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

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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

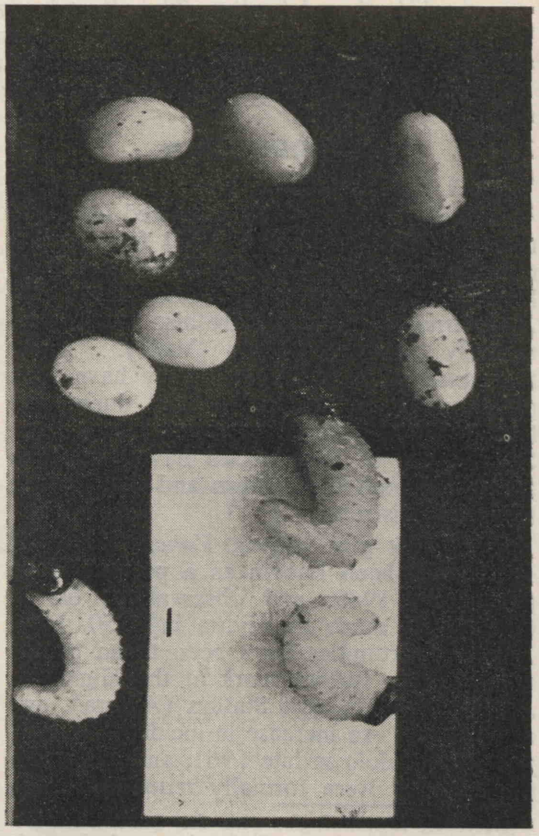


Plate I.—Eggs and first stage larvae of *V. oberthuri*. Foreign material is adhering to some of the eggs. (x 4.0; inset line = 1mm.)

[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.

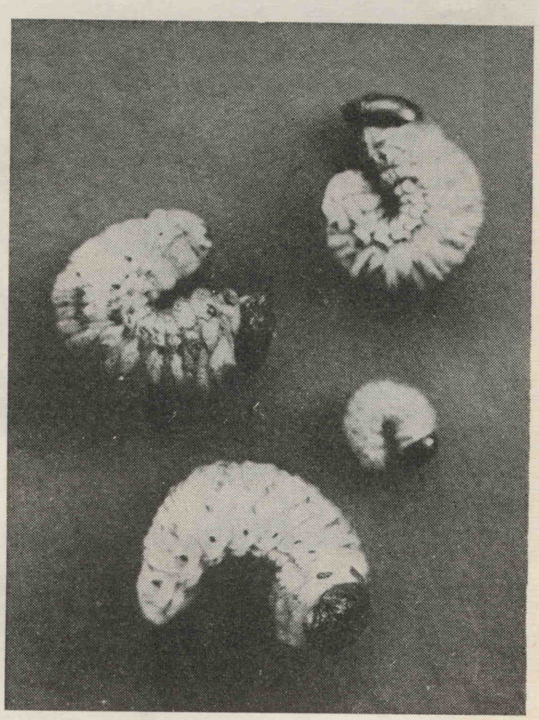
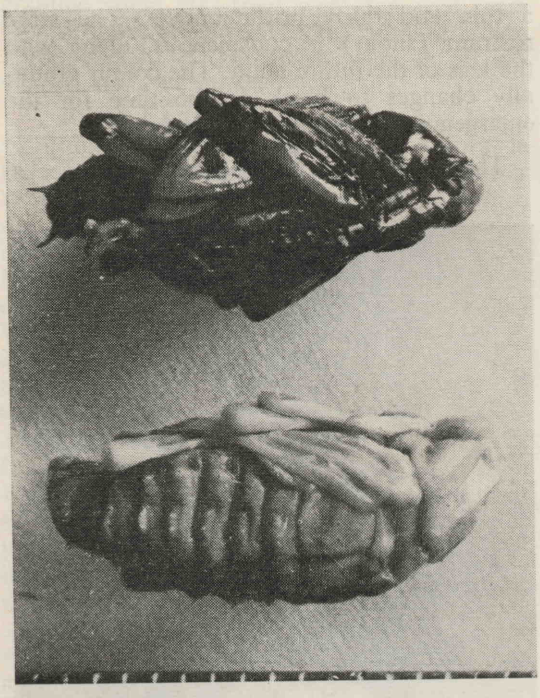


Plate II.—Final stage larvae of *V. oberthuri*. Note the dark coloured head capsule and the wide variation in size and the spiracles on the lower larva. (x 2.0 approx.)

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.)

