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The Coconut Trunk Borer (*Melittomma insulare* Fairm. Coleoptera: Lymexylidae) of Seychelles and its Associated Microflora

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Introduction

The wounds caused by insects are important in many diseases of crop plants. These diseases and the ways in which the insects are implicated are described by Leach (1940) and Carter (1962) whilst more general accounts are given by Austwick (1957) and Crosse (1957). In some diseases the relationship between the insect and parasite or pathogen is non-specific (not only the infection route, but also the parasite may be associated with more than one or many insect species, e.g. the apparent causal relationship between insects and fireblight of Rosaceae. More specific is the vascular wilt of cucurbits due to *Erwinia tracheiphila* (Erwin Smith) Holland which may overwinter in hibernating adults of the cucumber beetles *Acalymma* (*Diabrotica*) *vittata* (F.) and *Diabrotica undecimpunctata howardi* Barber. A somewhat different example is provided by the Dutch elm disease where there is a fairly specific relationship between the fungus and the insect vectors. The pathogen, *Ceratocystis ulmi* (Schwarz) Moreau is carried by and transmitted to elm trees by the bark-feeding beetles, *Scolytus scolytus* (F.), *S. multistriatus* (Marsham) and *Hylastes rufipes* Eichh. Conidia are introduced into vascular elements as the insect feeds on the bark.

Diseases of the coconut palm in Seychelles are few. Bud rot attributed to *Phytophthora palmivora* Butl. (Briton-Jones, 1940), although increasing, has not reached epidemic proportions. Stem-bleeding due to *Ceratostomella* sp. usually follow fire damage to the bole. *Mycosphaerella gastonis* (Sacc.) Lind. causes conspicuous leaf spotting on most islands. The five serious diseases of unknown etiology (Maramorosch, 1964) and red-ring disease are absent. *Ganoderma* and *Fomes* root and stem rots are unimportant. There is, however, an example of a highly specific relationship between a beetle whose larvae bore in the bole of coconut palms and a bacterial complex.

The distribution of the coconut trunk borer (*Melittomma insulare* Fairm.) is restricted to certain granitic islands on the Seychelles Bank and to scattered districts in NW Madagascar and the offshore islands of Nossi Bé and Nossi Comba (Fig. 1). The disease syndrome associated with the attendant bacteria is coincident with the very limited range of the beetle. In addition the necrotic, modified palm tissue (fermentation process) (Fig. 2) is of direct food value to the beetle larvae boring in the parenchyma. This is in contrast to the examples quoted earlier where the bacterial or fungal-infected tissues appear to play no part as a special food source for the vector. Bock, Ivory and Adams (1970) have recently described a lethal bole rot of young palms up to 8 years old, caused by *Marasmiellus cocophilus* Pegler, which reaches epidemic proportions in several areas along the coasts of Kenya and Tanzania. In the wetter areas with impeded drainage or waterlogging, secondary bacteria and fungi invade the tissues colonised by the primary pathogen and overgrow it.

Bacteria, unlike fungi, seem unable to penetrate directly the intact surfaces of a plant, though they can penetrate stomata in water films, lenticels (not found in monocotyledons) or wounds. The coconut trunk borer allows this bacterial complex to enter what would otherwise be a healthy palm.

The first detailed account of the biology and attack pattern of *Melittomma* was given by Vesey-Fitzgerald (1941). He pointed out that *Melittomma* only occurred on islands with palm-forest relics, especially *Stevensonia* and *Nephrosperma,* on the lower slopes. He suggested that a downhill spread of the borer from these primitive hosts (hard tissues, slow borer development) to the secondary palmetum (softer coconut tissues, rapid borer development) had probably occurred.

