantings at Bulolo in April, 1952. For a few years a practice of cutting infested trees was followed and the insect caused little more concern until late 1961, when the Forester-in-charge noted extensive damage in the twelve-year and the seven-year (Sawmill Creek) blocks. As a result of an intensified cutting programme some 500 trees were removed from foci of infestation in a total area of about 1,000 acres. All these trees were in an advanced stage of attack.

In the Eastern Highlands the first Hoop plantings were at Kainantu and Aiyura in the early 1930's, and at Goroka and centres to the west about ten years later. *V. oberthuri* damage, first seen in 1949, was investigated by Messrs. J. S. Womersley[1], A. J. Schindler and R. S. Carne[2] at Aiyura in 1950 (pers. com.) and reported by Szent-Ivany and Womersley (1958). The cutting of severely infested trees and the use of wires or sticks to destroy larvae in the bark of recently infested trees became general practice and by 1957 the plantations at Aiyura were virtually free of damage. Reinfestation developed about 1960, occasional flying adult weevils being seen in the intervening years. For the three years following 1960, the rate of removal of infested trees was about 0.1 per cent. per year.

Attack developed in a roadside row of some 50 trees at Akuna, a village about three miles east of Aiyura, in 1961. In April 1962, three dead and two severely damaged trees were noted by the agricultural officer from Kainantu.

An infestation in the Hoop pine stands in the Kainantu township area was allowed to develop and in January of 1962, one tree in every twelve (approx.) had to be removed. In March 1963, a further four per cent. of the stand was cut. The remaining trees were substantially free of black pine weevil attack.

Weevil damaged trees were removed from the 'depot' stand at Goroka in January, and again in June of 1962, under the supervision of the District Forest Officer. The initial cut of ten per cent. fell to one per cent. at the second inspection.

Over a number of years native Hoop pine stands were examined in various areas. Attack was noted in a small natural stand about ten miles south of Aiyura. A small area of young trees some five miles further south was free of attack in 1963. This site is on the Abura road in the Lamari river headwaters. A superficial examination of the extension Okapa forest about 30 miles to the west revealed no sign of damage. Scattered Hoop pine in areas west of Kainantu and a small block of very large trees near the 'Dirtiwata' bridge over the Dunantina river also remained free from attack.

Small stands or scattered trees are found in the Highland areas as far afield as the West New Guinea border, and also beyond. *V. oberthuri* attack was not observed in the Chimbu and Wahgi valleys, or in the vicinities of Wapenamanda, Wabag, and Laiagam in the Western Highlands, or Koroba, Mendi, Lake Kutubu and Erave in the Southern Highlands area during visits in 1960 and 1962. However, the larvae, although not regarded as edible, are known to the peoples of

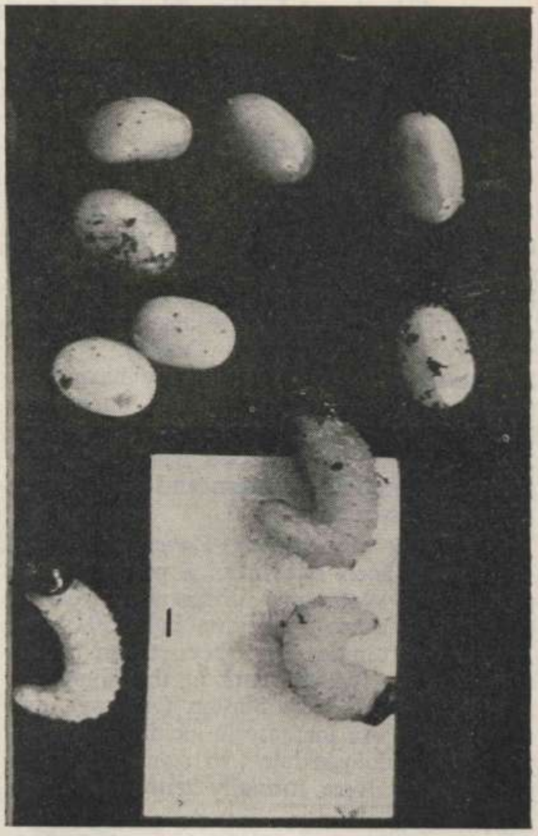


Plate I.—Eggs and first stage larvae of *V. oberthuri*. Foreign material is adhering to some of the eggs. (x 4.0; inset line = 1mm.)

[1] Then Forest Botanist, Department of Forests, Lae.
[2] Agronomists of D.A.S.F. at H.A.E.S., Aiyura.

most of these areas and it seems that the distribution of the insect is as wide as that of *A. cunninghamii*. Normal populations of the insect are very sparse.

LIFE-HISTORY.

Egg.

The egg (*Plates* I and V) is 4-5 mm. in length and 3 mm. in diameter. The surface is very smooth, shiny yet sticky, and of a cream colour. It is turgid when fresh and the shell is soft and moderately tough.

The duration of the egg stage is 10 days, with only slight variation.

Larva.

The general colour of the larva (*Plates* I and II) is creamy white. The head capsule is almost black, hard and well developed. The body tapers near the posterior and is clothed with numerous short bristles. The segments are relatively short, producing numerous folds across the body. Spiracles (breathing holes) appear as a row of dark oval spots on each side of the body.

Increase in larval size is made possible by the usual series of moults, the whole cuticle (skin) being shed, and the hard parts increasing in size by progressive steps. Newly hatched larvae have a head capsule width of about 2 mm. In mature larvae it varies normally from 7.5 mm. down to 5.5 mm. or even less. The number of instars appears to vary from 5 to 7; mature larvae ranging from 35 to 50 mm. in length. This species is unusual in that the proportional size increase of the head capsule from one stage to the next may vary between larvae. However, distribution curves of head-capsule widths do show poorly defined peaks, particularly for the early stages. These peaks vary in position between populations from different trees and head capsule width is of limited use in the aging of larvae.

The duration of the larval stages averages five months.

Pupa.

The fully fed larva becomes comatose for a period before changing to the pupal stage (*Plate* III). The pupa is creamy white with a thin and fairly brittle cuticle. The large rostrum (snout) is conspicuous, along with the legs of the future adult. The colour gradually changes to black as the time for the emergence of the adult approaches.

The pupal stage lasts about four weeks.

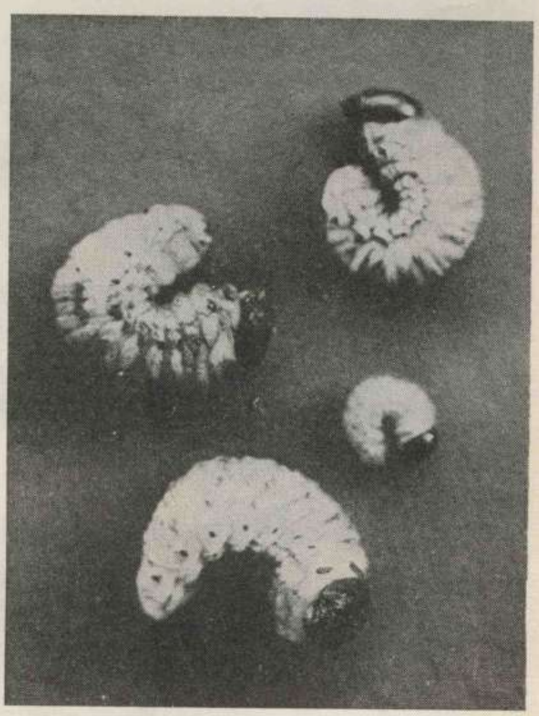
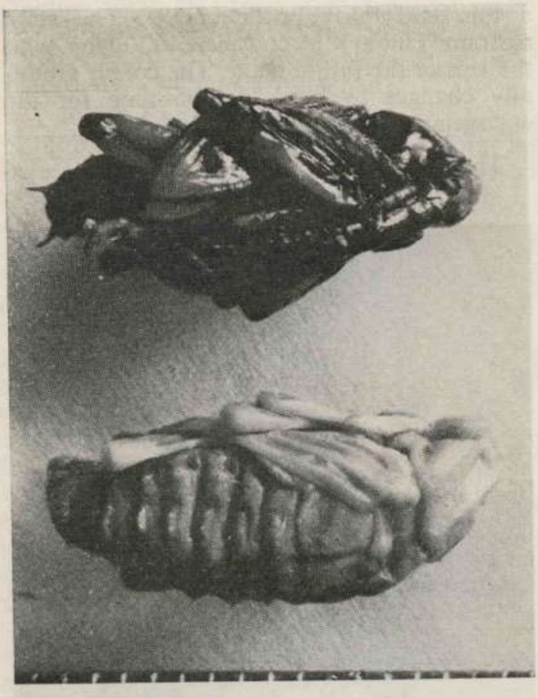


Plate II.—Final stage larvae of *V. oberthuri*. Note the dark coloured head capsule and the wide variation in size and the spiracles on the lower larva. (x 2.0 approx.)

Adult.

The adult weevil (*Plate IV*) is a black insect with long legs and large rostrum. The cuticle is very hard and shiny, with sculpturing on the prothorax and elytra. The males may be distinguished from the females by the presence of a short bristly 'beard' on the lower surface of the rostrum of the male.

Adults may vary from 30 mm. up to almost 60 mm. in length. Males, on the average, are larger than females.



HABITS AND ECOLOGY.

Egg.

Insertion

The egg is placed in a hollow or crevice in the bark or under the margin of a flow of resin, the site being hollowed out to shape prior to the placement of the egg. The exposed part of the egg is covered over with masticated bark and is very difficult to detect from the exterior. It becomes obvious when the outer layers of the loose bark are peeled back or if a mass of resin is broken away. (*Plate* V).

Location on the Tree

Early in an attack eggs are present in association with loose bark. This tends to accumulate at the base of branches. Bark on relatively clean sections of trunk may be infested if attack is heavy. Later, when resin

Plate III.—Pupae of *Vanapa oberthuri*. The darker pupa (above) is close to maturity. (x 2.5; Scale units 1.6 mm.)

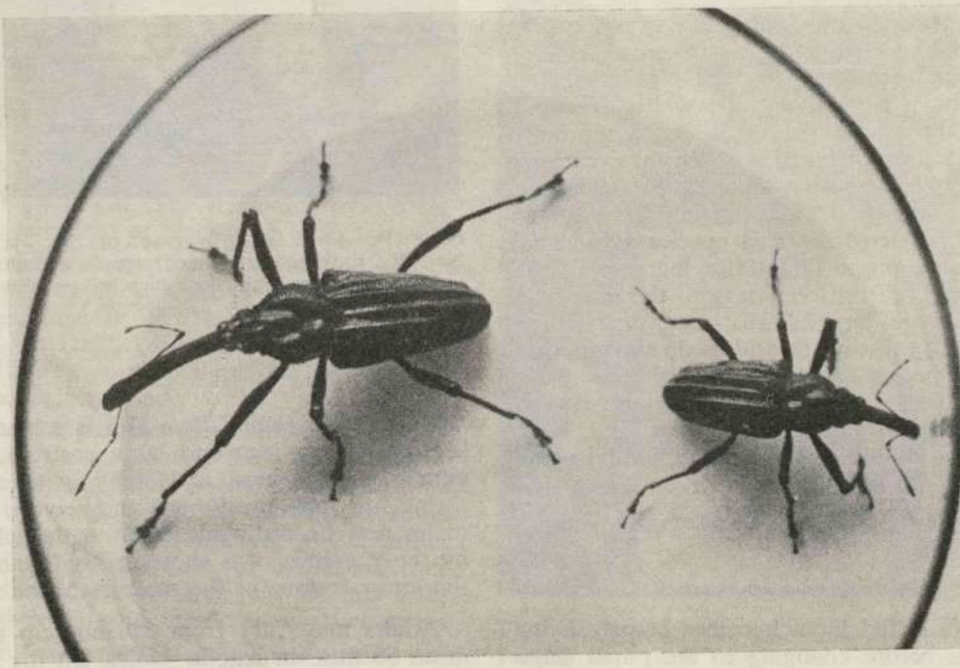


Plate IV.—Adult black pine weevils *V. oberthuri*. (Natural size; in round glass dish.)

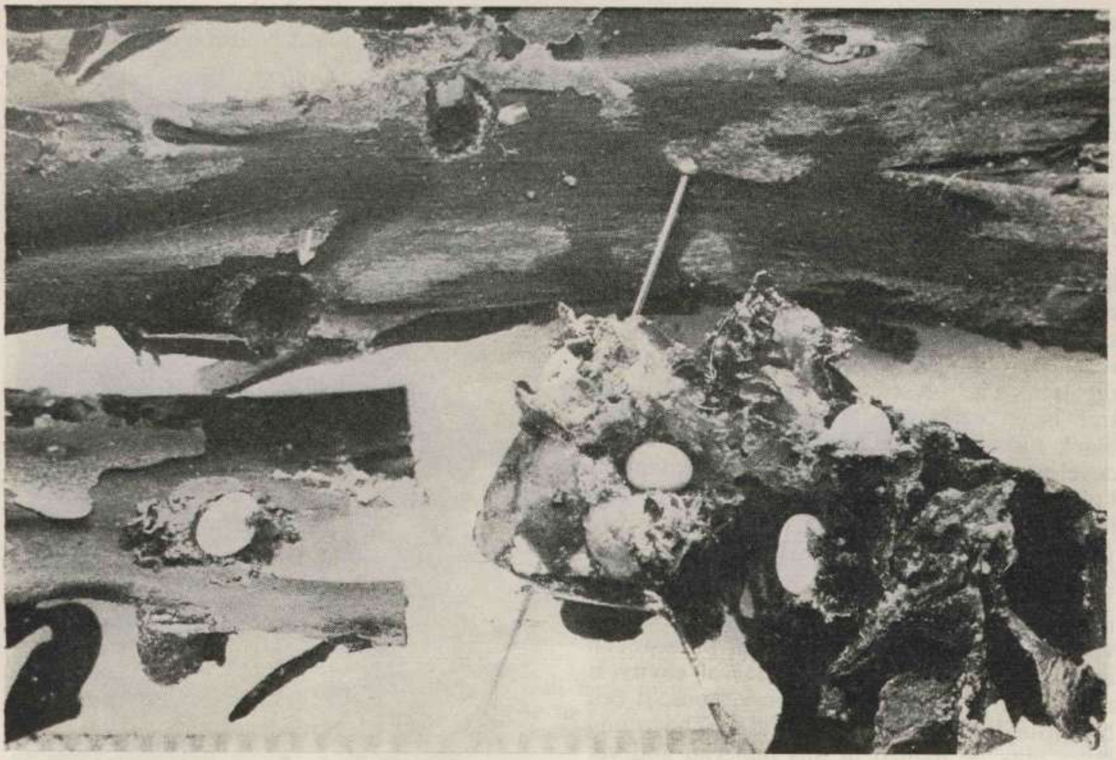


Plate V.—Eggs of *V. oberthuri* on inside of loose Hoop pine bark (lower left) and on inner side of resin mass (right). Egg sites are on the bark (above — 2 pointers) with eggs removed to show chewed cavity sealed on the outside with masticated bark. (x 2.0 — Scale units 1.6 mm.)

has begun to flow from damaged areas, the eggs may be concentrated on the margins of this resin mass.

In the past pruning cuts have been suspected as foci for attack but there is no field evidence in favour of this. It seems that the clean healthy resin which comes from such cuts is not attractive to the female.

Females held in laboratory cages in the absence of bark were noted to produce a number of eggs which fell free to the floor of the cage.

Larva.

Excavation of Gallery

The first stage larva chews through the remaining layers of horizontal bark (corky parchment) on the inner side of the egg cell and forms a small cavity in the soft outer bark (cortex). This is enlarged slightly over a period of three to four weeks and penetrates through the granular sclerenchymatous layer. The larva then begins to penetrate the inner bark which is composed of vertical phloem fibres. By this time the larva has reached the third stage and enlarges the gallery in a wandering manner as growth continues to the final stage. The width may be up to an inch with much broader areas of damage where sections of the gallery come together. Large larvae may leave part of the outer granular bark, all the fibrous bark being removed, and the channel may extend through the cambium layer into the wood to a depth of 3 or 4 mm. The finished gallery may be a foot in total length. The traversed area may be up to six inches along the trunk and a little more in a horizontal direction.

Along the path of the gallery one or more *ventilation holes* may be cut to the exterior. These are 5 to 10 mm. across. (*Plates* VI and VII).

Resin Flow

The flow of resin begins when the larva first cuts into the cortex and the amount increases progressively with the depth and size of the gallery until the fibrous layer is reached, but also depends on the health of the tree. The presence of a resin flow on a tree is an early indication of attack by the black pine weevil. Resin may flow from the developed egg site and later from ventilation holes, and also from the pupal chamber exit hole (*Plate X*).

Nature of the Resin

The resin from a clean wound or cut is milky white, and becomes very thick and viscous. In the case of successful pine weevil attack the resin in the early larval cavity is milky and tends to remain non-viscous. It can be washed away freely with water. The young larva may be bathed in this material and yet survive. This suggests that the larva produces an emulsifying agent or enzyme which changes the nature of the resin.

Normal resin will harden to a clear light amber colour. The resin from a larval lesion is dark amber to brown in colour and is initially more copious and liquid in consistency. Where a large larva is active an extensive mass remains at the mouth of the hole and from this long fine columns often form, hanging free of the bark. (*Plates* VIII and IX). This mass of resin material may extend horizontally, up to three inches from the bark.

It is notable that the liquified resin present in new larval galleries has a distinct odour suggestive of acetic acid. Another odour, suggestive of the essential oils of 'scented titree', may be associated with the mass of resin at the site of an older gallery.

Volume of Resin

A tree in the early stages of attack usually produces large amounts of resin. As the number of galleries increases the resin flow decreases and in the final stages larvae may enter the tree without resin being produced.

Clearing of the Gallery

The ventilation holes are also used as exits for the disposal of excess resin, frass and chewed bark. The larger larvae can be seen to move to and from these holes, sweeping material down a 'debris channel' which is

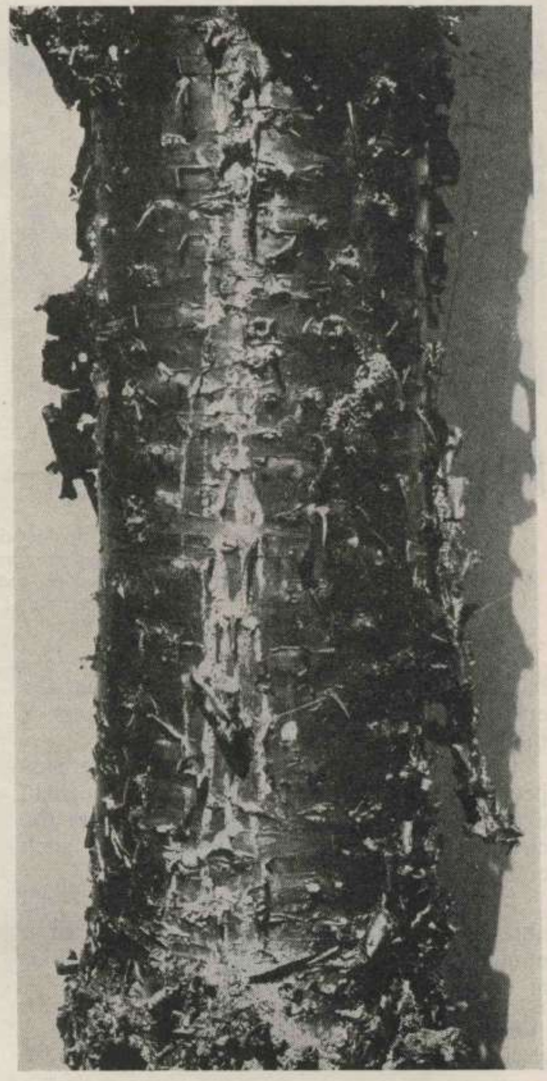


Plate VI.—Section of trunk of dead Hoop pine tree with *V. oberthuri* infestation showing old resin flow marks and ventilation holes.