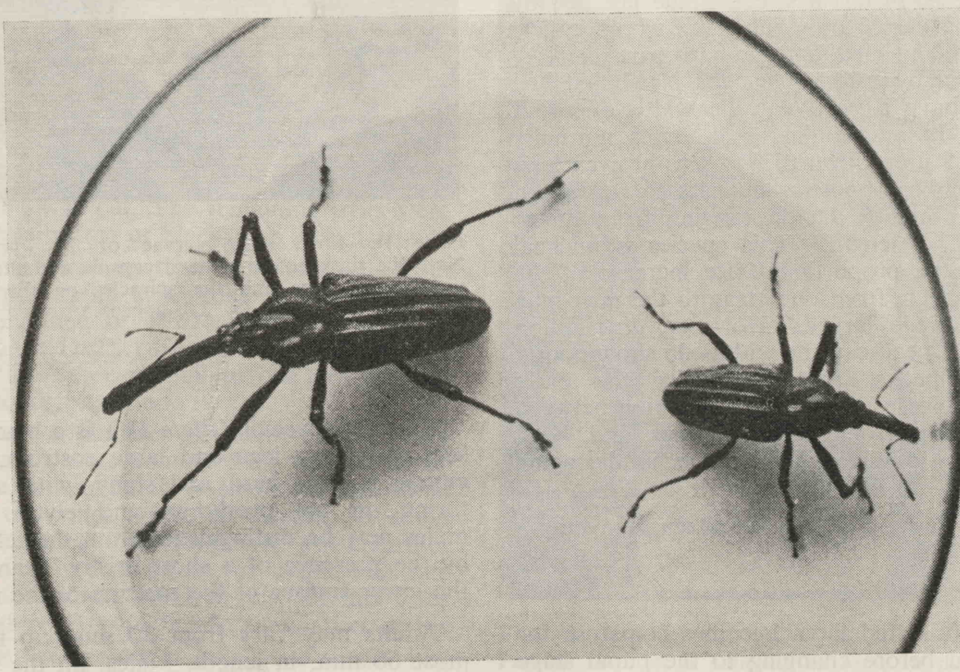


Plate IV.—Adult black pine weevils *V. oberthuri*. (Natural size; in round glass dish.)

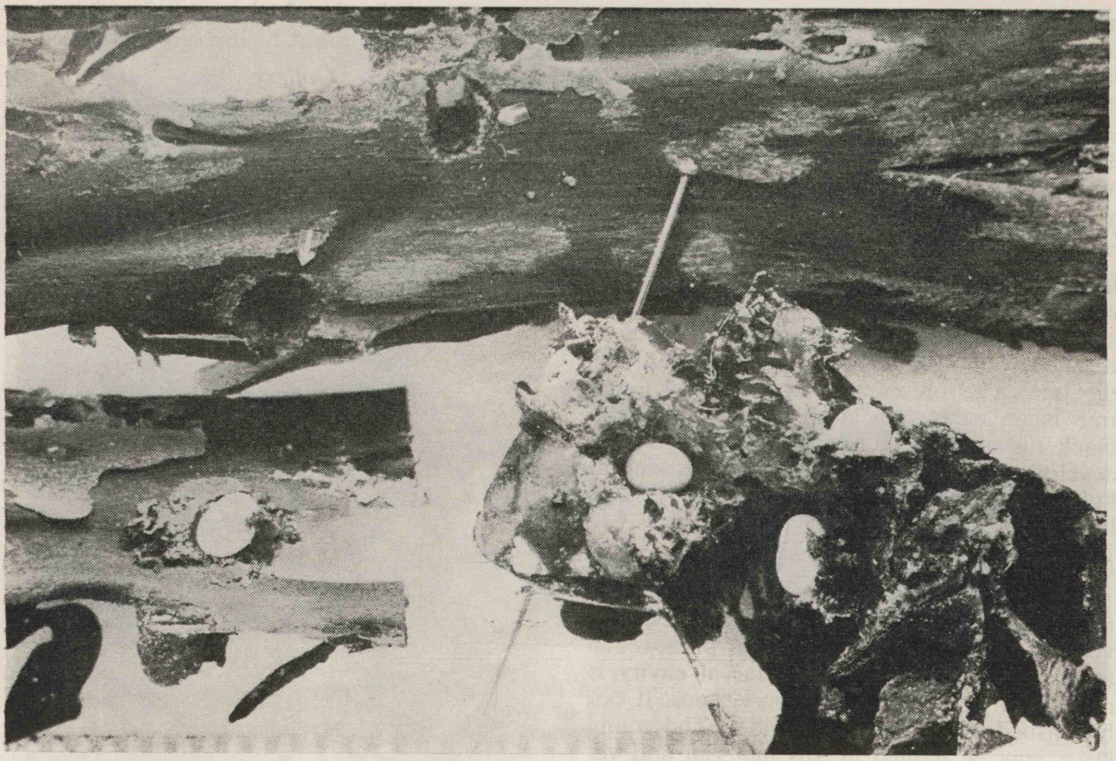


Plate V.—Eggs of *V. oberthuri* on inside of loose Hoop pine bark (lower left) and on inner side of resin mass (right). Egg sites are on the bark (above — 2 pointers) with eggs removed to show chewed cavity sealed on the outside with masticated bark. (x 2.0 — Scale units 1.6 mm.)