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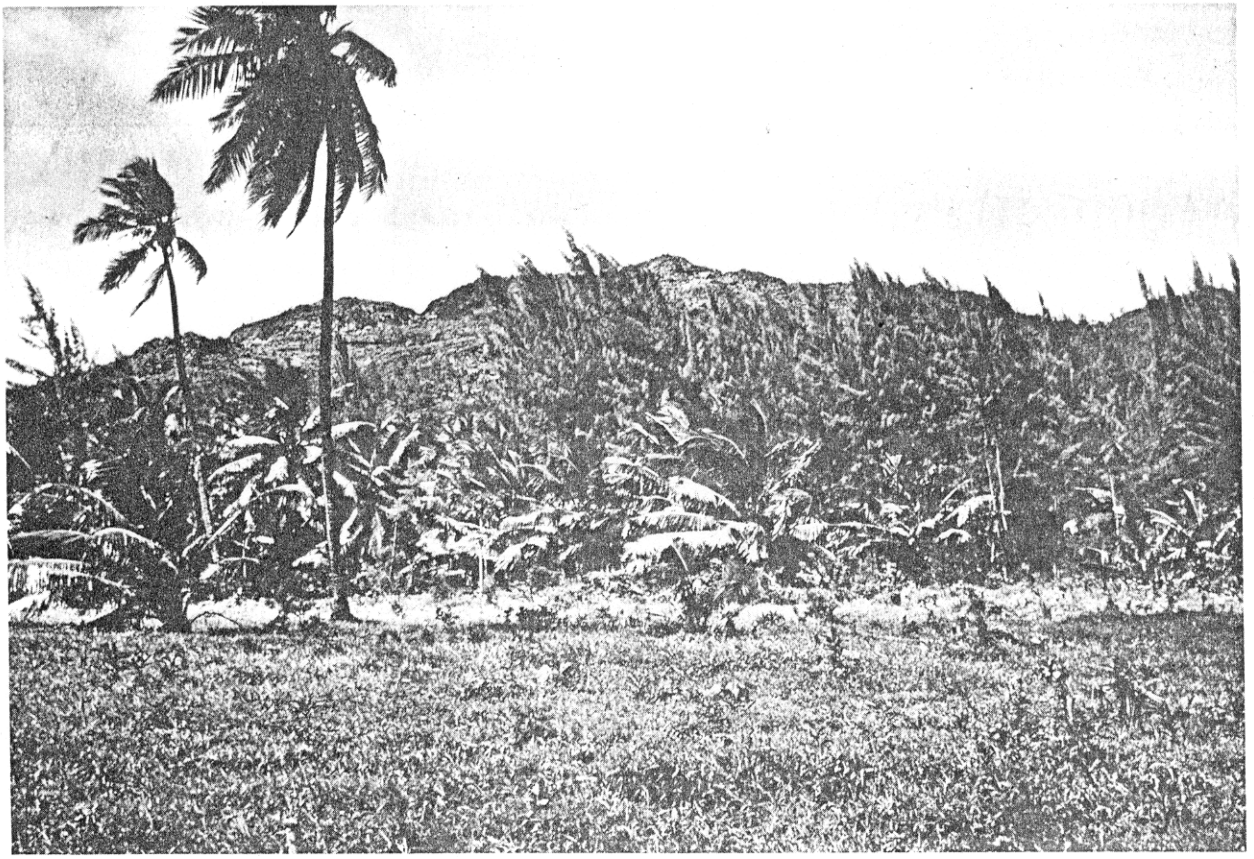

Fig. 1. Cote D'Or, Praslin. The palms have fallen through *Melittomma* attack; re-planting was prevented by severe coconut beetle attack (*Oryctes monoceros* Oliv.) and now by growing *Casuarina equisetifolia* L. (whispering 'pine').

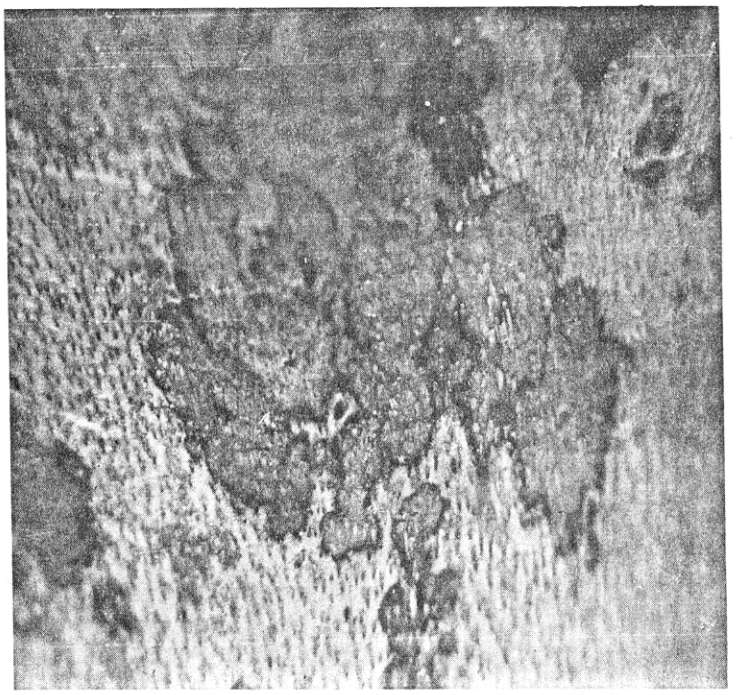

Fig. 2. Borer tunnels surrounded by fermenting tissue.