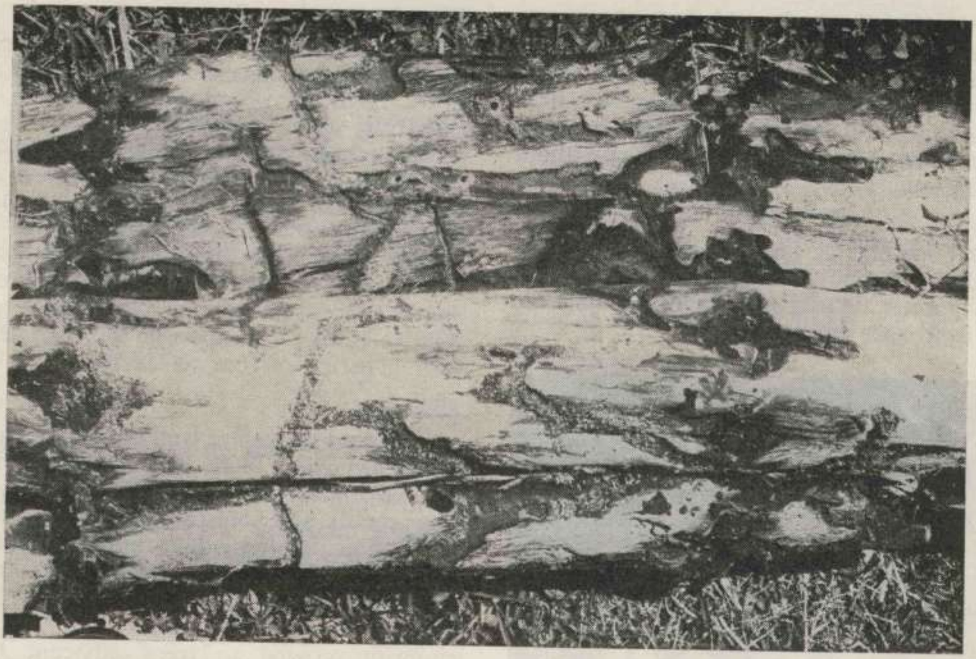


Plate VII.—Section of Hoop pine trunk with bark folded back to show damage to bark and wood by larvae of *V. oberthuri* (Tree as in Plate VI). Ventilation holes (upper centre) and an exit hole (lower centre) are showing in the bark.

formed along the top of the resin mass as it develops out from the tree. The inside of the gallery is kept clean for some distance from the exit. This may be necessary to provide for aeration and the escape of volatile decomposition products of the bark and resin.

With later reduction in resin flow only dry material is voided through the holes. When the pupal chamber is being formed an increased volume of small chips and chewed wood comes away from the *exit hole* (below).

Excavation of Pupal Chamber

An *exit hole* about 20 mm. across is cut to the exterior by the fully fed larva. This forms part of a larger cavity in the bark and from this cavity a gallery is cut horizontally into the wood to a depth of about two inches. It then turns sharply upwards for a short distance before turning outwards and coming close to the inner boundary of the bark at an oblique angle. This oblique section of the gallery forms the pupal chamber (*Plate* X).

The pupal chamber may be associated with a gallery in the bark-filled angle at the base of a limb. In this case the pupal chamber may be deep and difficult to locate.

The oblique portion of the gallery is enlarged by the larva. Bundles of fibres are cut off with the mandibles, being stripped along the grain and then cut off at the base to form flat slivers of up to 20 mm. in length. These are initially pushed out of the exit hole or remain as a tangled mass in the channel. As the hole nears completion the final slivers are placed in a downward pointing cone to form a plug in the base of the pupal chamber (*Plate* X). The wall of the chamber is smoothed off, with a progressive reduction in particle size, and this material is compacted to form the top layers of the plug.

Laboratory breeding

Eggs were collected and larvae allowed to emerge. The larvae were then placed in glass tubes and food supplied in the form of chips of fresh bark. Provided the bark was changed every few days larvae survived satisfactorily and could be reared to the adult stage. At Aiyura many adults were small in size, probably due to the bark sometimes being allowed to remain too long without renewal.

Pupa.

The abdomen of the new pupa is mobile, this ability to move decreasing with age. A very vigorous circular movement results from any disturbance or handling.

Plate VIII.—Resin flow from site of attack by *V. oberthuri* larva on trunk of Hoop pine. (Part of axe at lower left.)

Adult.

Feeding

Adults in cages feed on the bark of green Hoop pine branchlets and the amount indicates that it is a normal habit. It has not been noted in the field and probably takes place high on the host tree.

Mating and Sex Ratio

Mating has not been observed. Field collections of adults suggest a 1:1 sex ratio.

Longevity and Fecundity

The adult remains in the pupal chamber for about a week after the pupal skin is lost and then makes its way out through the exit hole. Adults have been kept alive in cages for up to six weeks. The normal life is probably four to eight weeks. Limited breeding studies suggest that the egg laying rate is relatively low; perhaps one or two per day over a period of four to six weeks.

Dispersal

The hind wings are well developed and the adults are active fliers. The occasional finding of individuals at some distance from Hoop pine stands and infestation of some isolated areas indicate that adults may fly as far as ten miles. However, observations of infestations and individual insects suggest a normal range of less than two miles, with the majority moving to trees adjacent to the 'parent tree' or to newly attacked trees in the general vicinity.

Development of Infestation.

Field incidence

This was dealt with in detail in section 'history and distribution'. Heavy infestation is more common in planted areas of Hoop pine than in natural stands. The insect is capable of eliminating groves of pine and the occasional mature trees in the native forest may be remnants of such groves. The tendency, in the Kainantu area in particular, is for small areas to be found many miles apart, suggesting that groves in intervening areas have been eliminated. The local people use the timber and so are partly responsible for this wide separation between groves or individual mature trees.

Plantation areas are often sited conveniently to centres of development. The higher incidence of attack suggests an increased susceptibility resulting from unsuitable conditions in many of these localities. However, attack does also take place where old pine areas have been replanted, as, for example, at Bulolo.

At Bulolo infestations tend to develop close to plantation margins with natural forest. Unthinned areas are less affected but these were also generally younger. Most damage has been found in areas aged over five years, with some fall off of the rate of attack at fifteen to twenty years.

The grouping of attacked trees reduces the value of a figure of 'percentage attack'. Small areas may be so severely affected as to produce extensive breaks in the plantation and yet the figure for overall 'percentage attack' may remain very low.

Selection of tree

Initially the attack on trees in any particular area appears to be at random. Trees debilitated by the attack of root fungi or by white ants do not show increased susceptibility to black pine weevil. Consideration of the pattern of field incidence and the development of an attack in a particular area (below), along with other factors, suggests that some general ecological factor e.g. soil type, may render an area of trees susceptible.

Progress of attack

The survival rate of larvae may be very low initially and successful attack depends on the laying of further eggs. Eggs collected at Kainantu and Goroka were placed on a healthy 15 year old tree at Aiyura. Survival of eggs was high but as soon as the young larvae chewed into the granular bark the resultant flow of resin was sufficient to drown the larvae. This has been observed under natural conditions in the field.

Adults commonly congregate on newly attacked trees and egg numbers rise markedly. An increasing percentage of larvae survives the first stage and the tree begins to show signs of decline. Successful attack leads to the death of the tree in six to twelve months.

Survival to the adult stage of larvae from eggs deposited less than about four months before the death of the tree is low, due to deterioration of the bark. Conversely, emergence of adults can be expected for up to about two months after the death of the tree.

In the absence of an active local population of adults the follow up infestation might not eventuate, and a newly infested tree may then survive. This was observed in the stand at Kainantu. Trees with only a few established larvae were able to recover following the general removal of infested trees with their load of maturing insects. In one case some 16 adults which had already appeared on a newly attacked tree were removed. The remaining eggs were not sufficient to lead to the death of the tree.

Secondary attraction

As noted above trees carrying small larvae have also been found to carry 10 or more adults. This congregation on such trees is apparently in response to a specific attraction. The volatile breakdown products from the resin at larval galleries seem likely to be the active agents in this attraction.

Effect on tree

The flow of resin from wounds is copious for three to six months and falls off if the vigour of the tree is reduced. Dead limbs may be expected at two to three months after attack begins, the whole crown dying in six to twelve months. The populations of secondary species build up in an infested grove and increase the rate of breakdown of bark. This may hasten the death of attacked trees and also result in a fall in the survival rate of black pine weevil larvae.

Size of tree

Bigger trees (50 inches girth at breast height or more) are not usually subject to serious attack. Occasionally very small trees (10 inches g.b.h. or less) are attacked and death may occur in less than six months. Trees five to fifteen years old, under normal growing conditions, are those most prone to damage.

Insect numbers

Small trees may produce four or five adults, these representing only twenty per cent. of the population of larvae. A tree of 35 inches g.b.h., cut at Kainantu in June 1962, at a stage when some limbs had died, carried a population of 127 larvae, 24 prepupae, 17 pupae, and 2 adults. Larvae were of all ages with a slight preponderance of those about two months old. Eggs were also present. The estimated time of death suggested that this tree would have produced over 100 adults, all young larvae and larvae emerging from eggs failing to mature. Examination of numerous infested and dead trees indicates that an average tree can be expected to produce 50 to 100 adult weevils.

Spread of infestation

It is usual for new attack to occur on trees in close proximity to a tree which is producing adults. A few scattered trees are infested at some distance and these develop as new foci of infestation. (See Dispersal).

Population Changes

Seasonal incidence in attack has not been observed. It is probable that symptoms show more quickly towards the end of the dry season (July-August).

As indicated in *'History and Distribution'*, population build up in New Guinea began in various areas following 1950, and again in the years following 1961. At Aiyura these were years of unseasonal high rainfall, followed by light summer rains in the following year.

ASSOCIATED INSECTS.

A number of other insects are found on trees damaged by black pine weevil. There is a sequence of species determined by the stage of decay to which each is adapted.

On a damaged tree at Kainantu a group of sixteen flat diamond-shaped eggs were found in a single layer, edge to edge, concealed in the dry outer bark. The eggs hatched and the larvae (Cerambycoidea — F.(?) Cerambycidae) survived on relatively dry sections of bark for a period of about six weeks. The species was not determined but is one of the earliest to arrive on the damaged tree. Heavy populations of a Cerambycid probably of the *Pachydissus* group may be found in the bark of some trees. A Cryptorhynchin weevil *Sympiezoscelus (?) spenceri* Wath. may also be present in very large numbers, mainly in the larval stage at the same time. This is a dark species about 10 mm. long, elongate

Plate IX.—Showing continued production of resin on Hoop pine trunk from sites of successful attack by larvae of *V. oberthuri*.

oval in shape, and with rather short stout legs. The larvae may be confused with those of *Vanapa* but are usually very numerous in the dead bark, along with the Cerambycid noted above.

A second weevil, the Cryptorhynchin *Tyrtaeosus (?) microthorax* Pasc., is less common. It is of similar size to *Sympiezos-*

celus, more elliptical in shape, and dark grey with a white diffuse mark on the elytra. Populations develop at a later stage.

The zygopine weevil *Illacuris laticollis* Pasc. is also present at a late stage and the larva appears to be a wood borer. The insect is slender, up to 20 mm. in length, and with relatively long legs. It is grey in colour with black and white markings. Specimens from Kainantu were similar to, though smaller than specimens from Queensland, while a series from Bulolo were still smaller, with indistinct marks.

Cerambycid larvae and other weevil larvae are also found in the wood, the exit from the pupal chamber of one of the former being oval in shape and closed with a white plug.

At Bulolo very large larvae, in radial galleries up to four inches deep in dead wood, were bred out to produce a lamiid of the genus *Dihammus*. The beetles were greyish-brown and up to two inches long with five-inch antennae. The emergence hole was about 15 mm. across and surrounded by a shallow circular excavation almost two inches in diameter. This should not be confused with the emergence hole of *Vanapa*.

The larvae of the click beetle *Calaus* sp. are occasionally encountered in old bark. The larva is shiny yellowish brown with a dark head carrying prominent sharp mandibles. They are predators on other beetle larvae, mainly of cerambycids, but will attack *Vanapa* larvae (in the laboratory). The adult is a large click beetle of over two inches in length, mottled grey and white in colour, with a few black marks.

A weevil similar to the pine bark weevil *Aesiotes notabilis* Pasc. of Queensland has been found at Aiyura (Brimblecombe, 1945). Some 20 individuals were taken on a fresh pine stump but this insect has not been found in association with the black pine weevil *V. oberthuri* or on pruned trees in plantations.

At Bulolo pale brown flattish beetles less than an inch long found on a damaged tree were of the unusual Family Parandridae. A similar larger species of the genus *Parandra* is known from Queensland. Ambrosia beetles F. Scolytidae and shot-hole borers F. Platypodidae may also be associated with damaged trees.

On some trees a number of insects are to be found associated with resin flows. Larvae of the fly families Phoridae and Stratiomyidae have been noted. Brimblecombe (1945) noted a trypetid fly — *Rioxa araucariae* Tryon-breeding under lifting bark on Hoop pine in Queensland.

NATURAL CONTROL (MORTALITY) FACTORS.

Egg Stage.

Unhealthy eggs have not been observed in the field. When eggs were placed on a tree the hatching rate was close to 100 per cent. In partially closed containers in the laboratory a build up in relative humidity was followed by fungal development on a proportion of eggs. On the other hand eggs became flaccid under conditions of low relative humidity.

There is no evidence that excess moisture is a factor in the field. Dehydration may be a mortality factor but the covering placed over the egg by the female may prevent this except perhaps in unusually dry seasons.

Larval Stage.

The Tree

The production of resin is the main defence against insect attack. It is assumed that the volume of resin produced at an injury is related to the general health and vigour of the tree; hence, an attack on a healthy tree is likely to fail. The larval survival rate increases as the resin production of the tree decreases under persistent attack.

In the final stage of deterioration the bark becomes unsuitable as a food and habitat. When the tree finally dies (all branches dead) the larger larvae are the only ones which can survive.

Diseases

Up to 10 per cent. of large larvae were found dead in the galleries of trees examined at Kainantu. The body contents of these larvae were watery, the cuticle being clear, with numerous white pustules on the inner wall. When held in the laboratory at room temperature there was a gradual breakdown without obvious odours or fungal growth.

Predators

Larvae of a large elaterid (click beetle) *Calaus* sp. are often found in the bark of severely damaged trees. These are predatory on beetle larvae. At the stage of damage at which they are encountered a major proportion of larvae were those of secondary species and the effect of this predator on black pine weevil is usually small. The larva is more adapted to life in a series of galleries than to movement from one to another. The effect of this predator on the production of pine weevil adults could only be marked in the late stages of an attack and little control on newly damaged trees can be anticipated.

Pupal Stage.

Moribund pupae are often present in dead trees. These may be abnormally small and nutrition of the larva might be responsible. Simple dehydration in the drying trunk could also be a factor.

The development of disease and the activities of elaterid larvae combine to reduce survival of pupae to some further degree.

Adult Stage.

Tree

Dead adults are commonly found in the pupal chamber. The factors responsible are probably the same as those which are active in the case of the pupa.

Dispersal of host tree

The dispersed nature of natural Hoop pine stands and the usually low population of black pine weevils do not favour a high rate of mating and subsequent egg-laying. The black pine weevil is one factor in the maintenance of the dispersal of Hoop pine stands. There appears to be a natural balance between the weevil and Hoop pine, moderated by the ecological factors which determine the vigour of Hoop pine trees in any particular area. This basic relationship is a density-dependant one, the *Vanapa* population tending to increase with tree density. A pure plantation stand probably represents the ultimate in terms of *Vanapa* survival.

FIELD CONTROL MEASURES.

The previous discussion suggests that the development of an outbreak is controlled initially by the condition of the trees in any particular grove and finally by the population of insects available to produce an attack. The control measures are aimed at the reduction of the population of adults in outbreak areas. Cultural factors are discussed later.

Detection.

This phase of control is the most important, and may also be the most difficult and costly.

Trees with sustained attack

The flow of brown resin from numerous holes in the bark, the death of branches, usually from the base upwards, and the presence of exit holes with associated clean wood debris are characteristic symptoms.

Trees attacked for three to six months

Few branches may be dead. Resin flows, if high on the trunk, are difficult to detect on unpruned trees.

Early attack

In pruned trees detection depends on the distinction between resin from larval sites and healthy resin from cut branches and wounds. In unpruned areas detection is very difficult and may be as low as 50 per cent. or even less at any particular inspection conducted on a routine basis.

Method of Inspection.

Systematic viewing of all trees in an area should be the aim. One worker should satisfactorily examine four rows of trees at each traverse. In areas of very low infestation in average terrain, rates of inspection should reach 50 to 60 acres per man per day at an acceptable level of efficiency, detection of very early stages of attack being accepted as poor.

Treatment.

Trees with Sustained Attack

The tree should be cut as soon as detected, the bark removed, and the pupal chambers cut out. Normally the pupa is found an inch or so above an exit hole but holes adjacent to limbs may lead to a deeper chamber. Removal of the bark will ensure the death of all eggs and larvae.

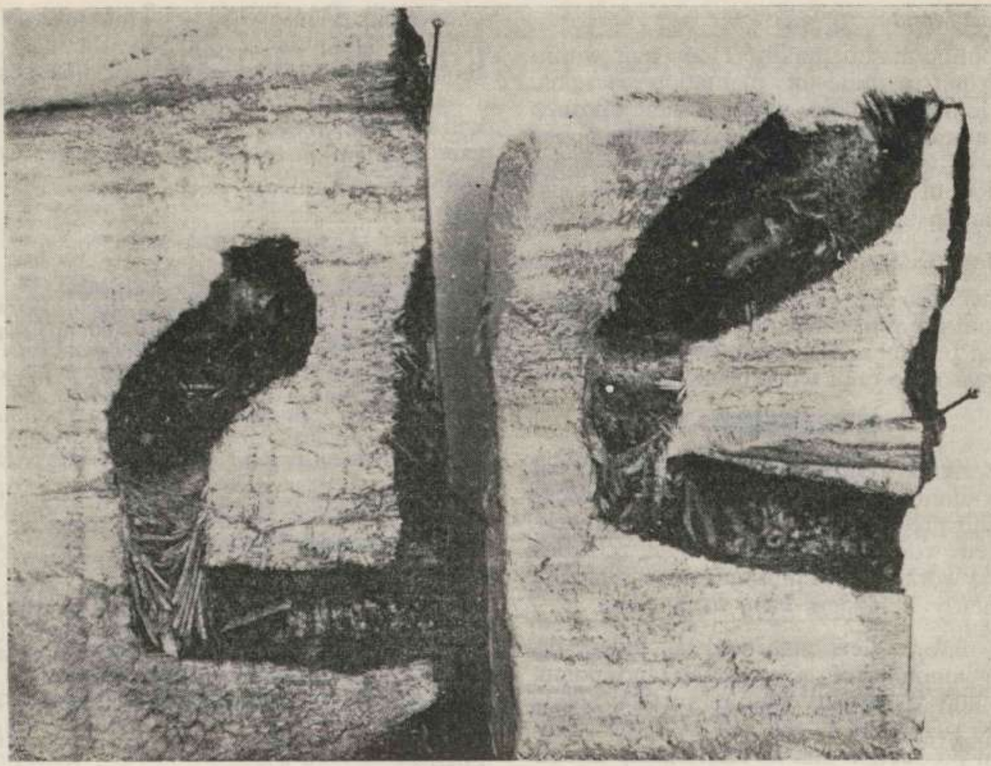


Plate X.—Pupal gallery of *V. oberthuri* in radial section of wood cut from outer part of Hoop pine trunk. The horizontal gallery, vertical gallery with characteristic plug of slivers and chewed wood, and the pupal chamber turning back towards the outside of the trunk (right) are characteristic features. (Natural size.)