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 ti-tree', 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

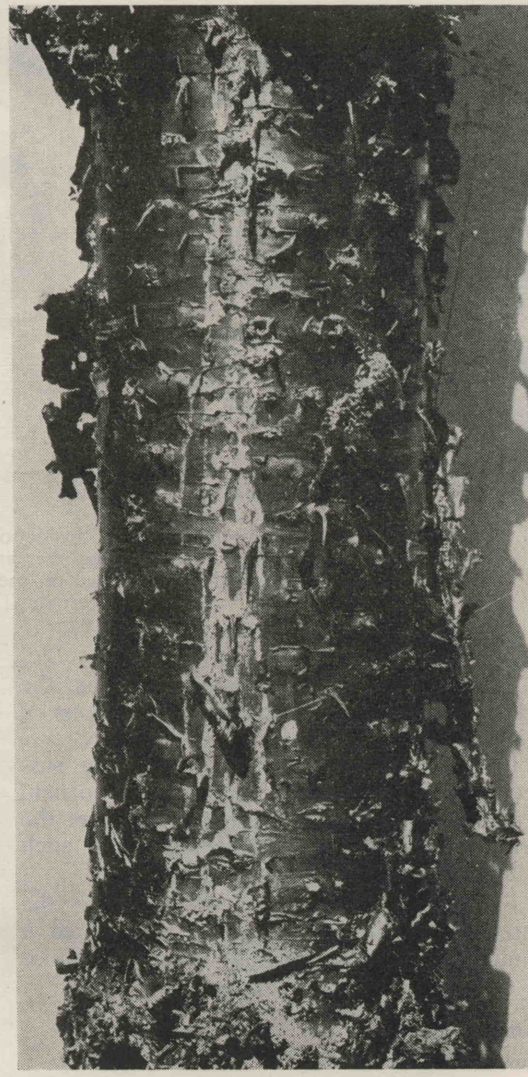


Plate VI.—Section of trunk of dead Hoop pine tree with *V. oberthuri* infestation showing old resin flow marks and ventilation holes.

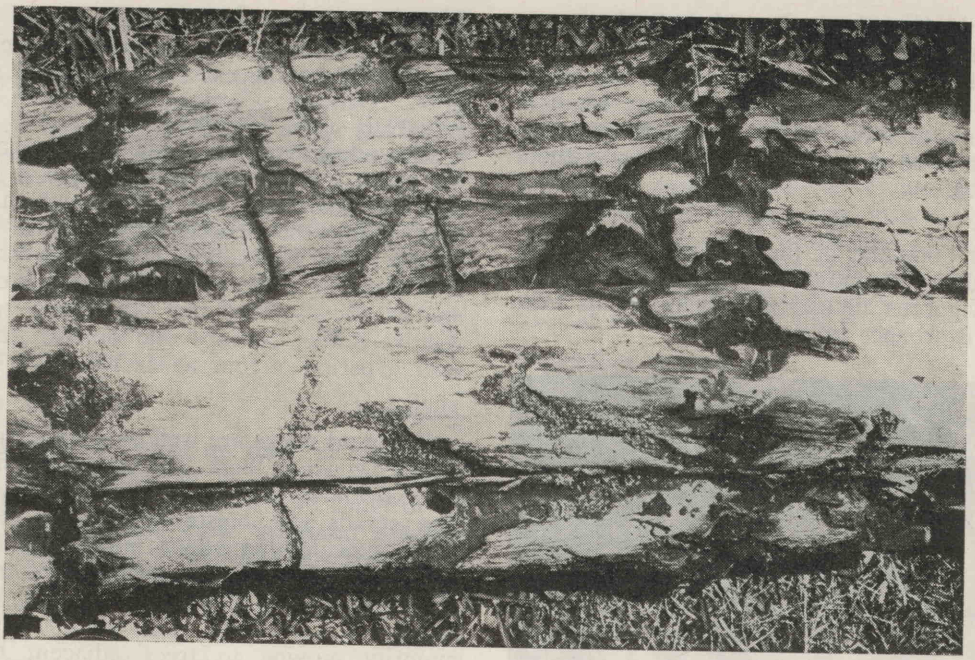


Plate VII.—Section of Hoop pine trunk with bark folded back to show damage to bark and wood by larvae of *V. oberthuri* (Tree as in Plate VI). Ventilation holes (upper centre) and an exit hole (lower centre) are showing in the bark.

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 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.