Brown (1954) devised a *p*-dichlorobenzene (PDCB) fumigation technique which proved unsuccessful, and made the first studies on the associated microflora. Nye (1961) advised another treatment based on a more thorough excision of the diseased tissue together with a high proportion of the larvae. The gouged surface was allowed to dry out before a liberal application of a special formulation of creosote—coal tar was made (Fig. 3). The expected effect of underpopulation on sexual reproduction did not materialise so that infestation of new palms and reinfestations (if examined 12—18 months later) were running at too high a level on Praslin Island (the mean for 1966—69 was 34%). The large area of marshy land on this island has aggravated the problem by producing very sappy, highly susceptible palms in the 5—20-year age group, ideal for borer development and rapid fermentation. During a study of the *Melittomma* problem on Praslin Island, the author concluded that priority should be given to the prevention of larval entry by applying dieldrin—BHC sprays to the basal 15 cm of the palm's trunk, to be coupled where necessary with the Nye technique. There is no substitute for surgery and tarring as a curative treatment after the palm has been attacked.

Fig. 3. Diseased bole of young palm following gouging.

Life cycle and attack pattern of *Melittomma*

The beetle would be very difficult to breed from egg to adult, and no serious attempt has been made because the life cycle is so long. Vesey-Fitzgerald (1941) suggested that the eggs (1·2 x 0·30 mm, sausage-shaped white, shiny, sparsely ornamented) are often laid in irregular clusters in a sticky matrix, frequently away from the trunk, mainly in loose soil where the female has burrowed down to roots. However, Brown (1954), Nye (1961) and the present author consider that the base of the trunk is the normal site. Females hide in crevices and wounds at the base of the trunk, in 'steps' cut higher up, between exposed adventitious roots and in vertical growth cracks between the scars of the leaf-bases. They show a thigmotactic response which automatically takes them to the most favourable oviposition sites. It is, however, common to see entry holes on smooth, healthy bark. Incubation lasts 10—12 days and after hatching the larvae stay aggregated and quiescent for a time before they disperse just before penetration. The pinhole entry holes are seen first on the root collar at soil level and the borings appear later. The larvae usually bore upwards and inwards traversing the parenchyma between the vascular bundles.

The larva has received most attention since it is the borer stage. It has a hoof-shaped sclerotised 'tail-piece' with a serrated edge which is used as a ram to push the chewed residues, frass and cast skins towards the tunnel mouth each day. These small pellets, resembling sawdust, are a diagnostic feature of borer attack. When a cavity is present inside the bole, dust is produced internally while the bole is seen to be superficially

intact. In this context adults can also emerge internally where they copulate and produce new larvae which start further borings. The larva undergoes about seven moults and the instar is of 4–18 months duration depending on the quality of the food supply, being short in young, sappy palms and long in old harder tissues. The pupal stage is of short duration lasting 10–15 days. After emergence adults live 2–6 days; their size depends largely on larval feeding conditions. They are nocturnal, males which are more active coming to light between 19.00 and 20.30 h. Females fly little and stay near the trunk, possibly attracted by the characteristic smell of the diseased tissue.

Spread is often slow, since palms in all stages of attack can be found together in a small area. Indeed larvae in the trunk may be progeny of those which started the attack. Once attacked, a palm generally stays infested for the rest of its life. When a palm falls the trunk starts to dry out, stops producing the characteristic smell, and no longer provides suitable sites for egg laying. Adults still continue to emerge for 2–3 months, then females need to disperse more widely than usual to an adjacent living palm. There is a marked tendency for a greater proportion of superficial infestations to occur in palms adjacent to one which has recently fallen. In Seychelles larvae of all stages, pupae and adults can be found throughout the year, so that life-cycle is not seasonal. In Madagascar there is evidence of seasonal behaviour in that egg-laying occurs mainly in October–January, i.e. at the beginning of the NW monsoon (Frappa, 1948).