Trees with recent attack

In the earlier stages of attack destruction of the tree may not be necessary. Procedure must depend more on economic considerations than on the necessity for control. Blocks of pruned trees selected for the final stand may be cleared of infestation. Trees with less than six larval attacks may be worth treating in such areas, or possibly in younger areas if costs are satisfactorily low.

Holes produced by black pine weevil larvae should be cut out to the depth of the clean bark, and all remnants of the gallery excised, along with the liquified resin. The new cut will produce clean resin. A 'bush-knife' may be preferable to an axe for this purpose.

Programme.

Infested blocks

Inspection and treatment at three monthly intervals, until three successive inspections show no new attack.

Sites of tree death

Inspection and treatment on two extra occasions (to give four inspections in the first six months) of about five trees in all directions from the site.

Clean areas

Areas older than three years may be checked once per year if other cultural practices have not necessitated detailed attention to these areas.

Natural forest

Attention may be paid to Hoop pine within about half a mile of plantation margins. Trees in natural stands within a short distance of plantations may maintain breeding populations of weevils and be responsible for the initiation of outbreaks in plantation stands. Destruction of infected trees is advisable.

Chemicals

Difficulties and dangers of application, cost, and the possibility of producing secondary pest problems have been considered sufficient reason to omit work on these materials.

DISCUSSION.

This simple control programme is practical in that thinning is a normal plantation procedure and presents no problem with relatively unskilled workers. Handling of insecticides by these workers does present certain dangers, particularly if ladders have to be used.

The information presented is based on varying amounts of investigation and points which may eventually require further attention are suggested by the text. A basic study of resin production and its relationship to soil fertility or other factors in the ecology of Hoop pine is necessary. Responses to artificial fertilisers, although of no value in the field, could shed useful light on the problem. Information of this nature would be of assistance in clarifying the basic reasoning behind the black pine weevil control programme and also in developing controls for other insects. It could also assist in determining the potential of new areas for reafforestation.

The measures indicated above were put into practice to a limited extent at Bulolo in 1963. At the time of writing the black pine weevil is no longer a problem in this area, and populations are so low that useful and reliable data cannot now be obtained. Although the recorded history of this pest is relatively short it seems likely that activity will again increase in the years to come and careful attention to control procedures would again become necessary.

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This paper has been read by Mr. B. Gray of the Department of Forests and his comments are acknowledged with thanks.

Vanapa oberthuri Pouill. was identified by the late Sir Guy A. K. Marshall of the British Museum. Other identifications were made by the author with the assistance of Miss Sue Hamlyn and Miss Janice Chiu Chong, Entomologist, of the Queensland Department of Primary Industries, and the reference collection of the Entomology Branch of that Department. This assistance is gratefully acknowledged.

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HELIOTHIS SPECIES LEPIDOPTERA : NOCTUIDAE IN PAPUA AND NEW GUINEA

J. H. BARRETT*

ABSTRACT

Hosts, pest status, natural controls (pathogens and predators) and records of H. armigera *and* H. assulta *are given; and* H. rubrescens *and also the Armyworm* Pseudaletia separata *are recorded. Classification of the group, keys to the adults and larvae of local species, and control with insecticides are included. This paper deals more particularly with the Highland areas.*

INTRODUCTION.

THIS group of pests is cosmopolitan and larval attack on maize, cotton, tobacco and tomatoes is a constant problem. Certain other crops are attacked less persistently. Little work has been done in New Guinea but results of research in Australia have been published in papers on tomatoes by Common (1948), cotton by Passlow (1959) and linseed by Passlow and others (1960). Sloan (1945) dealt with migration and Smith and Saunders (1961) with control on tobacco. Kirkpatrick (1961) recorded species distributions and hosts, and in a second paper (1961a) described the various stages of the Queensland species. Common (1953) examined the taxonomic and pest status of the group in Australia. A world study was presented by Hardwick (1965). In this paper a group of species previously included in *Heliothis* was removed to a new genus *Helicoverpa.* This has not met with general acceptance by all authorities and is used here as a sub-genus.

In New Guinea *H. armigera conferta* may be a serious pest of maize, tomatoes, soya beans and tobacco. Under Highland conditions in most seasons a pathogenic fungus is the most effective natural agent of control. *H. assulta assulta* has a more restricted host range and the favoured hosts are tobacco and cape gooseberry. Control of this species is also assisted by a pathogenic fungus.

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CLASSIFICATION.

The subfamily Heliothidinae consists of a group of species poorly distinguished from those of Noctuinae. Larvae of the Heliothidinae have the characteristic habit of feeding on the flowers and fruits of the host plant, the moths commonly frequenting the flowers of the same plant. Hardwick (1965) summarises the knowledge of the group.

The major genera of the Heliothidinae are *Schinia, Heliothis,* and *Helicoverpa.*

Schinia is concentrated in western North America where particular species are adapted to specific food plants, and restricted by the distribution of these plants — (Hardwick, 1958).

Heliothis is well represented in the Old and New Worlds, with one intermediate and less specialised species *H.* (*Thalpophila*) *rubrescens* Walker in Australia.

The genus *Helicoverpa* includes the least specialised *Heliothis armigera* Hubner and species closely related to it. This group of species is characterised by laying larger numbers of smaller eggs on a wider range of food plants and a tendency of the moths to fly longer distances than is the case with remaining *Heliothis* species.

The seventeen species placed in *Helicoverpa,* along with their five subspecies, may be divided into five groups.

The *armigera* group extends from southern Europe and Africa to New Zealand. The one main species has two forms, one of which, *H.* (*H.*) *armigera conferta* (Walk.), is found in the region east to south of the Celebes Islands, the limit of the distribution being New Zealand.

The *zea* group extends over all except the colder regions of the globe. The species *H. assulta* (Guenee) has a range from India and Japan to Australia and Fiji.

The monospecific *punctigera* group of Australia is related to the *gelotopoeon* group with four species in the Americas.

Two species in the Hawaiian Islands constitute the fifth group.

IDENTIFICATION.

Egg.

The egg is yellow, 'bun-shaped', and has numerous vertical ribs. Eggs are usually placed singly on buds or growing points.

Larva.

The basic colour is green and this may be marked by a diffuse brown or reddish pattern. Small larvae are often relatively dark. The body is covered with scattered short bristles (setae), each on a dark coloured base (tubercle). This gives the larva a characteristic 'rough' appearance.

Larvae may be distinguished as follows:

1. Vertical diameter of spiracle (breathing pore) on segment 7 (behind last pair of abdominal legs) larger than or occasionally equal to that of the seta—bearing tubercle above it .... *H. armigera.*
   Vertical diameter of spiracle much less than that of the tubercle (x0.6—x0.8). 2
2. Pigment of tubercle brown to dark brown. .... *H. assulta.*
   Pigment black. .... *H. rubrescens.*
   (Based on characters used by Kirkpatrick 1961a.)

Pupa.

The pupa is brown and usually found loose in soil or in plant debris on the ground. Characteristic features are few but are described by Kirkpatrick (1961a).

Adult.

The general colour of moths varies from yellowish grey to orange-brown or reddish brown, with varying degrees of fine black or dark markings. The hind wings are usually pale at the base, often with dark vein lines, and dark towards the terminal margin.

Differentiation of species is difficult, particularly with old or faded specimens. The following key will be satisfactory with the majority of specimens.

Heliothis armigera is illustrated in *Plate* I.
Moths may be distinguished as follows:

1. Pale diffuse spot in the terminal fascia of the hind wing. 2
   No pale diffuse spot. .... *H. rubrescens.*
2. Basal area of hind wing yellow or orange, with greyish suffusion. .... *H. assulta.*
   Basal area of hind wing whitish, with grey or greyish brown suffusion.
   .... *H. armigera.*

DISTRIBUTION AND HOST RECORDS.

A. *Heliothis* (*Helicoverpa*) *armigera conferta* Hubner. The common names are as follows: corn earworm, tomato grub, tobacco bud worm.

Zea mays L. MAIZE

Papua: Boroko, Port Moresby—15. VI. '56 (6).
14-mile farm, Port Moresby—13. III. '58 (2).
Erave, Southern Highlands District—18. X. '60 (1).

New Guinea: Aiyura (3)—20. I. '58; 11. VII. '58; on cobs with heavy population of *Pseudaletia separata* (Wlk) 22. VII. '58 ; 22. XI. '58 ; 23. VII. '59 with *P. separata* (1). Kainantu, Eastern Highlands District (5,100 ft.)— 5. XI. '54 (2). Goroka, E.H., (5,100 ft.)—10. X. '51 (1).

West New Guinea: Kota Nica—12. VII. '57; 2. VIII. '57 (4).

Lycopersicum esculentum Mill. TOMATO

Papua: Erave, S.H.D. (3,600 ft.)—18. X. '60 (1).

New Guinea: Aiyura—29. IV. '58; 28. V. '58; 1. XII. '58; 30. XI. '60; 23. XII. '60 (1).

Brassica oleracea L. CABBAGE

New Guinea: Aiyura—24. III. '58 (1).

Pisum sativum L. GARDEN PEA

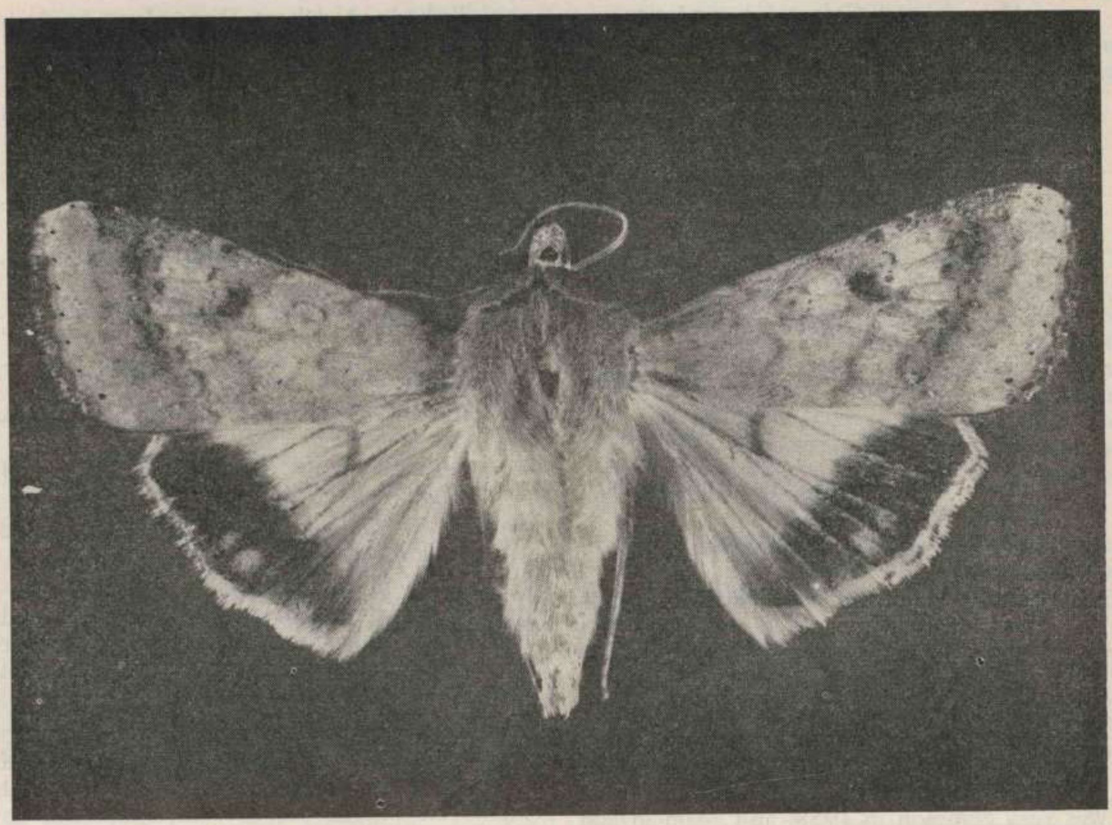

Plate I.—Corn Earworm Moth. *Heliothis armigera* Hubner.

New Guinea: Aiyura—1. XI. '57; 27. V. '58; 1. VI. '58; 18. XI. '60; 21. XII. '60; 10. I. '61 (1).

Glycine Soja max Merr. SOYA BEAN

New Guinea: Aiyura—1. XI. '61; 10. I. '62 (1).

West New Guinea: Kota Nica—3. IX. '57 (4).

Phaseolus spp. BEANS

West New Guinea: Kota Nica—15. VII. '57; 9. IX. '57; 12. XII. '57 (4).

Cajanus cajan PIGEON PEA

New Guinea: Aiyura—29. III. '58 (1).

Gossypium hirsutum COTTON

New Guinea: Erap, Morobe District—10. V. '60 (5).

Dianthus caryophyllus L. CARNATION

New Guinea: Kainantu, E.H.D.—20. XII. '54 (1).

Nicotiana tabacum L. TOBACCO

Papua: Sogeri Plateau, 1,500 ft. 1. II. '63 (2).

Theobroma cacao L. CACAO

West New Guinea: Kota Nica—1. XII. '57 (4).

Ambanz (Manokwari) '60 (4).

Dun (1964) records this species as a pest of pods.

Coffea arabica COFFEE

Recorded as a host (2) in both the Eastern and Western Highlands; and at Wau, 23. VII. '63 (2).

Dumbleton (1954) refers to a cyclostyled report by Mr. G. S. Dun in which maize, tomatoes, tobacco, lettuce, cacao, taro

(*Alocasia* and *Colocasia*), and rice are listed as hosts of *H. armigera*. Dun (1955) refers further to this species as a pest of horticultural crops, and Szent-Ivany (1961) quotes the cacao record.

Other Records: Light and field collections.

Papua: Mageri, Sogeri Plateau, Port Moresby (1,600 ft.)—August, (7).

New Guinea: Wau, Morobe Highlands 3,400 (ft).—7. IX. '58, (2).

Wantoat, Sarawaket Mts. (4,000 ft.)—September (7).

Aiyura—19. V. '58 ; 7. X. '58, (light) (1).

Goroka, E.H.—23. V. '58, (light) (1); 28. VI. '55, (light) (2).

Daulo Pass—September (8,000 ft.); October (6,500 ft.), (7).

Bainyik, Maprik, Sepik District—October, (7).

Gazelle Peninsula, New Britain—October and November, (7).

Lubuana Ptn., East coast, New Ireland —August, (2).

These records suggest that this species is seasonal in Highland areas, there being a lull in activity early in the year and again in August and September. At Aiyura the insect was very common in 1958, and again in late 1960, 1961 and early 1962. Damage was most severe on tomatoes, legumes, and maize in that order.

Records for the Lowlands suggest less activity in the hot wet part of the year.

B. *Heliothis* (*Helicoverpa*) *assulta assulta* (Guenee): Cape gooseberry budworm.

Physalis peruviana L. CAPE GOOSEBERRY.

New Guinea: Aiyura—14. III. '58; 12. VII. '58, (1).

Nicotiana tabacum L. TOBACCO

Papua: Sogeri Plateau, 1. II. '63. (2).

Other Records: Light and field collections.

Papua: Port Moresby (Newtown)—12. XII. '55 (light). (2) ; 9. V. '57, (light) March. (7).

Brown River, P.M.—August, (7).

Bisianumu, Sogeri Plateau (1,600 ft.)—July. (7).

Kokoda, Northern Dist.—June to August. (7).

Ekeikei—March and April. (7).

New Guinea: Wau, Morobe Dist. (4,000 ft.) —September. (7).

Oomsis (near Lae)—August. (7).

Aiyura—18. I. '59 (1); March, July, and December. (7).

Okapa, E.H.D. (6,000 ft.)—October. (7).

Goroka, E.H.D. (5,100 ft.)—23. V. '58. (7).

Mandi (near Wewak), Sepik Dist.—October. (7).

Bainyik, Sepik Dist. (1,000 ft.)—October. (7).

Keravat, New Britain—27. XI. '54 (light) (2).

West New Guinea: Kota Nica—June and September. (7).

H. a. assulta has been collected most frequently from May to August under lowland conditions, while the relatively small number of captures in highland areas have been well distributed throughout the year.

There is an indication that this is the more common species in lowland areas and it is much less common than *H. armigera* at higher elevations, probably as a result of its much narrower host range.

C. *Heliothis* (*Thalpophila*) *rubrescens* Walker: Indian weed caterpillar.

A single specimen has been collected.

New Guinea: Goroka, Eastern Highlands District, 5,100 ft.,—23. C. '58, at light, Col. J. H. Barrett.

Previous records are from Australia where the only known host plant is *Sigesbeckia orientalis* L. Indian Weed : (Kirkpatrick 1961).

FOOTNOTE:

(1) Author's records
(5) Col. A. Catley
(3) Highlands Agricultural Experiment Station, Aiyura, Eastern Highlands. (5,400 ft.)
(4) R. T. Simon-Thomas (1962)
(5) Coll. A. Catley
(6) Published in error as *H. assulta Szent-Ivany* (1956) (pers. com.)
(7) Records from Hardwick (1965).

V. CONTROL.

Natural Agents.

(a) *A pathogenic fungus* identified as *Nomuraea* (=*Spicaria*) *prasina* Maubl. has been responsible for heavy field mortality of larvae.

An infected larva is illustrated in a previous paper—(*Plate* XXIII : Barrett 1966), and the fungus is incorrectly titled Green Muscardine Fungus *Metarrhizium anisopliae* Metsch.

It appears responsible for the relative scarcity of insects in the wet conditions of early spring over the summer period, and also for the variations in larval populations from season to season. The type of incidence suggests that an area may become 'saturated' with spores which remain viable and may retard infestation of the following crop in that area. This is provided that weather conditions are suitable for the fungus when populations again begin to develop.

During periods of fungus activity in the field the loss of larvae brought into the laboratory was of the order of 95 per cent. There was undoubtedly some cross infection in the laboratory but segregation of larvae, sterilisation of glassware and other precautions, reduced the mortality rate of late stage field collected larvae by only a small percentage.

With the onset of the condition larvae become sluggish and then comatose, darken in colour, and under damp conditions the body will become covered by the growth of a white fungal mycelium. Over a few days this changes to an olive green colour and the fungal surface then becomes powdery. This is due to the maturation of the millions of spores which have developed. (*Plate* XXIII : Barrett 1966)).

(b) *Predators* Two pentatomid bugs are active against the larvae. *Amyotea* sp. is oval in outline, half an inch long, and dark brown and orange in colour. *Platynopus melacanthus* Boisd. is of a mottled brown colour, slightly smaller, and has a spike on each 'shoulder' : (*Plates* XXI and XXII : Barrett 1966). These bugs paralyse the larva, and liquefy and suck out the body contents.

(c) *Egg losses* are normally heavy but agents are not known. Ants may be responsible, along with a nabid bug.

(d) *Parasites* have not been recorded.

Chemical Control.

Over the years a range of materials have been tested in various countries, but DDT remains the most effective. It is relatively cheap and of reasonably low toxicity to humans. In the Highlands where chemicals have been little used 0.1 per cent. concentration in water, preferably made up from an emulsifiable concentrate, is effective against *H. armigera*. The higher concentration 0.2 per cent. may be necessary to control *H. assulta* on tobacco.