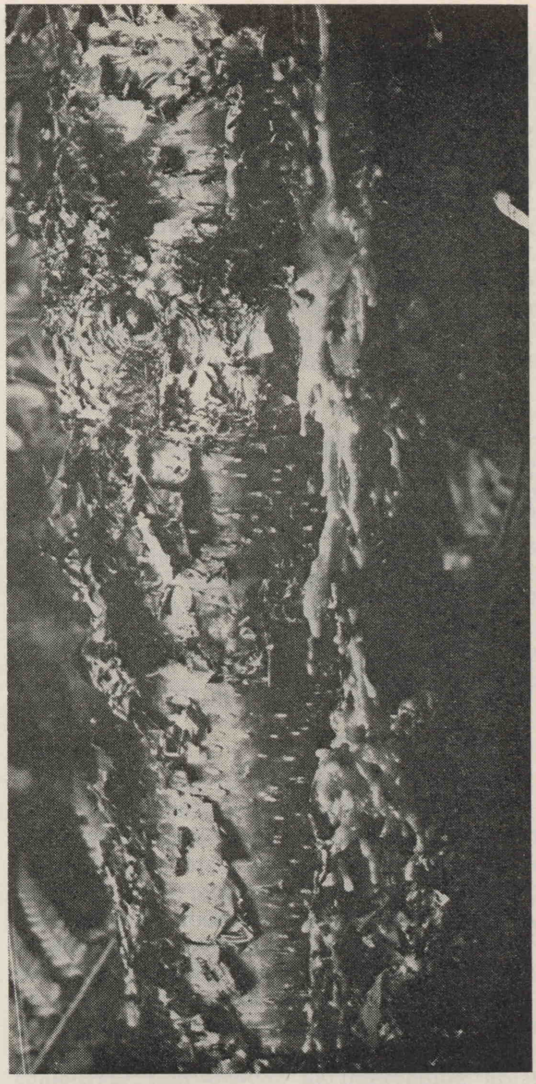


Plate IX.—Showing continued production of resin on Hoop pine trunk from sites of successful attack by larvae of *V. oberthuri*.

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.

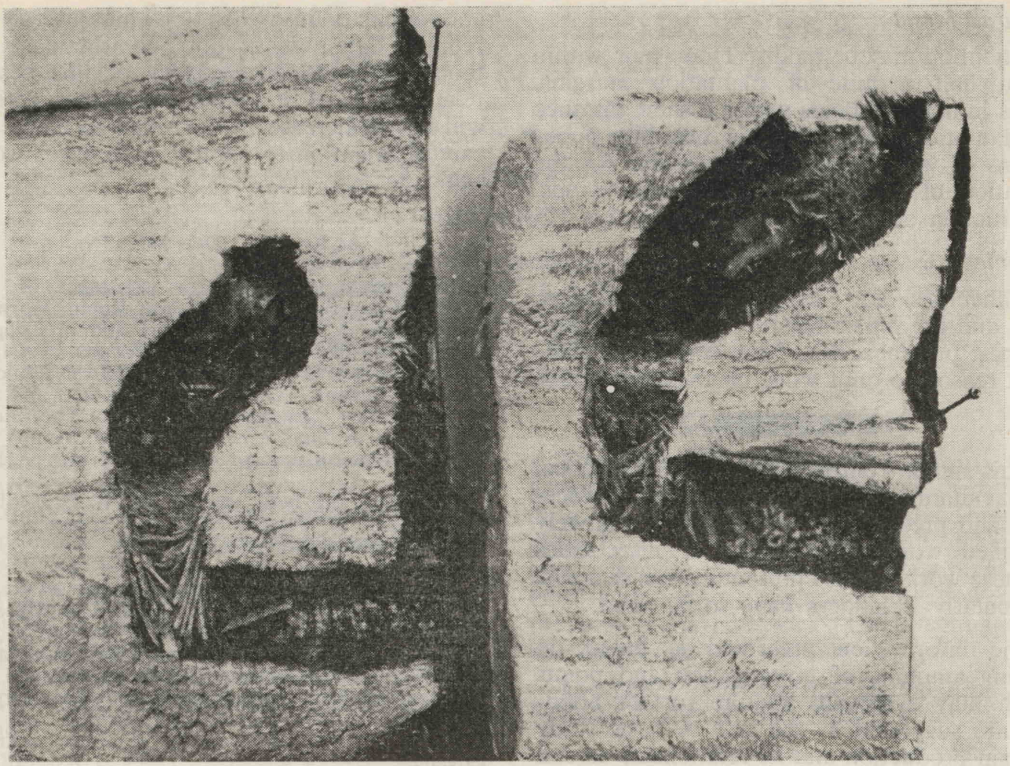


Plate X.—Pupal gallery of *V. oberthuri* in radial section of wood cut from outer part of Hoop pine trunk. The horizontal gallery, vertical gallery with characteristic plug of slivers and chewed wood, and the pupal chamber turning back towards the outside of the trunk (right) are characteristic features.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