Larval feeding habits and associated microflora

In advance of (up to 15 cm) and surrounding (0.5–1 cm) each tunnel is a zone of wood infected by bacteria and other micro-organisms associated with the damage. These zones spread out and coalesce in the softer, wetter central trunk. The mechanical damage caused by the larvae (perhaps 10–200 per bole) is slight, but the diseased zones affect a far greater volume of tissue. The damage is mainly pathological rather than entomological.

It was assumed that the larva was a wood-feeder, ingesting solid wood and partially digesting some of it, until Brown (1954) reported that there was no trace of wood or remains of cortical cells in the gut. The gut did contain a clear yellow/red fluid obtained from the fermenting, necrotic tissues ('bruised' tissue of Vesey-Fitzgerald, 1941). The fermenting tissue has a quite characteristic, sweet, aromatic odour. Healthy tissue (white) turns yellow, then fawn-pink, then rust-red, then dark brown to black as the tunnel is followed back to its source. Brown considered that yeasts and fungi were secondary parasites and that a small Gram-negative rod-shaped bacterium was of greatest importance. The fermenting area spreads further from grafts of diseased wood in the absence of *Melittomma,* but pure isolates from the bacterial complex do not cause disease spread when injected into healthy tissue. The exact role of the beetle larvae in the development of the fermentation process is unknown. Pure cultures would largely avoid the normal interactions of the bacterial species comprising the complex described later. Fungal moulds do not develop on fresh (fawn-pink) fermenting tissue but do so readily on healthy coconut tissue. This may be due to an antibiotic effect. The micro-organisms associated with *Melittomma* (unlike termites and their gut-microflora) are external and liberate suitable food for the borer, hence it comes to live as a natural result in humid, living tissue. Whether *Melittomma* is primary or secondary in the syndrome is therefore a matter of conjecture. Tunnelling in trees covers about 20 cm in 8 months, i.e. less than 1 mm/day. The rate in blocks is much faster at first, but then slows down (Brown, 1954).

Frequently during control treatments some fermenting tissue has to be left in deep infestations as a 'compromise' to prevent toppling of the palm, in an effort to maintain good relations with the planters. This residual fermentation will normally proceed up the trunk if the applied creosote fraction fails to penetrate far enough into the wood. The possible use of a more potent, penetrating bactericide/fungicide with the Nye method was considered in the current work, i.e. application to the gouged surface before coating with the creosote–coal tar. It was necessary therefore to know more about the microflora associated with this fermenting tissue. In this context the help of the Director and Dr J. F. Bradbury of the Commonwealth Mycological Institute was sought and received.

It was decided not to study the flora of excised fermenting tissue at Kew, following 4–5 days in transit. Nutrient agar cultures were therefore prepared in the Hospital Laboratory on Mahe from palm tissue in the transitional zone where the healthy and fermenting wood merged (incipient fermentation, where the normal white tissue is yellow to fawn-pink in colour). Isolates were prepared from 10 palms, each palm taken from a different site on Mahe. The samples, 1 cm^3 portions of tissue, were surface-sterilised in a hot flame by rapid passes to all faces for 10 s. Subcultures were prepared on agar slopes of the more important species and these were sent to Kew for a more detailed study.

The most common organism on all 10 isolates was *Escherichia* (= *Citrobacter*) *freundii* (Braak) Yale. Many streaks appeared to contain this species alone, but others were mixed. *Enterobacter* sp., probably *E. cloacae* (Jordon), *Achromobacter* sp., *Pseudomonas* sp., and the yellow *Erwinia herbicola* (Duggeli) Dye were found in small numbers in some of the streaks. Occasional colonies of other organisms, probably secondary or contaminating, were also found.

Seven of the ten slope cultures were also *Esherichia freundii,* including two which appeared slightly different (CMI Nos B4244 and B4245). A yellow colony (B4243) which grew white on all but one of the Kew test media, was probably *Alcaligenes faecalis* Castellani & Chalmers although yellow pigment has not been reported for this species. The ninth slope was *Micrococcus* sp. and the remaining slope was a mixture of *E. freundii* and *Pseudomonas fluorescens* Migula.