When sprays are applied mechanically a rate of 0.5 to 1 pounds per acre in as little as 15 gallons of water has been found effective.

Under Territory conditions where natural agents are important in control, applications of insecticide should only be made as a last resort and should not be repeated unless reinfestation occurs. This policy will produce the least possible interference with predators and will reduce the chances of the development of a mite problem.

On soya beans, where vigorous growth will produce a closed canopy of leaves, heavy populations of larvae may be present but have little effect on the yield provided that no appreciable break in the canopy results from their feeding. In small areas in village gardens the shaking of plants, followed by the destruction of fallen larvae, is a feasible control measure.

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CACAO FLUSH DEFOLIATING CATERPILLARS IN PAPUA AND NEW GUINEA *

G. S. DUN†

ABSTRACT

The distribution and importance of caterpillar species feeding on cacao flush in Papua-New Guinea is discussed and an outline is given of the type of damage they cause. The history of cacao growing and associated caterpillar damage in the Territory is discussed, and factors contributing to the nature and severity of the problem in various areas are considered.

INTRODUCTION.

Cacao is only of recent origin in the Territory of Papua and New Guinea. The first introductions of planting material were made about the turn of the century, but up to the commencement of the War both the area planted and the production were negligible. At that time the crop was only known to be attacked by a limited range of insect pests and of these only the weevil and the longicorn borers were thought to have any serious potential.

As from the end of the War, cacao planting was undertaken on a large scale and by the end of 1962-63 the area planted had risen to approximately 120,000 acres. As would be expected, this increase greatly influenced the insect fauna associated with the crop and to date some 300 separate species have been recorded as feeding on it and causing damage to varying degrees. All the species so far recorded are indigenous but many of them have ranges extending well beyond the limits of the Territory.

The main cacao growing areas are located on New Britain, New Ireland, Bougainville and the Northern District of Papua with lesser plantings in the Central district of Papua and in the Morobe and Madang Districts.

It is intended here only to summarise the position relating to the caterpillars which defoliate cacao flush. The main species are listed below:

Noctuidae:	*Achaea janata* L.
	Tiracola plagiata (Walk.)
	Ectropis bhurmitra (Walk.)
Geometridae:	*E. sabulosa* Warr.
Tortricidae:	*Adoxophyes sp.*
Thyrididae:	*Stringlina rufocastanea* Roth.
Limacodidae:	*Scopelodes sp.*
	Pinzulenza kukisch Hering
Lycaenidae:	*Jamides celeno* (Cr.)

In addition, various species of lymantriids and psychids appear always to be present in all the cacao-growing areas but no instance has occurred where they have reached a level of economic importance. The species causing most concern are *L. Achaea*, *Tiracola* and *Ectropis* (*Plate* I). *Jamides* occurs commonly in all the mainland areas but does not have the extensive damaging effect of the main species. *Scopelodes* and *Pinzulenza* differ from the other species in that they will feed on mature foliage as well as on flush growth. *Pinzulenza* was responsible for the complete defoliation of thousands of trees on Karkar Island and in parts of the Madang District over a period of about a year in the late 1950s but has since declined to a position of relative unimportance.

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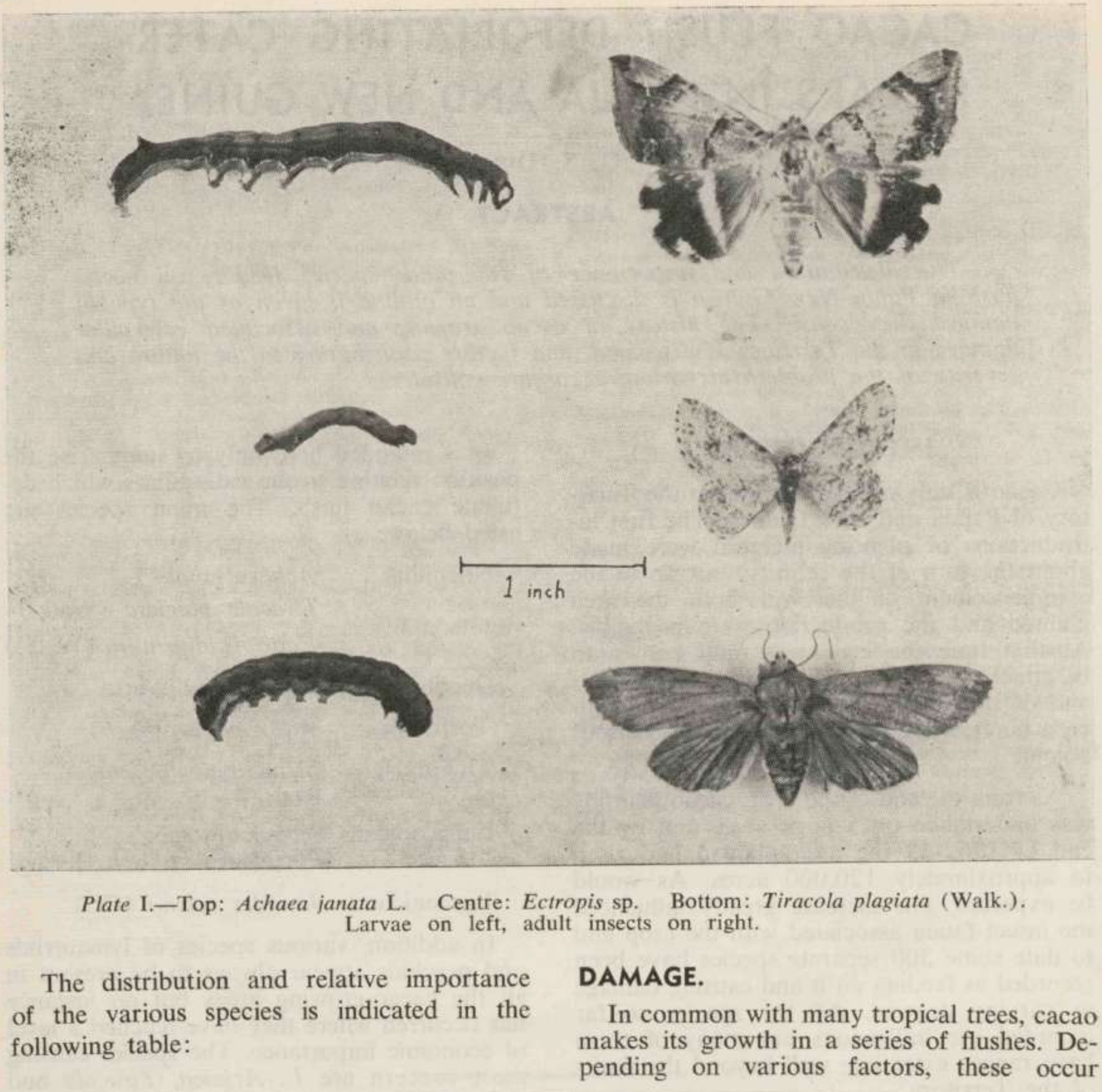

Plate I.—Top: *Achaea janata* L. Centre: *Ectropis* sp. Bottom: *Tiracola plagiata* (Walk.). Larvae on left, adult insects on right.

The distribution and relative importance of the various species is indicated in the following table:

DAMAGE.

In common with many tropical trees, cacao makes its growth in a series of flushes. Depending on various factors, these occur

	Papua		New Guinea		New Guinea Islands		
	Cent.	North	Morobe	Madang	N. Britain	N. Ireland	B'vle.
Achaea	x	xx	xx	xx	xx	x	—
Tiracola	x	xx	xx	xx	x	x	x
Jamides	—	xx	xx	xx	—	—	—
Ectropis	—	x	x	x	xx	—	—
Stringlina	—	x	—	—	x	—	x
Scopelodes	—	—	—	x	x	—	x
Pinzulenza	—	—	—	xx	—	—	—
Lymantriidae	x	x	x	x	x	x	x
Psychidae	x	x	x	x	x	x	x

approximately every six to eight weeks and usually most of the trees in a given area will flush at the same time. The flush leaves develop very quickly and harden off within two or three weeks. However, before the leaves harden they, are very susceptible to attack by insects, of which the defoliating caterpillar are the most serious. Once the leaves have commenced to harden they are no longer attractive to the caterpillars, although if the defoliation is sufficiently extensive the tree will continue to put out flush growth thus putting a further strain on its resources. An interesting feature is that the period between flushes approximates to the time required for a generation of the pest species and, since most of the latter do not coincide precisely, the chances of a tree maturing an appreciable proportion of its growth during a caterpillar epidemic are slight.

Feeding results primarily in the destruction of new leaf tissue. If the new tissue hardens before the attacking species is ready to pupate, the caterpillars will then feed on the newly induced flush, the bark of the new shoots, the growing points and, in the case of Tiracola, on flowers and pods. However, in view of the fact that a normal tree produces many more flowers and fruit than it is physically capable of maturing, it is doubtful whether their loss is economically significant. Apart from the natural setback to the tree resulting from the defoliation, there is gross proliferation of branches resulting in a badly formed tree, a delay in the time required for the tree to come to normal bearing and a lowering of the yield, particularly in the prematurity years.

HISTORY OF INFESTATION.

Gazelle Peninsula.

The principal areas of caterpillar damage are on the Gazelle Peninsula of New Britain and in the Northern District of Papua (Popondetta). Of the main species, *Achaea* and *Ectropis* have predominated in the former area and *Achaea* and *Tiracola* in the latter. It will be noticed that *Ectropis* is present at Popondetta but it has never assumed the importance it reached in New Britain. There is some evidence that outbreaks of caterpillars occur in cycles. In the late 1940s *Ectropis* and *Achaea* (mainly the former) caused considerable damage in parts of the Gazelle Peninsula. On the Experiment Station at Keravat it was estimated that *Ectropis* was responsible for somewhat more than half the flush growth destruction for the year during which the outbreak lasted. During this outbreak a build-up of tachinids was noted which finally supressed it and, presumably, held the species in check until the current outbreak commenced early in 1960. This occurred at approximately the same time throughout the Territory and was not confined solely to species affecting cacao; among others, heavy and protracted infestations occurred of noctuids and psychids on *Poinciana,* torticids on *Peltophorum,* pierids on *Cassias,* etc. As distinct from the previous outbreak, the area under cacao on the Gazelle Peninsula now comprised many thousands of acres and both *Ectropis* and *Achaea* quickly increased to epidemic proportions. Up to the time of the outbreak, the amount of cacao planted at Popondetta was negligible. However, at this juncture an extensive settlers' project was started and the area under cacao has expanded rapidly until it is now of the order of 7,500 acres. The normal process of planting cacao comprises felling the primary bush, burning the detritus and *Achaea,* and planting the shade followed by the planting of the cacao. Up to this time both *Achaea* and *Tiracola* had been recorded as incidental pests of various crops in different parts of the mainland of New Guinea from sea level up to about 6,000 ft. Following the extensive clearing and burning at Popondetta the main regrowth weeds were very suitable hosts for *Tiracola,* which was able to reach dense populations there before cacao was even planted. *Achaea* did not appear in numbers until cacao was available as a host.

The course of the outbreak has been markedly different in the two main areas of infestation. On the Gazelle Peninsula, successive generations of both species remained at a very high level until the end of 1962 and during this period extensive spraying was necessary over most of the area. On the Experiment Station at Keravat a decline in numbers of both species was observed in

October, 1962. At the same time, a distinct rise in the rate of parasitism was observed. This increased rapidly in the several subsequent generations and both *Ectropis* and *Achaea* had fallen away to insignificant numbers by March 1963, a position that has been maintained until the present time. Recovery elsewhere in the Peninsula was somewhat slower, and it was not until early in 1964 that general spraying was no longer necessary. Thus, the position on the Gazelle Peninsula at the moment is that neither species is causing material setback to the development of the trees.

It is reasonable to ascribe this decline almost entirely to the action of parasites. From *Ectropis*, two species of tachinids have been reared; *Calozenillia sp.* and *Winthemia? diversa*, the latter greatly predominating. Two species have also been reared from *Achaea; Winthemia? diversa* and *Exorista sp.* nr. *sorbillans*. The latter species is not very common and, although the former oviposits readily enough on its host, the yield of parasites is very low. In the case of *Achaea*, it is thought that egg parasites were responsible for its decline. Two species of wasps have been reared from its eggs in abundance; a scelionid, *Telenomus sp.*, and a trichogrammatid, *Trichogramma japonicum*. In hatching over several generations the former generally predominated. No egg parasites have been reared from the eggs of *Ectropis*, possibly because they are very difficult to locate being usually secreted in crevices of the shade tree, *Leucaena*. At the peak of the outbreak at Keravat, a very appreciable portion of the larvae, particularly of *Ectropis*, were taken by *Bufo marinus* as they descended to pupate.

Northern District.

The position at Popondetta is quite different. As has been mentioned, *Tiracola* had a massive start with the availability of several hosts before the cacao was even planted. *Achaea* did not assume importance until cacao was available for it and at first was not considered to be of particular importance. However, despite its late start it has been responsible for an appreciable proportion of the damage at Popondetta.

At the start of the outbreak, populations of both *Tiracola* and *Achaea* remained at high to very high levels during successive generations and, since the two species do not overlap, the trees suffered accordingly. Although precise figures are not available on this point it would appear that the succession of generations at high levels of population lasted about two years. After this, the populations levelled out considerably with peak populations occurring at irregularly spaced intervals. At the present stage of growth of the cacao at Popondetta it is variously estimated that its growth has been set back by anything from six to eighteen months at its present average age of five years. Currently the position there is that both species are still present in troublesome numbers and are capable of appearing in epidemic proportions at unspecified intervals.

The parasite position at Popondetta is not nearly as favourable as it is on the Gazelle Peninsula. In mid 1963 it appeared that the *Achaea* problem would be coped with by the action of egg parasites. At this stage what appeared to be the same species that were operating in the Gazelle Peninsula were present in appreciable numbers at Popondetta; in some areas parasitism figures of over 90 per cent. were found in the western sector; for reasons that are not apparent these figures were not maintained. The tachinid *Exorista fallax*, and the ichneumonid *Echthromorpha insidiator* have been reared from both *Tiracola* and *Achaea*, but in very limited numbers and there is no indication that they are ever likely to prove effective. No egg parasites have been reared from *Tiracola* eggs although *Trichogramma* has frequently been observed walking over them and ovipositing. Recently, an as yet unindentified tachinid has begun to operate in the Popondetta area in appreciable numbers and is achieving a hopeful degree of parasitism. It does not appear to be effective against *Achaea*, however. Predators are present in appreciable numbers in cacao in all districts where the crop is grown, but they do not appear to exert any noticeable effect.

Other Areas.

It is not proposed to go into details of outbreaks of caterpillars in other districts. In general they have been much less widespread or damaging. However, there are several interesting features of the distribution of the principal species and their importance in areas other than those where they are major pests. It has been noted that *Ectropis* was the principal species in the Gazelle Peninsula; at Popondetta it has never been of more than incidental importance. It has also been recorded in the Morobe and Madang Districts —again in low numbers. *Tiracola,* since it has been a problem at Popondetta, has been recorded on four occasions outside the mainland of New Guinea. It has been recorded on two occasions in Bougainville, once on the leguminous cover crop, *Pueraria,* adjacent to cacao interplanted with coconuts at Baniu Plantation on the northern end of the island and again in the Kieta area in a young cacao planting. In neither case was there any recurrence of the caterpillar. On two occasions also it has been recorded in two widely separated areas in New Britain—again with no recurrence. The reasons why it has not been able to persist on Bougainville and New Britain are not clear.

IMPORTANCE OF SHADE TREES.

Under natural conditions, cacao grows under primary forest. Accordingly, it is standard practice to grow it on plantations under some type of shade cover. In New Guinea this is typically *Leucaena* and it is under this shade that the caterpillar problem has been most felt. Both *Tiracola* and *Ectropis* will feed and oviposit on this shade tree. Another widely used shade is coconuts. Their use originally was probably fortuitous but has proved highly satisfactory. As soon as the caterpillar outbreaks on the Gazelle Peninsula became apparent it was noted that the conditions provided by this combination were entirely unsuitable for the development of the more important species. It is more than likely that the freedom of New Ireland and Bougainville from caterpillar attack is a direct result of this, as the majority of their cacao is planted under coconuts. Unfortunately most Territory planters of recent years have not been able to avail themselves of this method of control.

More recently, as the severity of the caterpillar problem continues to be felt, there has been an increasing tendency to plant cacao under 'bush'. Here the primary forest is selectively felled leaving a high cover of larger trees. The result is the same as with planting under 'bush'. Here the primary forest is between the top of the cacao and the lower limits of the top cover instead of, as with *Leucaena,* the tops of the cacao being continuous with the lower limbs of the shade tree. Again there is a complete absence of caterpillar damage. The same position occurs when cacao is planted under rubber. The fall-off in caterpillar population from cacao/*Leucaena* to cacao/'bush' planting is very sharp; only an occasional straggler will be found in the high cover block. As a result of the association of caterpillars with *Leucaena* shade there is an increasing tendency to remove the latter to varying degrees up to complete removal; certainly this has a depressing effect on the *Tiracola.* The effect on *Achaea* is not so clear at the moment.

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PROGRESS REPORT ON RUBBER SEED INVESTIGATIONS

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ABSTRACT

The literature on the storage of rubber, Hevea brasiliensis *seed is reviewed.*

Details are given of a series of experiments intended to determine the optimum packing methods for the preservation of rubber seed viability.

Germination figures are presented to show the changes in seed quality during different stages of the rubber seedfall, and in the clonal composition of seed produced in a young polyclonal rubber seed garden.

It is evident that seed of the clone PR 107 *is generally of poor viability, while seed of the clone BR* 2 *(female parentage) produced by young trees has apparently a low viability and is slow in germinating during the early stages of the development of the seed garden. Details are given of treatments applied in an effort to break the possible impermeability of the seedcoat and dormancy of the BR* 2 *seed.*

INTRODUCTION.

The rubber tree, *Hevea brasiliensis*, is a native of Brazil. The species was introduced into the Far East during the late 1870s and early 1880s, the expeditions of Cross to Panama and Wickham to Brazil both having taken place in 1876. Some small plantings were made by the turn of the century, but large scale plantation establishment did not commence until about 1910. The plants for these early plantings were, naturally, raised from seed. The selection of high yielding rubber trees commenced at an early date and was followed by experiments on the vegetative propagation of *Hevea*. The first handbook on the subject was published in 1918 and the "budgrafting" of buds of superior clones onto ordinary root stock became the general practice about ten years later. In view of the very considerable improvement in yields obtained from vegetative propagation, it is not surprising that little attention was paid to the rubber seed and to preserving seed viability. Although some practical methods were evolved for storing the seed for short periods, it was only following the development of the so called 'clonal' seed that some work was commenced in the 1950's and 1960's to study methods of maintaining the viability of rubber seed.

Kidd (1914) attributed the prolongation of the life of otherwise rapidly deteriorating *Hevea brasiliensis* seed to the presence of 40 per cent. carbon dioxide produced by the seed in a closed flask. He assumed that the gas will induce narcosis and a state of dormancy.

Dijkman (1951) summed up the general position by stating that *Hevea* seed loses its viability quite rapidly and that stored without protection, germination drops within a month to less than 45 per cent. He also states that reasonable viability may be maintained for a period of six to eight weeks, if the seed is packed in a mixture of damp charcoal powder and sawdust (in equal parts). The seed should be packed in layers, in cases with air-vents, the damp sawdust-charcoal mixture being in layers of at least 2 cm. between the seed.

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Maas (1950) suggests that when packing rubber seed, it must be protected from drying out. Small quantities can be sent over a distance without any additional packing material under cool conditions, such as in the cool storage chambers of ships.

Edgar (1958) mentions that it has been found that freshly gathered rubber seed can lose 50 per cent. of its moisture in three days and most of the remainder in the following ten days, and that the percentage germination curve closely follows the curve for loss of moisture. He considered that fresh ungerminated rubber seed could be packed in gunny bags without any other packing material, but such seed may be stored for a longer period in damp charcoal (adding 20 per cent. of water by weight to the dry charcoal). If germinated seed has to be kept for a longer period he recommends that it should be packed in moist sawdust in sealed tins.

Experiment work on solving some of the storage problems of *Hevea brasiliensis* seed carried out at the Rubber Research Institute of Malaya is only briefly reported in successive Annual Reports of the Institute. No comprehensive account of the experiments appears to have been published.

A small scale trial of coating fresh seed of *Hevea brasiliensis* with shellac, wax and latex concentrate indicated that there is little promise of such treatments prolonging the viability of the seed under normal storage conditions. Fresh untreated seed had a 60 per cent. germination, but failed to germinate after four, and eight weeks' storage. Treated seed gave 1-2 per cent. germination following four weeks' storage and none germinated after eight weeks (RRIM 1958).

The following year seed of the clone Tjirandji 1 was stored in polythene bags in a cold store at 40 degrees F and at room temperatures. After 12 weeks' storage, 68 per cent. of the seed germinated in the former treatment and 62 per cent. in the latter. Initial viability was 89 per cent. (RRIM 1959).

In a storage test with seed having a poor initial viability of 34 per cent. (from the February harvest), seed kept in small polythene bags at room temperature failed to germinate after one month's storage;—seed left at a temperature of 40 degrees F had a 10 per cent. germination after eight weeks. In another experiment rubber seed with an initial viability of 69 per cent. was kept for 12 weeks in polythene bags at a temperature of 40 degrees F. Germination was 60 per cent. When stored at room temperatures for the same period, germination fell to 17 per cent. The viability of seed stored in hessian bags, at both temperatures, fell below 10 per cent. after six weeks (RRIM, 1960).

It was then reported that evidence was increasing that the storage of rubber seed at a low temperature (40 degrees F) in sealed polythene bags is effective for a limited period only. A severe drop in germination was experienced in two experiments after fourteen weeks of storage. Storage at room temperatures in charcoal or sawdust having a 20-30 per cent. moisture content maintained a high germination for a longer period (RRIM 1961).

Variable germination results have been obtained with different batches of rubber seed kept in different storage conditions, in polythene bags, with and without packing material. In some trials seed stored well for up to four months when packed with moist sawdust in polythene bags and kept at room temperature (RRIM 1962).

Later experiments were concentrated on the aeration factor in rubber seed storage. Seed was stored for two months in small polythene bags with and without perforations, using sand or sawdust media with three levels of moisture content, and at 4 degrees C or ambient temperatures. It was found that the viability after storage was often much more affected by the physiological conditions of the seed at the time of collection than by the treatments. However, there was no loss of viability after two months' storage at ambient temperatures in aerated sand or sawdust. Storage at 4 degrees C resulted in germination losses ranging from 20-80 per cent. with little evidence of any effect of aeration or medium, but there was an indication that the highest moisture content, especially with sand, was the least favourable. Storage in sawdust in unperforated bags at ambient temperatures resulted in total loss of viability but seed survived in perforated bags. When using sand as a medium in the bags, perforations were of no benefit. There were also indications that the size of the container or the number of seeds in a sample may affect results, therefore results obtained from small samples may not be applicable to large scale storage (RRIM 1964).

The effect of the number of seeds per container on the viability of the seed stored at ambient temperatures was also investigated. Perforated polythene bags containing 200, 500, 900, 1,400 and 2,000 seeds were used for storage. The seed was mixed with sawdust containing 15 per cent. moisture. The moisture content was found to be excessive. Germination figures showed that after two months, viability was lower in the larger seed samples. There was an approximate 20 per cent. germination loss in sample of up to 900 seeds per bag and a 40-50 per cent. loss in bags with 1,400 and 2,000 seeds. After two months, viability decreased more markedly in the smaller samples, so that after four months' storage the loss in germination was 68-70 per cent. in all containers. In no case was there a total loss of germination (RRIM 1965).

Van Haaren (1963) reported that at Prang Besar Estate near Kajang in Selangor in Malaysia, a well known producer of polyclonal rubber seed, surplus seed is stored at a temperature of 40-50 degrees F. Under these storage conditions seed was said to maintain its viability for up to six months. Van Haaren (1963) also reported that at the Experiment Station of the Rubber Research Institue of Malaya at Kuala Lumpur, rubber seed for despatch to various parts of the country was packed in polythene bags with a few breathing holes. Ten lb. of seed per bag is mixed with an equal quantity of moist sawdust (10 lb. dry sawdust with 3 lb. of water). The rubber seed so treated was claimed to remain viable for up to three months.

Comprehensive trials on the storage of rubber seed were reported by Ong Thian Pa and Lauw Ing Koen (1963). Their results indicated the following:

(a) There is a relationship between moisture content and germination. Rubber seed with a moisture content above 20 per cent. has the best germination; the death point seems to be at 12 per cent. moisture content.

(b) Coating the seed with paraffin wax, varnish and animal glue had an unfavourable effect on the viability.

(c) Seed stored in a refrigerator in an open container did not germinate after one month's storage, while seed stored in sealed plastic bags had a germination of 88 per cent. and 80 per cent. after one and two months' storage respectively. The moisture content of the seed was considered to be the determining factor.

(d) Seed kept in 100 per cent. carbon dioxide did not germinate after one months' storage. In 50 per cent. carbon dioxide viability fell after one month from 96 per cent. to 72 per cent. in one replicate and to 17 per cent. in another.

(e) Although packing rubber seed in damp quicklime powder prevented mould development, viability declined.

(f) Seed stored in water for 30 days can be destroyed by bacterial action. The surviving seed germinates rapidly.

(g) Stored rubber seed requires an atmospheric moisture content in excess of 40 per cent. R.H. in the storage chamber.

(h) Rubber seed stored in sealed plastic bags at atmospheric temperatures suffered no decline in viability after 30 days.

(i) Further elaboration of method (h) indicated the need for some ventilation, as oxygen in the bags was rapidly exhausted and the seed perished. At the same time the hole or holes must be small enough to prevent a significant loss of moisture in the rubber seed. Provided these two conditions were met, rubber seed could be stored for 60 days at room temperatures without loss of viability.

(j) Further experiments confirmed that the successful storage of *Hevea* seed in an air-tight container is only possible if there is enough oxygen available within the container during the period of storage.

(k) Plastic bags with one or two small holes ($\frac{1}{2}$ mm to 1 mm in diameter) gave good results and the viability of the rubber seed remained unchanged after four months storage at room temperatures. The insertion of wet filter paper in the bag had a harmful effect by causing high humidity and encouraging fungal development which spread from the paper to the seed.

(l) 50-180 seeds is the optimum amount per bag.

(m) It is advisable to treat the seed with an organic mercurial fungicide.

(n) Seed of different clones had a similar response to methods of storage.

PART I

RUBBER SEED PACKING TESTS.

The Department of Agriculture, Stock and Fisheries is distributing a large quantity of rubber seed each year for planting in various parts of the Territory of Papua and New Guinea. Despite air transportation, delays frequently occur at transhipment points, which can have a deleterious effect on the viability of the seed. Therefore, simple tests were carried out to determine the efficacy of various packing methods in preventing a decline in the viability of rubber seed in the course of delays that may occur, in a humid tropical lowland environment, between seed collection and planting at the place of destination.

The seed for these tests was collected from a 30 acre area of 25 years old "Tjikadoe" seedling trees growing at the Bisianumu Rubber Centre at Sogeri in the Central District of Papua.

The following packing treatments were applied:

(1) Seed in a hessian bag.

(2) Seed in a sealed plastic bag.

Table I.—RUBBER SEED PACKING TEST 1964.

TREATMENT	No. of days after collection	No. of seed used in test	Percentage seed germinated at unpacking	Percentage germination weeks after planting				
				1	2	3	4	5
Control	2 (at 1800 ft.)	200	—	7.5	21	75	84.5	86
Hessian bag	9	100	1	1	28	57	69	79
Hessian bag + moist sawdust	9	100	8	10	55	90	94	97
Plastic bags, no holes	9	100	—	1	18	47	61	69
Plastic bags, no holes + moist sawdust	9	100	1	2	51	80	84	91
Plastic bag and few holes	9	100	—	—	46	80	83	87
Plastic bag, few holes + moist sawdust	9	100	10	10	48	65	74	84
Plastic bag, many holes	9	100	—	—	17	56	76	83
Plastic bag, many holes + moist sawdust	9	100	4	5	45	76	85	89
Plywood box + moist sawdust	9	100	2	2	59	82	87	93
Hessian bag	21	100	—	—	27	45	49	53
Hessian bag + moist sawdust	21	100	2	7	64	72	78	78
Plastic bag, no holes	21	100	—	—	78	89	90	90
Plastic bag, no holes + moist sawdust	21	100	3	10	77	84	87	88
Plastic bag, few holes	21	100	—	2	61	76	84	87
Plastic bag, few holes + moist sawdust	21	100	6	19	77	83	90	90
Plastic bag, many holes	21	100	—	—	28	59	66	67
Plastic bag, many holes + moist sawdust	21	100	5	16	83	91	93	93
Plywood box + moist sawdust	21	100	16	29	79	84	89	89

(3) Seed in a plastic bag with few breathing holes (40-50 holes).

(4) Seed in a plastic bag with many breathing holes (160-200 holes).

(5) Seed in plywood box, packed in moist sawdust.

Treatments 1-4 were divided into two groups (A) seed only and (B) seed packed in moist sawdust.

The moist sawdust was prepared by mixing 10 lb. of dry sawdust with 3 lb. of water. Approximately 1 lb. of moist sawdust was used per 100 seeds. The size of the plastic bags was 16" x 12" and the breathing holes were 6 mm. in diameter. There were 100 seeds per bag.

Two days after collection, the seed, packed as above, was taken to Port Moresby which is in the tropical lowlands and kept there under atmospheric conditions for 5 and 17 days respectively, before being returned to the nurseries for planting. A control lot of 200 seeds was planted 2 days after collection i.e. was stored for 2 days without treatment at an altitude of approximately 1,800 ft. in a cool environment.

The germination results over a five weeks' period are recorded in *Table* 1.

The above experiment indicated that the storage of rubber seed under atmospheric conditions in the tropical lowlands can result in a decline of seed viability from 86 per cent. to 79 per cent. after 7 days and to 53 per cent. after 19 days' storage. The addition of moist sawdust had improved the storability of the seed in all treatments except in the case of sealed plastic bags. It also showed that the customary method of packing rubber seed in Malaysia in moist sawdust in plywood boxes was efficient in maintaining seed viability for up to 21 days' storage. The results using plastic bags were not as clearcut as those reported by Ong Thian Pa and Laum Ing Koen possibly because (a) the shorter duration of the tests (b) the sealed bags were probably not absolutely airtight and (c) the perforations were more numerous and of larger diameter.

The experiment was repeated in 1966. Moist sawdust was obtained by mixing eight lb. of dry sawdust with four lb. of water. Two lb. of moist sawdust was used to 200 rubber seeds. The results appear in *Table* II.

Table II. RUBBER SEED PACKING TESTS 1966.

TREATMENT	No. of days after collection	No. of seed used in test	Percentage seed germinated at unpacking	Percentage germination weeks after planting					
				1	2	3	4	5	6
Control	4 (at 1,800 ft)	100	—	1	67	75	76	76	76
Hessian bag	9	200	—	—	15.5	47.0	55.5	56.5	60.0
Hessian bag + moist sawdust	9	200	6.0	22.0	47.0	52.5	56.5	58.0	60.5
Plastic bag, no holes	9	200	—	3.0	45.0	77.5	79.5	79.5	79.5
Plastic bag, no holes + moist sawdust	9	200	—	11.0	51.00	59.0	60.5	60.5	62.5
Plastic bag, many holes	9	200	—	—	20.0	58.5	65.5	66.0	66.5
Plastic bag, many holes + moist sawdust	9	200	29.5	46.5	65.5	70.0	71.0	71.0	71.5
Hessian bag	21	200	—		1.5	5.0	7.0	7.0	7.0
Hessian bag + moist sawdust	21	200	19.5	19.5	28.5	30.0	30.0	30.0	30.0
Plastic bag, no holes	21	200	—	2.5	74.0	81.5	82.0	82.0	82.0
Plastic bag, no holes + moist sawdust	21	200	—	—	26.5	29.0	35.5	38.0	40.0
Plastic, bag, many holes	21	200	—	—	13.0	24.5	29.5	30.0	30.0
Plastic, bag, many holes + moist sawdust	21	200	45.5	49.0	64.0	65.5	66.0	66.0	66.0

This experiment confirmed previous results that when rubber seed is stored in the hot humid tropics, a rapid decline in viability may take place unless special measures are taken to prevent the drying out of the seed. When the seed was packed in hessian bags only, germination declined from 76 per cent. to 60 per cent. after seven days storage in the lowlands, then to 7 per cent. after 21 days' storage, but it was possible to slightly arrest this decline by the addition of moist sawdust (which however was already dry by the time the seed was unpacked). When using plastic bags with many holes, seed desiccation took place during the period of storage, depressing the germination during the 21 day period. The addition of moist sawdust helped to maintain viability, although the sawdust was already dry on conclusion of the 21 days' storage. Rubber seed packed in plastic bags with no holes, but not sealed airtight, maintained a high level of viability even after 21 days' storage. In this treatment the addition of moist sawdust depressed the germination, possibly due to excess moisture in the bags. It is noteworthy that despite this fact, in this treatment no germination took place prior to planting inside the bags which had no punched holes, either with or without the addition of moist sawdust (the sawdust was still moist on unpacking these treatments). As against this, germination commenced in the other treatments having moist sawdust.

The above tests confirm the validity of storage practices reported by van Haaren (1963) namely that in Malaysia rubber seed for despatch was packed in polythene bags with a few breathing holes, but did not contribute any data to support some recent commercial practice in Malaysia of despatching rubber seed for export in perforated cardboard boxes without moist sawdust as a packing medium. The experiments upon which this new practice were based (private communication 1965) involved storage for four to six days, thus would probably only apply to conditions where it would be certain that the seed would reach its destination and be planted within a matter of a few days. The value of packing rubber seed in plastic bags which are not hermetically sealsed, was also indicated.

PART II — THE EFFECT ON THE GERMINATING MEDIUM.

In respect of germinating beds Dijkman (1951) recommends as the generally used method to lay out specially prepared beds in which the ground is loosened to a depth of 15 cm. Maas (1950) suggested a layer of 5 cm. of sand over ordinary nursery soil. However, in the course of raising rubber seedlings at Bisianumu, a differential effect of the germinating medium was noted. Therefore a small test was set out, using polyclonal seed imported from Malaysia, which was planted three days after despatch from Singapore.

The results are shown in *Table* III.

The above tests confirm the superiority of medium to coarse river sand over soil as a medium in germination beds and indicate that better results may be obtained by pregerminating rubber seed between two layers of wet bags (the bags to be kept moist by frequent sprinkling of water).

Table III. THE EFFECT OF GERMINATING MEDIUM.

Treatment (germinating medium)	No. of seeds in test	Percentage germination—weeks after planting					
		1	2	3	4	5	6
Soil	200	0	14.5	28.5	30.5	40.0	41.0
Sand	300	0	35.0	58.3	63.7	66.0	67.0
Bags	200	0	5.5	41.5	70.5	75.5	75.5

Table IV. GERMINATION OF COMMON RUBBER SEED.

Year	Period of seedfall	No. of seed in test	Percentage germination weeks after planting					
			1	2	3	4	5	6
1964	Early seedfall (May)	700 (400, 200, 100)	12.6	51.4	73.4	81.4		
	Peak seedfall (June)	10 x 200	8.2	76.8	90.0	92.6		
	Late seedfall (July)	2 x 200	3.0	27.5	44.7	61.2		
1965	Late seedfall (June, July)	3 x 100			14.0	19.0		27.0
1966	Early seedfall (early June)	2 x 100	0	28.0	37.0	38.5	40.5	41.5
	Peak seedfall (June-July)	5 x 100	0	31.6	65.2	74.8	77.4	79.4
	Later seedfall (July-August)	2 x 100	0	49.5	66.0	69.0	71.5	71.5

PART III — QUALITY OF RUBBER SEED DURING THE SEEDFALL.

The Department of Agriculture, Stock and Fisheries is selling considerable quantities of rubber seed each year from a 30 acre area of 25 year old trees originating from a "Tjikadoe" seedling plantation. This so called "common seed" is used for the raising of seedling rootstock for budgrafting. The seeding season varies from year to year, but occurs generally from March to July. Seed samples were taken from the above area throughout several seasons. These tests indicate that seed collected during the early and late fall has a tendency towards lower viability than seed from the main or peak fall. Typical results are shown in *Graph* I. Some of the results are tabulated in *Table* IV.

In 1965, only the seed produced at the end of the seed fall was tested due to the absence on leave of one of the authors. In 1966, seed collection was discontinued shortly after the end of the peak seedfall.

PART IV — CHANGES IN THE CLONAL COMPOSITION OF SEED PRODUCED IN A YOUNG POLYCLONAL SEED GARDEN AND THE DIFFERENTIAL GERMINATION OF CLONAL RUBBER SEED.

A polyclonal rubber seed garden was established at the Bisianumu Rubber Centre in 1958-1959 for the production of 'clonal' seed. The seed garden is 40 acres in extent and consists of the clones Tjir. 1, AVROS 157, RRIM 501, PR 107 and BR 2. The clones are randomized so as to give maximum cross pollination.

The first seed was collected from this area in 1964 when the trees were six years old. Seedfall commenced early in June and was practically finished by the end of July. The main fall occurred from 20th to 30th June. The clonal composition of the seed collected varied at different times of collection, but BR 2 predominated, particularly towards the end of the seedfall. It is evident that the BR 2 trees matured earlier and were more prolific seed producers at this early stage of the development of the garden. The clonal composition of the seed produced in 1964 is shown in *Table* V.

The 1965 seedfall was rather prolonged due to unseasonal weather conditions in 1964. Seedfall commenced near the end of March and finished in the first week of September. Flowering, which is usually during August-October, extended from August 1964, to January 1965. The main flowering was in September 1964, and all five clones flowered again during January 1965. Consequently there were two peak falls, one in April 1965, and the other in August 1965. The clonal composition (female parentage) of the seed collected during this prolonged seedfall is set out in *Table* VI.