After determining the nature of the bacterial complex, limited observations were made with sprays of copper (colloidal copper oxychloride), organomercury (canker paint), tin (fentin acetate and hydroxide) and 2-phenylphenol applied to the freshly gouged surfaces. Their activity on the various types of residual fermenting tissue after a 'compromise treatment' indicated that none was superior to the creosote–coal tar formulation and its continued use was advised. Application of the preservative one day after gouging was not ideal. Even in dry weather drying out of the exposed tissues is limited so that the creosote only penetrates 1–3 mm after this interval, giving only a surface kill of bacteria. In humid conditions little or no drying out occurs after one day and since creosote and water are immiscible penetration is minimal, permitting even more superficial tissues to become diseased. Conversely, if the gouged surface is allowed to dry out for an extended period (e.g. a few weeks) the bacteria would tend to rapidly follow the moisture gradients inwards. Here the penetration of creosote, even in dry coconut wood, may not be sufficient to reach the residual fermentation bacteria. It was recommended that there should be a 3–5 day interval between gouging and applying the preservative for optimal results.

Discussion

The importance of bacteria in tropical plant disease is well known, the Seychelles palm syndrome providing an excellent example. The bacteria are deeply seated in the bole of the palm so that systemic activity would be needed for a possible chemical approach. As yet there is no systemic anti-bacterial compound for field use on a wide range of crop plants. One is therefore unable to control this disease by chemical or agronomic means alone.

Although *E. freundii* is not considered to be a plant pathogen, its occurrence in every isolate suggests that it may be of importance in the etiology of the fermentation process. Dr Bradbury has isolated this or a similar species from rotting trunks of rubber trees in Malaysia. Rishbeth (1969; pers. comm.) in a recent talk on 'Bacterial wetwood' mentioned that an organism 'rather like *Enterobacter* sp.' was frequently isolated from wood showing this condition. Without the detailed studies made by Dr Bradbury the Rishbeth description could easily have covered *E. freundii* as well. Both species are members of the Enterobacteriaceae.

The complex of bacteria involved in this fermentation process are all Gram-negative species (coli–aerogenes group), and under normal conditions could only be considered as potentially weak plant pathogens. With regards to their carbohydrate metabolism it should be stated that coconut tissues provide high levesl of glucose, fructose and especially sucrose (8.6–14.8%). Sucrose is the basal medium for gram-negative bacteria, i.e. they will ferment sugars very readily. Consequently, the very sappy conditions in the bole of many Praslin palms, coupled with the high ambient temperatures, provide an ideal substrate (Fig. 4). Inositol occurs in higher concentrations in the date palm and it is of interest that this carbohydrate was less readily utilised by the above microflora.

It is considered that these bacteria are normally present in the crown or on the trunk of the palm (externally) and that rainwater washes some of these colonies down to the base of the palm and adjacent soil. Concentrations probably occur in crevices which also attract gravid females of *Melittomma.* Brown (1954) provided some slender evidence that egg transmission of these bacteria may occur in *Melittomma,* so that larvae are automatically infected on hatching and inoculate the coconut tissue on entry. It is thought that egg transmission is unlikely and it is more feasible that the first-instar larvae become contaminated with the inoculum (either externally, internally or both) in their limited wandering prior to entry. The sticky matrix which covers the eggs offers a promising substrate for bacteria from which larvae may be infected at hatching. Time did not permit a more detailed consideration of this most interesting problem. The bacterial isolates had the following characteristics:

aerobic facultatively anaerobic motile Gram-negative rods (which agrees with Brown's findings);
Kovac's oxidase negative;

do not liquify gelatin;
reduce nitrate to nitrite;