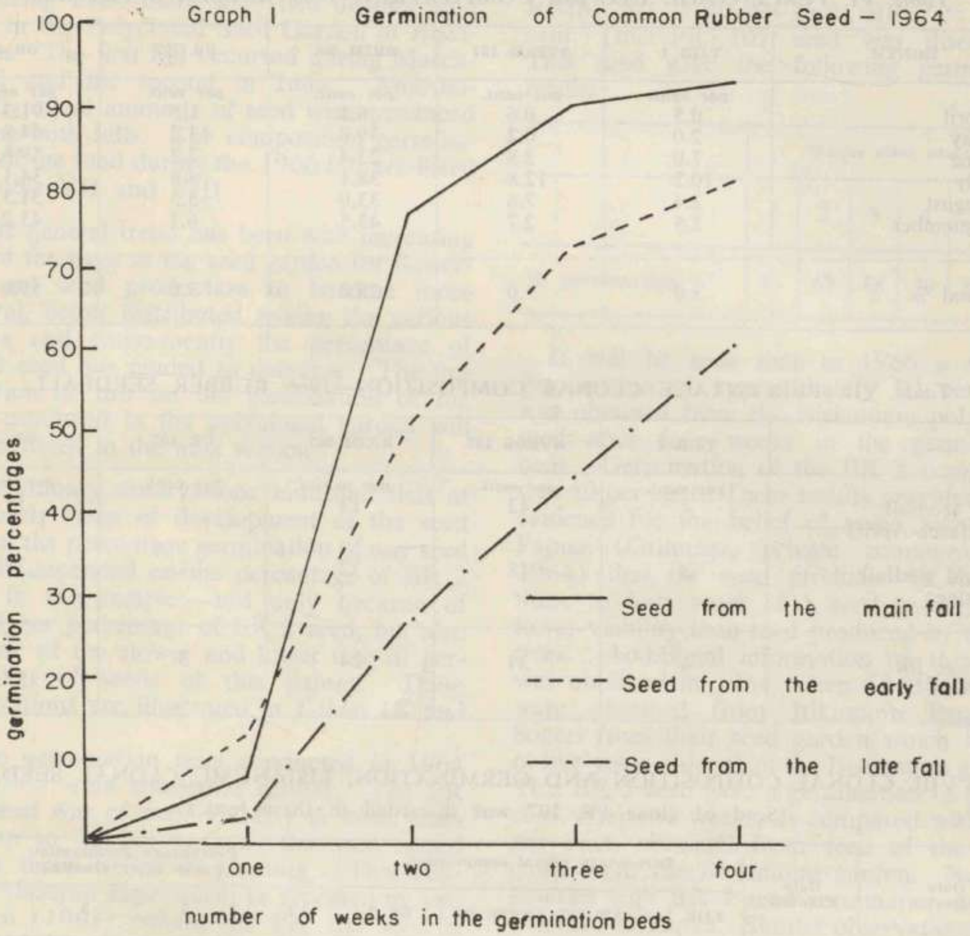

Table V. CLONAL COMPOSITION OF RUBBER SEED 1964.

Clone	Per cent. of seed		
	main seedfall (sample of 1118 seeds)	late seedfall (sample of 1928 seeds)	Average for the year (total 44,179 seeds)
TJIR 1	17.0	3.1	13.0
AVROS 157	8.0	2.6	7.0
RRIM 501	13.0	10.1	14.0
PR 107	7.0	4.2	7.0
BR 2	55.0	80.0	59.0
	100.0 per cent.	100.0 per cent.	100.0 per cent.

Table VI. PERCENTAGE CLONAL COMPOSITION—1965 RUBBER SEEDFALL.

MONTH	TJIR 1	AVROS 157	RRIM 501	PR 107	BR 2
	per cent.	per cent.	per cent.	per cent.	per cent.
April	0.5	0.6	6.1	1.5	91.3
May	2.0	0.2	39.8	13.2	44.8
June	7.0	2.8	23.4	7.2	59.6
July	10.2	12.8	38.1	4.8	34.1
August	2.4	7.6	33.0	5.5	51.5
September	2.5	2.7	43.5	6.1	45.2
Total %	3.0	5.0	28.0	5.0	59.0

Table VII. PERCENTAGE CLONAL COMPOSITION—1966 RUBBER SEEDFALL.

	TJIR 1	AVROS 157	RRIM 501	PR 107	BR 2
	per cent.	per cent.	per cent.	per cent.	per cent.
First seedfall (March-April)	4	42	13	2	39
Second seedfall (June)	4	18	37	4	37
Average for 1966	4	31	24	3	38

Table VIII. CLONAL COMPOSITION AND GERMINATION, BISIANUMU CLONAL SEED 1966.

(Seed of clone PR 107 was discarded in these tests.)

	Date Collected	Date Planted	Percentage clonal composition				Percentage germination weeks after planting			
			TJIR 1	AV 157	RRIM 501	BR 2	1	2	3	4
First seedfall	14.3.66	21.3.66	3	91	5	1	0	51	78	85
First seedfall	19.3.66	24.3.66	5	91	3	1	0	16	47	73
First seedfall	21.3.66	28.3.66	6	66	15	13	0	24	58	68
First seedfall	24.3.66	1.4.66	7	50	19	24	0	18	19	24
First seedfall	28.3.66	4.4.66	3	16	15	66	0	3	3	17
Second seedfall	2.4.66	7.4.66	2	16	10	72	8	10	18	23
Second seedfall	27.5.66	31.5.66	6	32	40	22	15	67	78	79
Second seedfall	1.6.66	6.6.66	10	20	40	30	0	39	64	65
Second seedfall	17.6.66	23.6.66	5	25	30	40	0	41	79	80
Second seedfall	30.6.66	7.7.66	4	28	38	30	0	26	51	69

During 1966 there were two distinct seed falls in the Polyclonal Seed Garden at Bisianumu. The first fall occurred during March-April and the second in June. Approximately equal amounts of seed were produced during both falls. The composition germination of the seed during the 1966 fall are listed in *Table* VII and VIII.

The general trend has been with increasing age of the trees in the seed garden for flowering and seed production to become more general, better distributed among the various clones and consequently the percentage of BR 2 seed has tended to decrease. The implication of this on the germination of the seed produced in the polyclonal garden will be discussed in the next section.

Preliminary observations indicated that at this early stage of development of the seed garden the percentage germination of any seed sample depended on the percentage of BR 2 seed in the sample;—not only because of the higher percentage of BR 2 seed, but also because of the slower and lower rate of germination of seeds of this parent. These observations are illustrated in *Tables* IX and X.

The germination tests conducted in 1964 and 1965 were somewhat similar. The PR 107 seed was of poor viability in both years and up to 75 per cent. of the seed rotted within three weeks of planting. This confirms Malayan experience, as reported by van Haaren (1963), where the PR 107 seed is removed from polyclonal rubber seed sold, as it tends to go mouldy rapidly. It is evident that the inclusion of this clone in a polyclonal garden must be due to its quality as a pollen parent. It also constitutes only a small percentage of the total seed produced.

In both years seed of the clone BR 2 was slow in germinating and generally only about 50 per cent. of the seed germinated even after eight weeks in the seedbed. There was, however, a marked improvement in 1966, in both the speed and rate of germination of seed of all the clones in the seed garden (*Table* VIII). A bulk sample of 6,062 seeds collected during the peak of the seed-fall in 1966 had a clonal composition of Tjir 1 = 6 per cent., AVROS 157 = 32 per cent., RRIM 501 = 40 per cent., BR 2 = 22 per cent. (the PR 107 seed was discarded). This seed gave the following germination results:

	Weeks after planting					
	1	2	3	4	5	6
% germination	15	67	78	79	80	81

It will be seen that in 1966 a normal germination of approximately 80 per cent. was obtained from the Bisianumu polyclonal seed after four weeks in the germination beds. Germination of the BR 2 component was 50 per cent. These results provided some evidence for the belief of some planters in Papua (Grimmer, private communication, 1964) that the seed produced in the first three to four years of a seed garden is of lower viability than seed produced by mature trees. Additional information on this point was obtained in 1964, when 50 BR 2 seeds were obtained from Itikinumu Estate at Sogeri from their seed garden which is four to five years older than the Bisianumu garden. This BR 2 seed gave a germination of 80 per cent. after five weeks, as compared with 30.3 per cent. obtained from seed of the same clone from the Bisianumu garden. But difficulties with BR 2 seed germination are not confined to Papua. Similar observations were made in Malaysia (Rubber Research Institute of Malaya, private communication, 1964). There, it was considered that the plumule does not easily pierce the seed coat of BR 2 seed and therefore cracking the seed coat or widening the micropyle would improve the rate of germination.

GERMINATION OF SEED OF OTHER CLONES.

Maas (1950) reported that seed viability depends on the genetic origin, quite apart from outside factors (such as method of storage and planting techniques). Seed of the clones included in the Bisianumu Seed Garden also exhibited widely differing viability and rate of germination.

Table IX. GERMINATION OF BISIANUMU POLYCLONAL SEED. JUNE-JULY SEEDFALL 1964.

Clone (female parent)	No. of seed in test	Percentage germination—weeks after planting							
		1	2	3	4	5	6	7	8
TJIR 1	3 x 100) 1 x 200)	1.8	27.2	57.8	68.8	50.4	84.0	86.0	87.0
AVROS 157	,,	1.0	34.8	55.2	63.4	67.2	67.5	69.5	70.0
RRIM 501	,,	1.4	41.8	69.4	81.4	84.8	90.0	91.7	92.0
PR 107	,,	0.8	21.2	30.6	32.2	32.6	33.0	33.0	33.0
BR 2	,,	0.0	1.2	18.2	25.4	34.8	46.4	52.8	57.0

Table X. GERMINATION OF BISIANUMU POLYCLONAL SEED. JULY-SEPTEMBER SEEDFALL 1965 (Summary of five tests).

Clone (female parent)	Seed in test		Percentage germination—weeks after planting			
	No.	per cent.	2 weeks	4 weeks	6 weeks	8 weeks
TJIR 1	95	10	1.0	40.0	59.0	65.0
AVROS 157	100	11	2.0	39.0	54.0	59.0
RRIM 501	209	22	0.0	31.0	49.0	57.0
PR 107	81	9	0.0	10.0	14.0	14.0
BR 2	449	48	0.0	12.0	30.0	42.0
TOTALS	934	100	0.3	22.0	38.0	47.0
Comparable figure for 1964	500	—	2.0	22.8	34.5	45.7

Table XI. PERCENTAGE GERMINATION OF SEED OF FIVE ADDITIONAL CLONES. 1964.

Clone (female parent)	No. of seed in Test	Percentage germination—weeks after planting							
		1	2	3	4	5	6	7	8
PB 5/51	300	7.0	67.6	76.3	77.0	77.3	77.6	77.6	77.6
Koitaki 1	300	0.0	5.3	15.3	26.0	39.0	49.0	54.3	58.3
PB 12/127	300	2.0	16.7	45.3	58.3	65.3	79.0	91.3	95.3
NAB 12	300	0.0	0.0	4.3	10.3	20.3	34.3	49.0	54.0
LCB 1320	300	0.0	12.0	44.0	50.7	55.0	61.0	67.3	68.0

A further check on clonal variations in seed viability was made in 1964, with seed collected from the Museum Plot No. 1 at Bisianumu. This is an eight acre plot planted in 1955-1956 comprising 24 clones, but is not planted as a seed garden. Seed was collected from five clones which were noted for their prolific seed production. Two tests were carried out (1 x 200 and 1 x 100 seed per clone). The results are shown in *Table* XI. Comparable figures for seed for the Polyclonal Seed Garden can be found in *Table* IX. It will be noted that the rate of seed germination of these clones from the Museum Plot was generally similar to that from the Seed Garden.

Table XII. BREAKING OF IMPERMEABILITY OF BR 2 SEED, 1965.

Treatment	No. of seed in test	Percentage germination, weeks after planting							
		1	2	3	4	5	6	7	8
Control	100	0	0	5	19	45	48	50	50
Micropyle roughened with file	100	0	1	42	51	54	54	54	54
Seed cracked	100	0	0	8	19	39	42	46	47
Hot water on seed left seeping 12 hours	100	0	0	0	0	—	—	—	—
BR 2 seed from Itikinumu seed garden	100	0	0	7	39	68	79	81	81

PART V — EXPERIMENTS TO IMPROVE THE GERMINATION OF BR 2 SEED BY SEED TREATMENT.

The slow and low rate of germination of seed of the clone BR 2, as reported earlier in this paper, led to experiments to try to break this apparent hard seededness or dormancy of the seed. The fact that seed of some clones was slow in germinating was recognised though not widely reported. Dijkman (1951) mentioned that : 'viable seed germinates (depending on the percentage) between 3 and 25 days. Seeds which germinate slowly, like AV 163 ill. should be pretreated by removing the micropylar cap to speed germination'. The Rubber Research Institute of Malaya (private communication, 1964) also suggested that cracking the seed coat of BR 2 seed or widening the micropyle before setting in the beds may improve the germination.

The first approach was made on the assumption that perhaps BR 2 seed had a hard impermeable seed coat which prevented the absorption of moisture in the seedbed or admitted it only rather slowly, resulting in a delayed and prolonged germination period. Seed from the August 1965 seedfall was given various treatments and planted in a sand germination bed. The results are shown in *Table* XII. Unfortunately in the second treatment (filing the micropyle) ants entered the seed through the micropyle and destroyed the embryo in 41 seeds, while rodents ate 10 seeds in the treatment with the cracked seed coat. Thus results must remain inconclusive although a promising start was made in the germination. The hot water treatment resulted in the death of the seeds, which rotted in four weeks. The BR 2 seed from Itikinumu Estate again gave satisfactory results.

The treatment of roughening the micropyle with a file was repeated, using sand and soil as germinating medium. The sand gave superior results, compared with soil. The test had to be discontinued after four weeks, due to losses from rodents and rotting of the seed (old seed). At this stage, filing the micropyle resulted in 18 per cent. germination, as against 5 per cent. in the control.

In 1966 experiments were based on the possibility that difficulties experienced in germinating BR 2 seed may be caused through an impermeable seed coat or the need for an after-ripening period. The treatments applied and germination results obtained in a series of tests are recorded in *Table* XIII.

Contrary to the general indications obtained in previous years, the results of the tests in 1966 (*Table* XIII) gave largely inconclusive results, but are given in detail in order to record the treatments applied. It is evident that both the hot water and the sulphuric acid treatment resulted in the death of the embryo. Neither rendering the seed coat more permeable by means of filing, nor exposure of the seed to the sun while enclosed in clear plastic, gave consistent results, except perhaps in one series of experiments.

Table VIII. TESTS ON BREAKING THE IMPERMEABILITY AND DORMANCY OF BR 2 SEED, 1966.

Date collecting seed	Date planted	TREATMENT	No. of seed in test	Percentage germination—weeks after planting					
				1	2	3	4	5	6
4.6.66	9.6.66	Seed for ½ hour in the sun under clear plastic	200	0	0	15.0	26.5	34.0	38.0
,,	,,	Seed for 1 hour in the sun under clear plastic	200	0	1	16.5	21.0	26.0	34.5
,,	,,	Seed for 2 hours in the sun under clear plastic	200	0	0	12.0	21.0	27.5	34.0
,,	,,	Seed for 5 min. in hot water	200	0	0	0	0	0.5	0.5
,,	,,	Seed for 10 min. in hot water	200	0	0.5	1.0	1.0	1.0	1.0
,,	,,	Seed coat filed	200	0	0	44.5	51.5	54.0	57.5
,,	,,	Control	200	0	1	54.0	65.5	67.0	74.5
7.6.66	10.6.66	Seedcoat filed	200	0	0	46.5	61.0	62.0	63.5
,,	,,	Seed soaked for 10 min. in hot water	200	0	0	0	0	0	0
,,	,,	Seed for 10 min. in hot sun under clear plastic	200	0	0.5	39.0	53.5	58.0	63.0
,,	,,	Seed for 2 min. in conc sulphuric acid	200	0	0	0	0	0.5	0.5
,,	,,	Seed for 5 min. in conc sulphuric acid	200	0	0	0	0	0	0
,,	,,	Seed for 10 min. in conc sulphuric acid	200	0	0	0	0	0	0
,,	,,	Control	200	0	0	51.5	69.0	69.5	70.5
10.6.66	17.6.66	Seed for 5 min. in the sun under clear plastic	100	0	0	24.0	33.0	38.0	40.0
,,	,,	Seed for 10 min. in the sun under clear plastic	100	0	2	26.0	44.0	48.0	50.0
,,	,,	Seed for 15 min. in the sun under clear plastic	100	0	0	15.0	30.0	35.0	35.0
,,	,,	Seed for 20 min. in the sun under clear plastic	100	0	0	24.0	38.0	47.0	48.0
,,	,,	Seed for 25 min. in the sun under clear plastic	100	0	3.0	34.0	52.0	59.0	59.0
,,	,,	Seed for 30 min. in the sun under clear plastic	100	0	0	23.0	47.0	49.0	51.0
,,	,,	Seed for 45 min. in the sun under clear plastic	100	0	0	21.0	35.0	44.0	45.0
,,	,,	Seed for 60 min. in the sun under clear plastic	100	0	0	25.0	45.0	49.0	50.0
,,	,,	Control	100	0	2.0	19.0	47.0	53.0	55.0
17.6.66	17.6.66	Seed for 15 min. in the sun under clear plastic	100	0	2.0	28.0	45.0	50.0	54.0
,,	,,	Seed for 25 min. in the sun under clear plastic	100	0	2.0	29.0	42.0	49.0	57.0
,,	,,	Seed for 35 min. in the sun under clear plastic	100	0	1.0	24.0	49.0	54.0	59.0
,,	,,	Seed for 45 min. in the sun under clear plastic	100	0	0	22.0	38.0	47.0	52.0
,,	,,	Control	100	0	4.0	15.0	31.0	37.0	38.0

Table XIII. (Continued).

Date collecting seed	Date planted	TREATMENT	No. of seed in test	Percentage germination—weeks after planting					
				1	2	3	4	5	6
24.5.66	5.7.66	Seed untreated, planted 11 days after collection	400	0	0	1.25	16.75	23.75	26.0
30.6.66	5.7.66	Seed untreated, planted 5 days after collection	400	0	0	9.75	33.25	48.75	54.5
24.6.66	5.7.66	Seed untreated, planted 11 days after collection	200	0	0	1.0	6.0	9.0	13.5
"	"	Seed coat filed, planted 11 days after collection	200	0	0	0.5	1.5	3.0	3.5
"	"	Seed for 15 min. in the sun under clear plastic, planted 11 days after collection	200	0	0	1.0	13.0	17.5	21.5
30.6.66	"	Seed untreated, planted 5 days after collection	200	0	0	9.5	24.5	33.5	39.5
"	"	Seed coat filed, planted 5 days after collection	200	0	0	11.0	23.0	32.5	40.0
"	"	Seed for 15 min. in the sun under clear plastic, planted 5 days after collection	200	0	0	13.5	33.5	48.5	51.0

NOTES

(1) In experiments planted on 10.6.66 all the seed treated with sulphuric acid became mouldy within five days; on the seventh day the seed was washed in a solution of copper oxychloride, then dipped in copper oxychloride powder before replanting. The mould re-occurred within a few days.

(2) Heat treatment in the sun was carried out by placing not more than 200 seeds in a closed clear plastic bag 15" x 12", the seed being in a single layer. Treatment was carried out between 10 a.m. and noon.

(3) The hot water treetment consisted of placing the seed in hot, but not boiling, water.

(4) In the sulphuric acid treatment the seed was washed in clear running water immediately after removal from the acid.

(5) When filing the seed coat, 'flat' side of the seed, i.e. not the micropyle, was rubbed on a metal file until the shiny dark brown colour of the epidermis disappeared.

On the other hand, it seems evident that delaying the planting of the seed from 5 to 11 days resulted in a considerable drop of the viability (20 per cent.) even in the cool environmental conditions at Bisianumu. It would seem that the somewhat poor and slow germination of BR 2 seed could not be substantially improved by making the seed coat more permeable or by providing some after-ripening treatment or period. Rather, it must be due to physiological conditions in the endosperm which corrects itself when the trees of this clone reach mature age, as evidenced by the satisfactory germination of BR 2 seed from the older trees at Itikinumu Plantation situated only a few miles from Bisianumu. A similar trend towards improved germination was observed in the BR 2 seed produced at Bisianumu in 1966. (*See Note.)

CONCLUSIONS.

(1) Seed of *Hevea brasiliensis* retains its viability for only a relatively short period following maturity and seedfall, particularly when the seed is stored or is in transit in a humid tropical coastal environment. However, the seed maintains its viability well for nine days following harvest and this period is ample to effect delivery to most centres in Papua and New Guinea requiring rubber seed, provided no undue transit delays take place. Packing the seed in moist sawdust helped reduce the decline in viability even when stored for 21 days. When using moist sawdust, it may be necessary to prevent its drying out e.g. by packing the seed in plywood boxes or in perforated plastic bags. Plastic bags without ventilation holes, but not hermetically sealed, were also effective in preserving viability; in this treatment the addition of moist sawdust appeared to be disadvantageous.

(2) Sand was a superior germinating medium to soil in nursery beds and pre-germination in wet bags produced better results.

(3) The quality of the rubber seed collected from the main seedfall period was superior to that collected either early or late during the seeding season.

(4) The rubber trees in the Bisianumu Polyclonal Seed Garden are not yet mature. During this early period the clonal composition of the seed produced varied from year to year and from season to season. Trees of the clone BR 2 are more advanced and are prolific seed producers. Therefore early seed crops were dominated by seed of BR 2 female parentage. As the trees of other clones in the seed garden are approaching maturity the percentage of BR 2 seed tends to decline.

(5) Seed of PR. 107 female parentage has only a low percentage of germination, therefore the principal use of this clone in a seed garden must be as a pollen parent. At an early stage of the development of the seed garden, seed produced by the BR 2 trees had a lower and slower rate of germination than seed of the clones Tjirandji 1, AVROS 157 and RRIM 501. There is evidence from the performance of BR 2 seed in 1966 and from another somewhat older seed garden in the Sogeri area that this is likely to be only a temporary effect.

(6) There is evidence of variation among rubber clones in the quality of the seed produced and the length of time required for germination.

(7) Tests were carried out to try to break any hardseededness or dormancy that may occur in seed of the rubber clone BR 2. Hot water or acid treatment resulted in the immediate death of the seed. Roughening the micropyle or the seedcoat with a file or cracking the seedcoat did not improve the rate of germination, but resulted in losses from ants entering the micropyle and rodent damage. Similarly, the exposure to hot sun of the rubber seed packed in clear plastic for varying periods did not produce improved germination. It is concluded that physiological conditions other than impermeability of the seedcoat or dormancy must be responsible for the slow and relatively low rate of germination of seed produced by rubber trees of the clone BR 2 during the early years of seed production.

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*NOTES.

Germination results of BR 2 ill. seed from the 1967 seedfall are becoming available at the time of writing and confirm the above observations. The germination of seed collected the Polyclonal Seed Garden at Bisianumu during the 1967 seedfall was as follows:

Seed collection date	Clone	No. of seed in test	Percentage germination—weeks after planting					
			1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks
3.3.67	TJIR 1	1674	13	60	94	96	96.4	96.4
	AVROS 157	1502	12	64	81	83	83.8	83.8
	RRIM 501	618	14	40	65	73	77	77
	BR 2	5740	0.3	16	70	80	83	84
15.3.67	TJIR 1	170	0	44	84	87	87	87
	AVROS 157	961	2	84	87	87	87	87
	RRIM 501	954	6	94	96	96	96	96
	BR 2	6806	0.1	15	42	45	46	51
18.3.67	TJIR 1	92	0	16	82	85	87	87
	AVROS 157	507	0.5	60	85	86	86	86
	RRIM 501	538	0.9	78	96	96	96	96
	BR 2	4347	0.2	3	68	79	84	85
5.4.67	polyclonal sample	100	9	39	60	62	64	64
11.4.67	polyclonal sample	100	19	70	84	89	89	89

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RAT BAITS INCORPORATING PARAFFIN WAX

Rats are an agricultural pest of some consequence in Papua and New Guinea and have been fairly serious in Bougainville in the last two or three years. The main crops affected have been cacao (damage to pods) coconut (damage to developing fruits) and food crops (destruction of starchy roots and tubers). Damage to coconut has not generally been so serious as is reported from many other countries.

Although a number of highly effective poisons are available, a major problem in control of rats in the field has been that of preserving baits from weather damage. Use of bamboo containers has proved successful, but is laborious. In Jamaica, this problem was attacked by the incorporation of conventional rat baits in paraffin wax and the method was reported to be highly successful (Smith 1965). Blocks of bait prepared in this way proved highly attractive to rats on first exposure, but subsequent mould growth reduced their attractiveness for a period. Later, the mould dried off and baits again proved acceptable. Careful observations showed very great reduction in rat damage to coconuts when the wax baits were scattered through palm groves.

A number of trials of this baiting technique have been made in Papua and New Guinea. Although no formal experiments have been conducted, observers have reported that baits were readily eaten by the rats and crop damage was very substantially reduced. The method can therefore be recommended as probably the cheapest available for control of rats in the field.

The following basic recipe was used for preparation of baits in most cases.

- 1 lb. 0.5 per cent. "Warfarin" (or 0.08 oz. 100 per cent. "Warfarin")
- 10 lb. wheatmeal
- 1 lb. sugar
- 7 lb. paraffin wax

Dry ingredients were mixed together and stirred into melted commercial grade paraffin wax. Temperature of the wax was kept as low as possible to avoid damage to the warfarin. The mixture was poured into trays and broken into lumps (about two inch cubes) after setting. Active ingredient in these baits was "Warfarin" (3- (alpha-acetonylbenzyl) -4-hydroxy coumarin) an anti-coagulant which causes death through internal bleeding. Apparently satisfactory results were obtained also with baits incorporating "Raticate" (containing "Shoxin": 5-(alpha-hydroxy-alpha-2-pyridylbenzyl) -7-(alpha-2-pyridylbenzylidene) norborn -5-ene-2, 3 dicarboximide) at recommended levels. This material is more expensive but could perhaps be preferred if there were any danger of other animals being poisoned by the baits ("Shoxin" is a poison highly specific to rats).

Apart from the active ingredient and use of wax to protect against weather damage, the composition of the baits is of no importance so long as they are attractive to rats. This will be influenced by the availability of alternate food sources. Any meal or crushed grain could be substituted for wheatmeal, and fish, meat or fat could be added to increase the attractiveness of the baits if necessary. Commercial prepared rat bait mixtures could be incorporated in wax for field use, if desired.

Quantities of bait required would also be influenced by the availability of alternate food sources. Rates of 5-6 blocks of bait per acre were reported to give effective protection for about two years in Jamaica coconut groves. Experience in Bougainville has indicated that at least ten baits per acre are needed in food gardens.

REFERENCE.

SMITH, R. W. (1965). "Rat Damage" *Fifth Rep. of Res. Dept. Coconut Industry Board Jamaica*, p. 24.

PETIOLE DISEASE OF COCONUT IN PAPUA

DOROTHY E. SHAW* AND
C. BOOTH†

ABSTRACT

A disease with dark brown lesions leading to frond break of coconut in Papua, caused by Anthostomella cylindrospora, *is described. The control measures adopted against the disease, perhaps combined with a drought, have to date prevented any further occurrence of the condition. The area is being kept under close surveillance.*

INTRODUCTION.

IN early August 1965, specimens of diseased coconut petioles were collected on a coconut plantation in the Gulf District of Papua by Mr. A. E. Charles and the owner of the plantation. The latter stated later in correspondence that the condition appeared to be confined to young palms, 538 being affected in the main block. Of these all except two were affected in the lower fronds only; the two exceptions were badly affected in all fronds and even the new centre fronds were breaking. The owner further stated that young palms in the "Abuku" block (about one mile from the main block) were not badly affected at the time—only a few slightly affected areas comprising 95 palms had been found.

SYMPTOMS.

The condition involved infections of coconut leaf petioles with lesions leading to frond break (*Plate* I).

The lesions were dark brown, from a centimetre long to over 30 cm. when coalesced, at first nearly circular, later more angular (*Plates* II and III). A fine line a few millimetres outside the edge of the lesion surrounded some young lesions (*Plate* III). The lesions were more extensive on the upper (adaxial) surface than on the lower surface. The surface of most lesions showed slight blistering with some depressions. Advanced lesions caused a collapse of the tissue resulting in a bend in the petiole leading to frond break, as shown in *Plates* I and II. The leaflet midribs and the blades were not affected in the specimens examined.

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Plate I.—Crown of 8-year old coconut showing (a) brown lesions and break in petiole and (b) small depressions on undersurface of petiole.

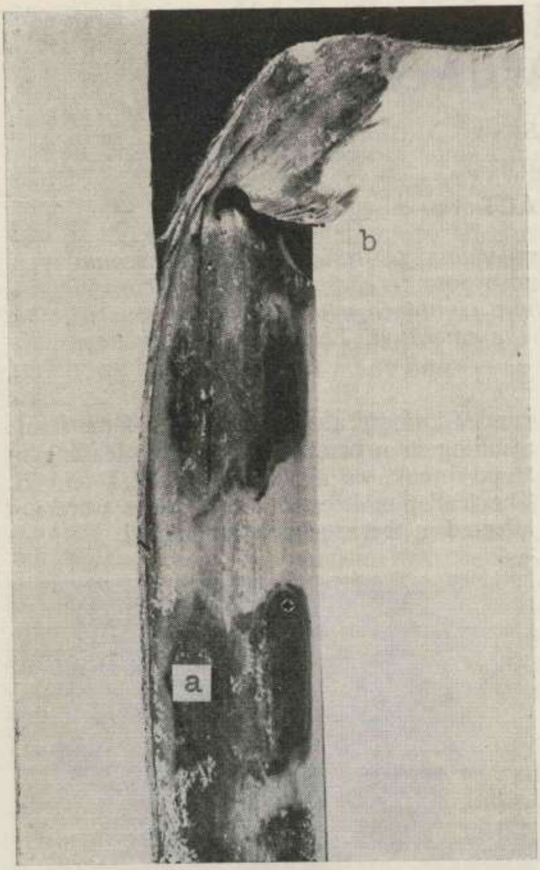

Plate II.—Coconut petiole showing (a) dark brown lesions and (b) petiole collapse at site of advanced lesion.

The fungus permeated the tissue of the coconut petiole, especially the parenchyma. In advanced lesions the hyphae became congregated and eventually formed a very dark brown stromatic tissue immersed in the host tissue. The deeply embedded locules were lined with ascogenous hyphae, paraphyses and immature asci. Ascospores were found free in the locules as well as extruded on the surface.

EXTRUSION OF SPORES.

When first received from the field the lesions on the petioles were covered by a fine deposit of spores, but during the next few days masses of spores were noticed building up on the surface of the lesions in the laboratory (*Plate* IV). Later the specimens were moved to a position undisturbed by air movements, and then cirri extruded from many small circular openings about 0.5 mm. wide or less in the surface of the lesion.

One lesion was placed under the stereomicroscope and the extruding spores were kept under continuous observation. The cirri did not resemble the coiled tendrils of some species of Sphaeropsidales but appeared as slightly stiff irregularly jointed fragile brown strings comprising longitudinal rows of spores about six or so spores wide, all loosely adhering and not moulded together as in slimy pycnidial cirri. When the stick or stiff string of spores reached a certain length—perhaps

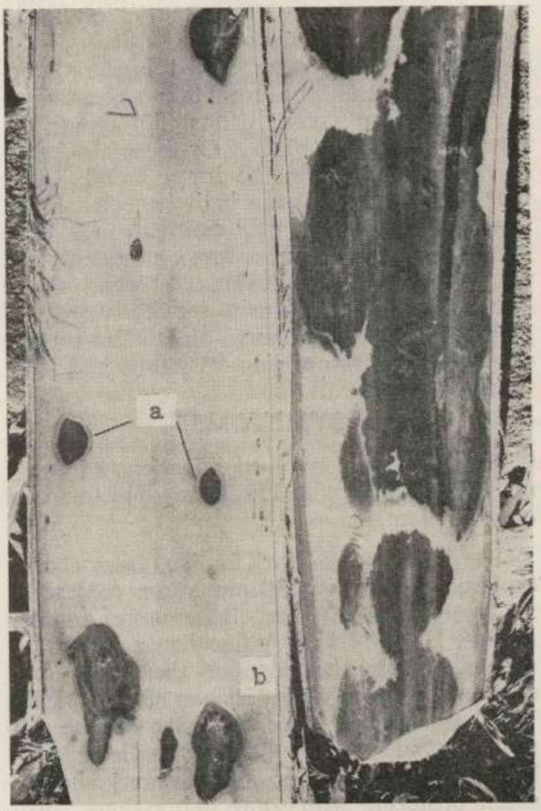

Plate III.—Upper surface of coconut petiole showing different stages in the development of lesions. Note (a) fine line around younger lesions and (b) spore dust around some lesions.

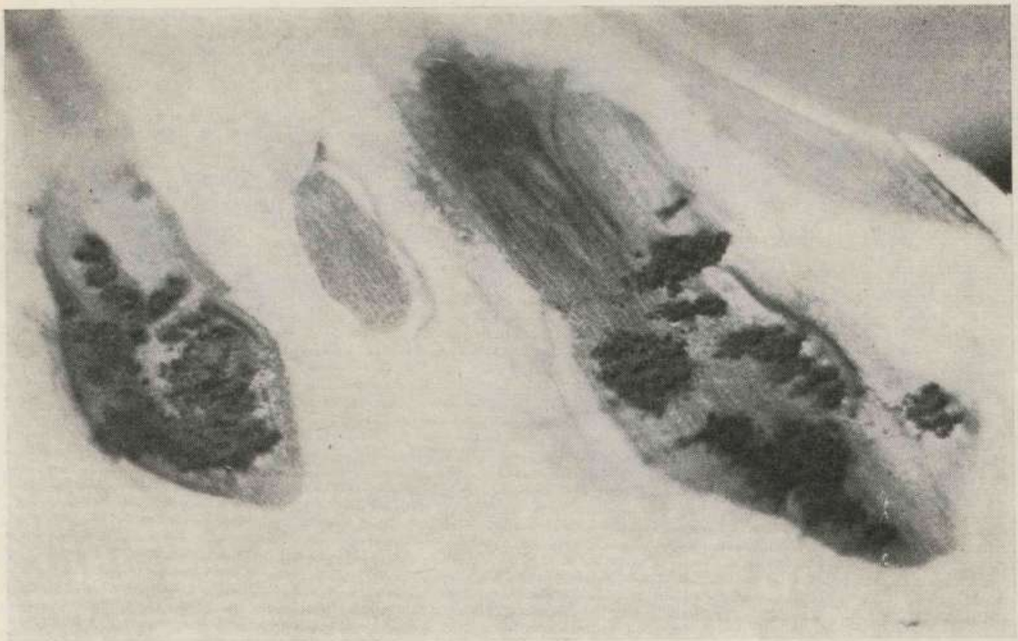

Plate IV.—Ascospores massed on surface of lesions of coconut petiole.

over a centimetre or more long—it collapsed under its own weight, and fell on to the surface of the substrate with the spores still more or less in position. Many such strings issued out of one exit and fell in lines radiating from it, the position of the lines being determined by the angle of the substrate. *Plate* V shows the deposit patterns of spores extruded in cirri from the lower surface of the petiole while cirri ex-

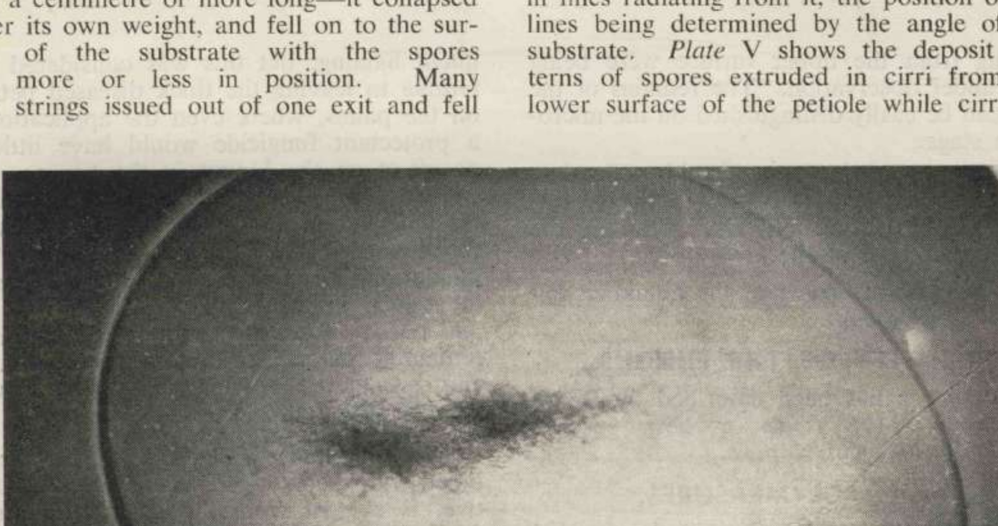

Plate V.—Deposit of ascospores in cirri on miscroscope stage in the laboratory.

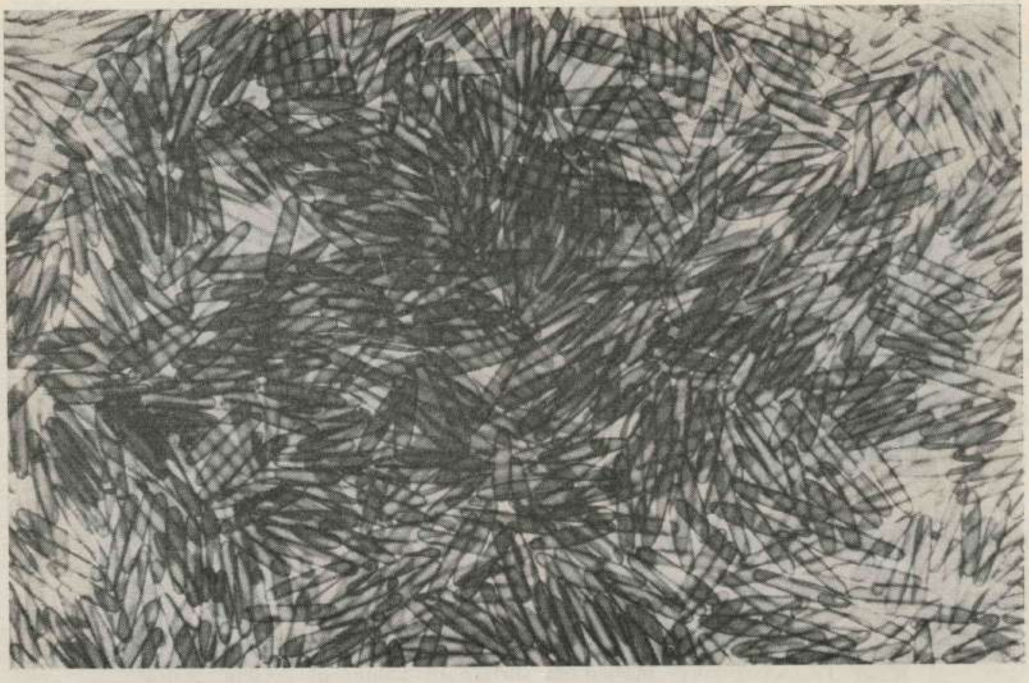

Plate VI.—Abundant ascospores deposited on slide from lesion. x 300.

truding from the upper surface were being kept under observation. The remains of the cirri can be easily distinguished on the microscope stage.

The spores of the fungus in this collection, therefore, were passively, not actively, dispersed by extrusion of "dry" cirri in the relatively still air of the laboratory.

Plate VI shows some of the abundant extruded ascospores.

IDENTITY OF THE FUNGUS.

The fungus has been described by Booth and Shaw (1967) as a new species, *Anthostomella cylindrospora.*

CONTROL MEASURES.