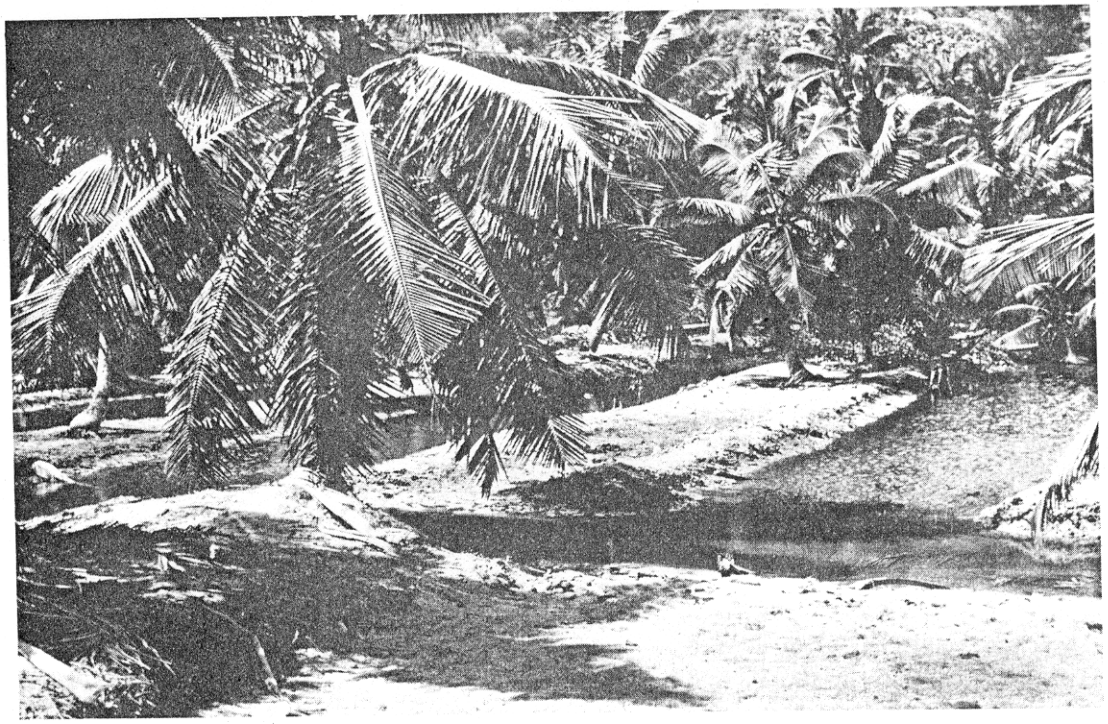

Fig. 4. Praslin Island where a high water table produces sappy, young palms ideal for borer development and rapid fermentation.

produce acid and gas aerobically and anaerobically from glucose, sucrose, meso-inositol (usually within 48 h but not within 24 h) and salicin;
methyl-red positive;
Voges-Proskauen negative;
gluconate negative;
Simmon's citrate positive;
Christensen's urease positive;
produce H_2S weakly or not at all;
indole positive;
Thornley's arginine negative;
have no pectolytic activity (i.e. are not soft-rot bacteria).

Some variations were found in the rapidity of acid production from lactose and salicin and two isolates (B4234 and B4235) did not produce acid from these substrates within the test time of 4 weeks. One isolate (B4253a) failed to produce acid from lactose, was arginine-positive and apparently nitrate-negative. It was typical in all other respects. Cultures B4237 and B4241 were conserved by freeze-drying as typical isolates, whilst B4234 and B4253a were kept as atypical isolates.

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References

AUSTWICK, P. K. C. (1957). *Biological aspects of the transmission of disease.* Ed. C. Horton-Smith. Edinburgh and London, Oliver & Boyd.

BOCK, K. R., IVORY, M. H. and ADAMS, B. R. (1970). Lethal bole rot disease of coconut in East Africa. *Ann. appl. Biol.* 66: 453–464.

BRITON-JONES, H. R. (1940). *The diseases of the coconut palm.* London, Bailliere, Tindall & Cox.

BROWN, E. S. (1954). The biology of the coconut pest *Melittomma insulare* (Col. Lymexylonidae) and its control in Seychelles. *Bull. ent. Res.* 45: 1–66.

CARTER, W. (1962). *Insects in relation to plant disease.* New York and London, John Wiley.

CROSSE, J. E. (1957). *Biological aspects of the transmission of disease.* Ed. C. Horton-Smith. Edinburgh and London, Oliver & Boyd.

FRAPPA, C. (1948). Un parasite du cocotier dans la region nord-ouest de Madagascar. *Agron. trop.* 3: 274–281.

LEACH, J. G. (1950). *Insect transmission of plant diseases.* New York and London, Mc-Graw Hill.

MARAMOROSCH, K. (1964). *A survey of coconut diseases of unknown etiology.* Rome, FAO.

NYE, I. W. B. (1961). The control of the coconut pest *Melittomma insulare* (Col. Lymexylidae) in Seychelles. *Bull. ent. Res.* 52: 489–499.

VESEY-FITZGERALD, D. (1941). *Melittomma insulare* Fairm. (Col. Lymexylonidae), a pest of coconut in Seychelles. *Bull. ent. Res.* 31: 383–402.