Measures to control the disease carried out by the owner involved the cutting off of diseased fronds which were then hauled away from the coconut area by tractor and trailer, and burnt. It was realised that spores would be spread during the cutting off and subsequent hauling, but this was considered preferable to leaving the thick diseased petioles on the palms, where even the application of a protectant fungicide would have little or no effect on the fungus in the tissues. Because of the drought being experienced at the time, the planter considered it inadvisable to attempt burning in the vicinity of the plantation. The two badly diseased palms mentioned in the Introduction were cut out and burnt. After the diseased fronds on the remaining palms had been lopped, removed and burnt, the crowns still standing were sprayed with fungicide.

That the above treatment, perhaps combined with the drought, was apparently effective, is evident from the owner's letters of 26th April 1966, and of 19th September, 1967, in which he stated that up till that time (i.e., 25 months after the treatment), no sign of the disease had occurred since the control measures had been carried out. He considered that the fungus may have been able to spread in the plantation because of the weakened condition of the palms due to the severe drought.

The area is being kept under close surveillance in order to detect any future outbreak.

Planters throughout the Territory are requested to notify H.Q. immediately if a similar condition is noticed on their coconuts.

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ACKNOWLEDGEMENTS

The owner of the plantation is thanked for reporting the condition, for the prompt measures taken to control the disease and for his continued surveillance of the area. The assistance of Mr. A. E. Charles in bringing the specimens to Port Moresby in good condition and for *Plate* I is gratefully acknowledged.

REFERENCE

BOOTH, C. AND SHAW, DOROTHY E., (1967). *Anthostomella fusispora* sp. nov. and *A. cylindrospora* sp. nov. on *Cocos nucifera*. *Papua and New Guinea agric. J.* 19: (2). 94-98.

ANTHOSTOMELLA FUSISPORA SP. NOV AND A. CYLINDROSPORA SP. NOV. ON COCOS NUCIFERA

C. BOOTH* AND

DOROTHY E. SHAW†

ABSTRACT

Anthostomella fusispora *sp. nov. and* A. cylindrospora *sp. nov. are described. The former was recorded on coconut in Malaya and New Caledonia and the latter on coconut in Papua.*

The two species described herein differ from previously described species of *Anthostomella*. In some respects their morphological characteristics are atypical of the genus, particularly with regard to their large locules and very limited clypei. These characters, however, are assumed to be adaptive features to their specific habitat on the rachis of coconut palms. The presence of a stroma surrounding the perithecial wall, the apically free paraphyses and the presence of periphyses lining the schizogenously formed ostiole are, together with the brown amerospores, characters of the Xylariaceae in general. The immersed uniloculate perithecia place them in the genus *Anthostomella*.

Anthostomella fusispora sp. nov.

The disease on the axis of coconut fronds is visible as extensive and irregular raised areas of the epidermis which is sparsely covered with black dots marking the position of the clypeus and ostiole. The raised areas are due to the formation of black stromata in the ground parenchyma below the outer one or two rings of vascular bundles. Growth of this extensive stroma begins after the dark mycelium from the point of infection has ramified both inter- and intra-cellularly through the outer parenchyma of the axis. Ground parenchyma cells are penetrated through the pits in the cell walls and hyphae normally 3-4u wide narrow to approximately 1u wide to penetrate these pits. Initially small aggregations of thick walled globose cells form a pseudoparenchyma between the vascular bundles and as this increases in size a schizogenously formed cavity develops to form the locule. Growth of the stroma tends to continue until it meets the outer wall of an adjacent stroma developing from another centrum. Between the two locules the walls merge and form what appears to be a pillar of elongated cells. At this stage the stroma has occupied the available space between the outer and inner vascular bundles. The locules are oblong in section and lined with the wall of the perithecium which consists of several layers of thin-walled cells.

In the central region of this curiously shaped locule the upper cells of the stroma grow outwards to form a column which finally ruptures the epidermis and forms a small darkened region around the ostiole. The ostiolar canal develops through the centre of this cone of cells and becomes lined with periphyses. (*Plate* I).

The asci develop from the basal region and grow upwards between the abundant paraphyses. They are unitunicate, clavate and have a thin wall without an apical ring. They measure 60-85 x 14-20u and possess eight obliquely distichous ascospores.

The ascospores, initially hyaline, soon become straw coloured to light brown; they are smooth, broadly fusoid and occasionally slightly wider above the central region, aseptate and measure 28-37 x 8.5-11u.

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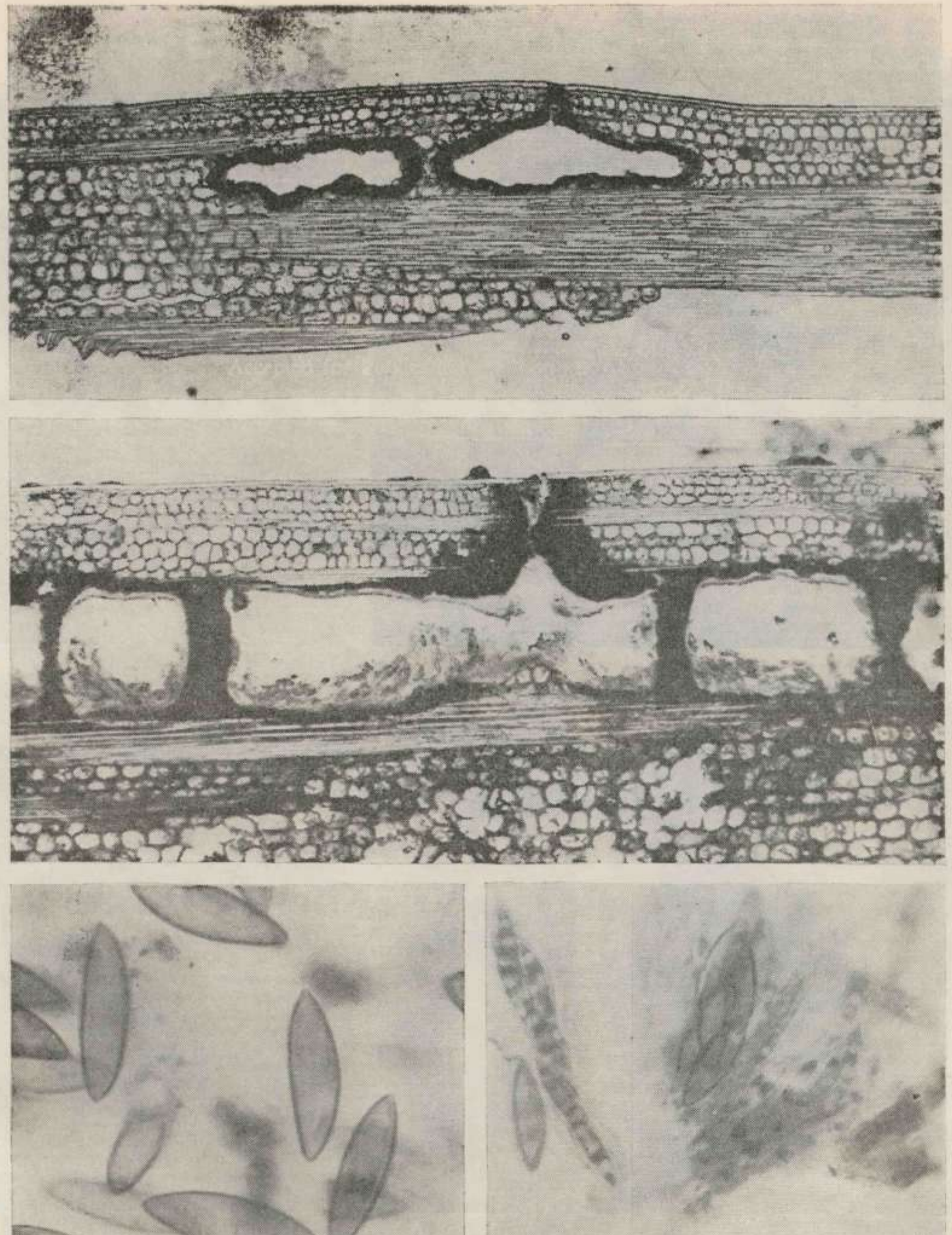

Plate I.— *A. fusispora.* Top: Young perithecial stroma. x 70
Centre: Mature perithecial stroma. x 70
Bottom Right: Asci. x 500
Ascospores. x 800

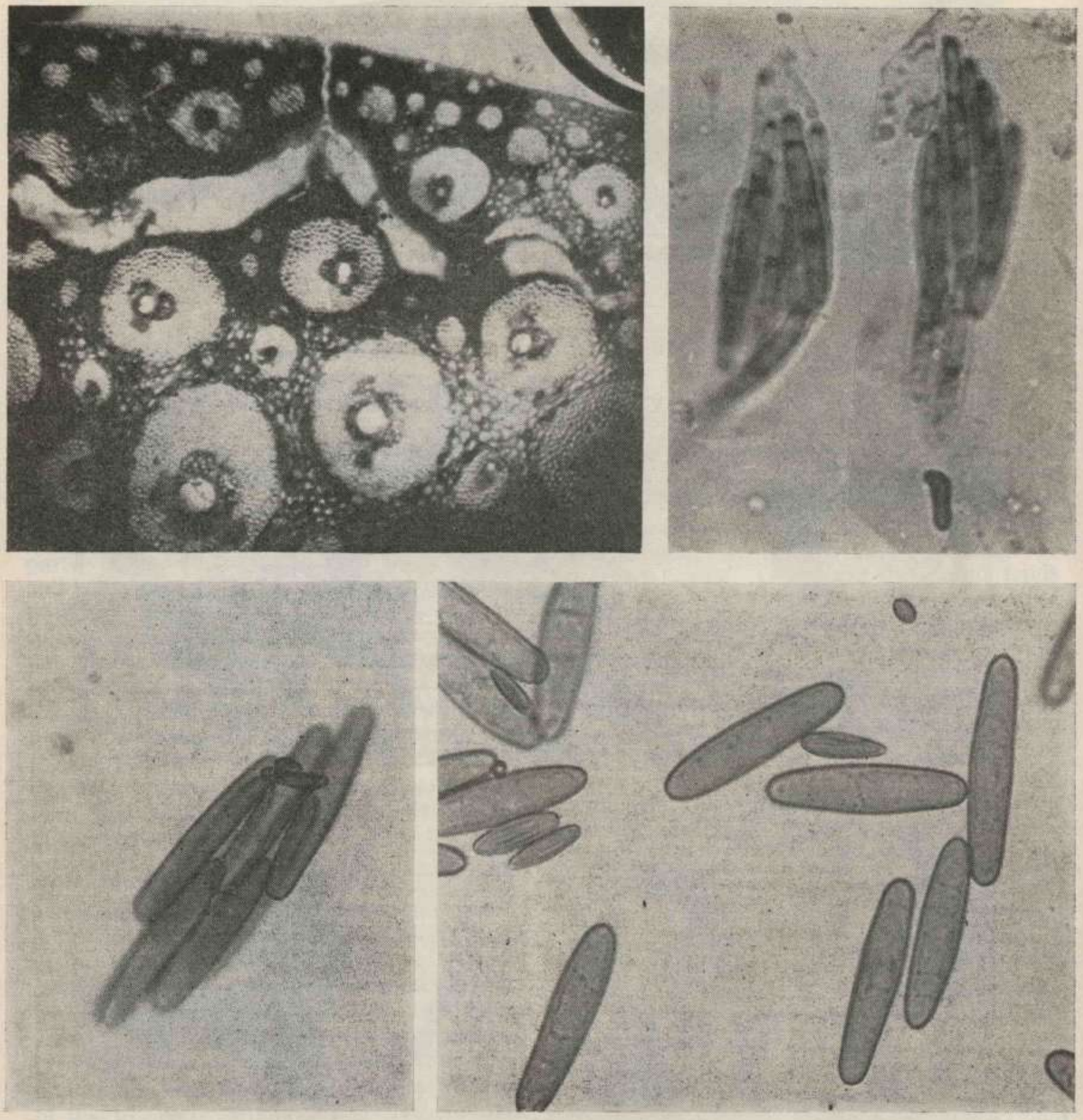

Plate II.—*A. cylindrospora.*

Top Left: Dense stromatic tissues and developing locule. x 40

Top Right: Immature asci. x 650

Bottom Left: Ascus contents with three diminutive ascospores. x 650

Bottom Right: Mature ascospores together with diminutive or abortive spores. x 650

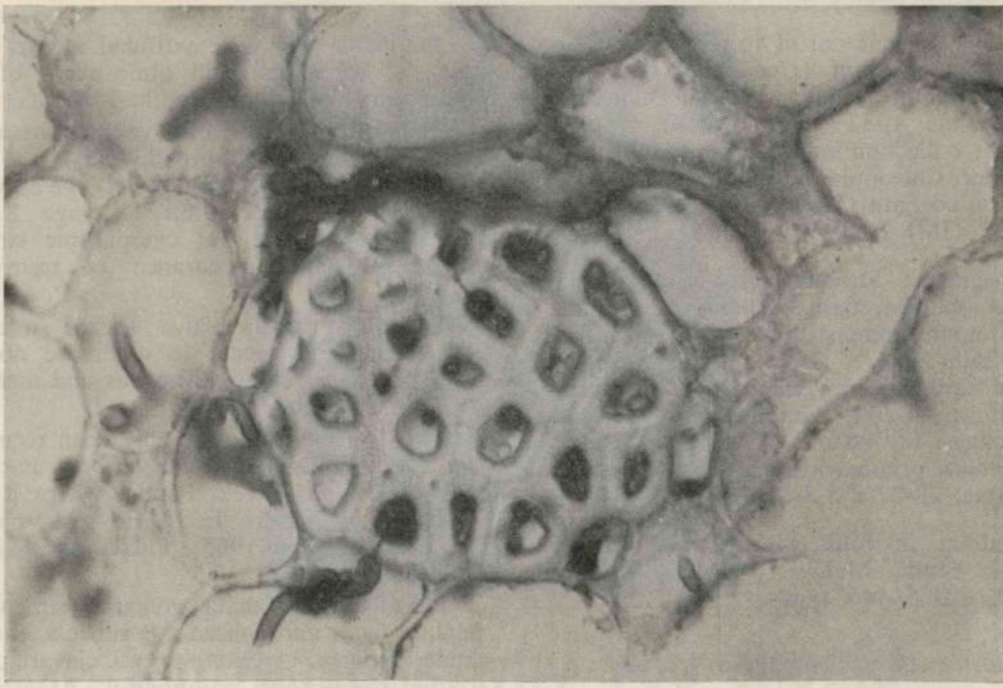

Plate III.—*A. cylindrospora.*

Top: Hyphae in one of the small bundles of fibres. x 500

Bottom: Inter- and intra-cellular hyphae in parenchyma cells. x 700

The type material of this species was collected on coconut (*Cocos nucifera* L.) at Perak South, Malaya, A. Johnstone, June 966, June 1953 (IMI 54446) type. A further collection was made by B. Huguenin in New Caledonia during December 1963, also on coconut (Herb. I.F.O. Noumea, N.C. 63212 (IMI 104089)).

Diagnosis: Stromata gregaria, subepidermalia, oblonga, nigra, carbonacea. Perithecia in stromate immersa, oblonga, 1 mm. longa, 200-250u alta. Asci unitunicati, clavati, apice rotundati, brevissime stipitati, octospori, 60-85 x 14-20u, paraphysati. Ascosporae distichae, fusoidate vel oblongo-fusoideae, continuae, primum hyalinae deinde brunneae, guttatae, 28-37 x 8.5-11u.

Habitat in foliis vivis *Cocos nuciferae*. Perak South, Malaya. A. Johnston, June 1953, IMI 54446, typus.

Anthostomella cylindrospora sp. nov.

The fungus causes dark brown lesions from one to 30 cm. long when coalesced on the surface of the petiole and permeates the underlying tissue. The hyphae are brown, 3-5u wide but narrowing to 1u or less when passing through pits in the cell walls; they are inter- and intra-cellular and occur in the parenchyma (*Plate* III) and to a less extent in the xylem and fibres (*Plate* III). An extensive stroma is developed with a schizogenously formed cavity to form the locule which occasionally bisects the bundles of fibres, as shown in *Plate* II. The locule is lined with asci and paraphyses.

The asci are unitunicate but the discharge mechanism in this collection appeared to be nonfunctional, the ascus wall disintegrating soon after the formation of the six to eight ascospores. After liberation of the ascospores in the locule they were extruded as cirri from the ostiole in the still atmosphere of the laboratory (Shaw and Booth, 1967).*

The ascospores are yellow-olivaceous, smooth, cylindrical to broadly ellipsoidal with rounded ends and measure 38.8-47.2 (average 43.2u) by 6.8-9.6u (average 8.5u). They are aseptate but cytoplasmic strands often give the appearance of transverse pseudo-septa.

Diminutive or abortive spores, oval to cylindrical, may occur in otherwise normal asci; they are yellow-olivaceous and measure 9-22.5 x 2.8-5u.

This fungus has so far only been recorded on the petioles of coconut (*Cocos nucifera* L.) at Ou Ou Creek, Papua, where it was collected by Messrs. E. R. Edwards and A. E. Charles, 4.viii.1965, TPNG 4659 (IMI 114957).

Diagnosis: Stromata gregaria, subepidermalia, nigra, carbonacea. Perithecia in stromate immersa. Asci unitunicati, clavati, apice rotundati, 6-8 spori, paraphysati. Ascosporae subdistichae, cylindriae, continuae, brunneae, utrinque rotundatae, 38.8-47.2 x 6.8-9.6u.

Habitat in foliis vivis *Cocos nuciferae*, Ou Ou Creek, Papua. coll. E. R. Edwards et A. E. Charles, 4 viii. 1965, TPNG 4659 (IMI 114957), typus.

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* Unsuccessful attempts were made to germinate the ascospores found on the surface of the lesions, as well as the newly exuded spores and spores from the locules, on PDA and in water at Port Moresby and on agar and under "black light" at the C.M.I.

ACKNOWLEDGEMENTS

Our thanks are due to Mr. F. C. Deighton for correcting the Latin diagnoses and to Mr. Fry for *Plate* I.

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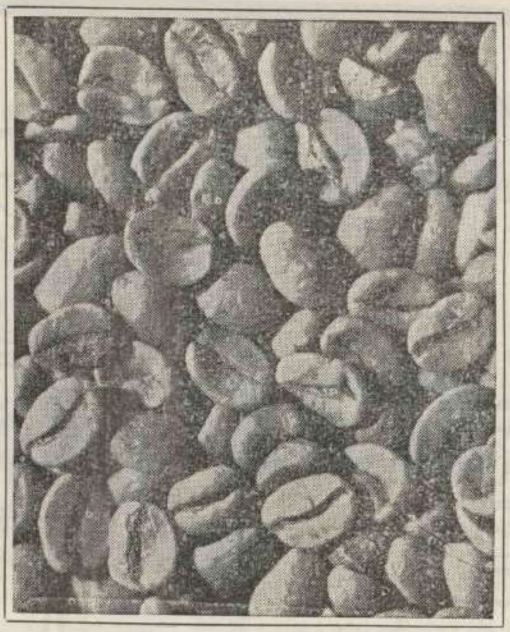
SHAW, DOROTHY E. AND BOOTH, C., (1967). Petiole disease of coconut in Papua. *Papua and New Guinea agric. J.* (2): 89-93.



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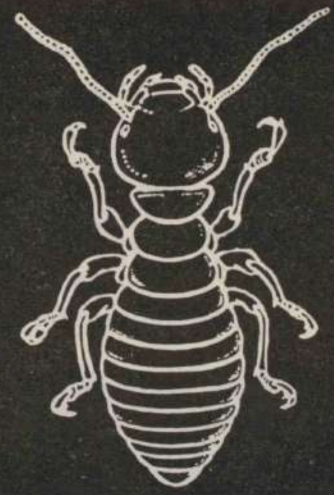

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