QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES
DIVISION OF PLANT INDUSTRY BULLETIN No. 695

BIOLOGY OF MACADAMIA NUT BORER (CRYPTOPHLEBIA OMBRODELTA (LOWER))

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SUMMARY

In Queensland *Cryptophlebia ombrodelta* (Lower) occurs on macadamias throughout coastal areas and often contributes to poor yields. However, it is less prevalent in elevated areas of south-eastern Queensland. Thirty-three host plants from Australia and overseas are listed.

A brief description of the insect is given and its habits are discussed. In the laboratory the life cycle is completed within 5 weeks during summer as follows: egg 4 days, larva 21 to 27 days, pupa 8 days. Five parasites and one predator are listed.

During development of the macadamia nut, the larva tunnels into and feeds on the kernel, but the shell as it hardens 'resists' larval entry and damage is usually confined to the inner husk. Premature nut fall resulting from husk damage causes crop loss even after shells have hardened. The insect is active throughout the year but the most severe damage occurs from December to February.

Varieties of *Macadamia* spp. differ in their susceptibility to damage and crop loss can be minimized by selecting and growing varieties which mature early and produce nuts having shells of even medium thickness and closed micropyles.

I. INTRODUCTION

The macadamia nut borer (*Cryptophalebia ombrodelta* (Lower)) was first recorded by Froggatt in 1897 on *Acacia farnesiana* in northern New South Wales. It has since been reported to reduce yields of macadamia nuts in Queensland (Officers of the Department of Agriculture and Stock, 1951).

Bradley (1953), in his revision of the genus *Crytophlebia,* established the present nomenclature of the species.

Macadamia plantings in Queensland have increased rapidly in recent years and exceed 100 000 trees (Bureau of Census and Statistics, Brisbane 1972). Further increases in plantings are anticipated.

To determine optimum control measures for *C. ombrodelta,* a greater knowledge was required of the insect and its habits on macadamias. This work was undertaken to investigate aspects of the biology and ecology with particular reference to host damage.

II. DISTRIBUTION AND DISPERSAL

C. ombrodelta has been recorded from the Northern Territory, Queensland, New South Wales, and from several overseas localities by Bradley (1953). Comments on notes and an exhibit by Davis (1962) indicated that the species was probably established in Hawaii by 1958.

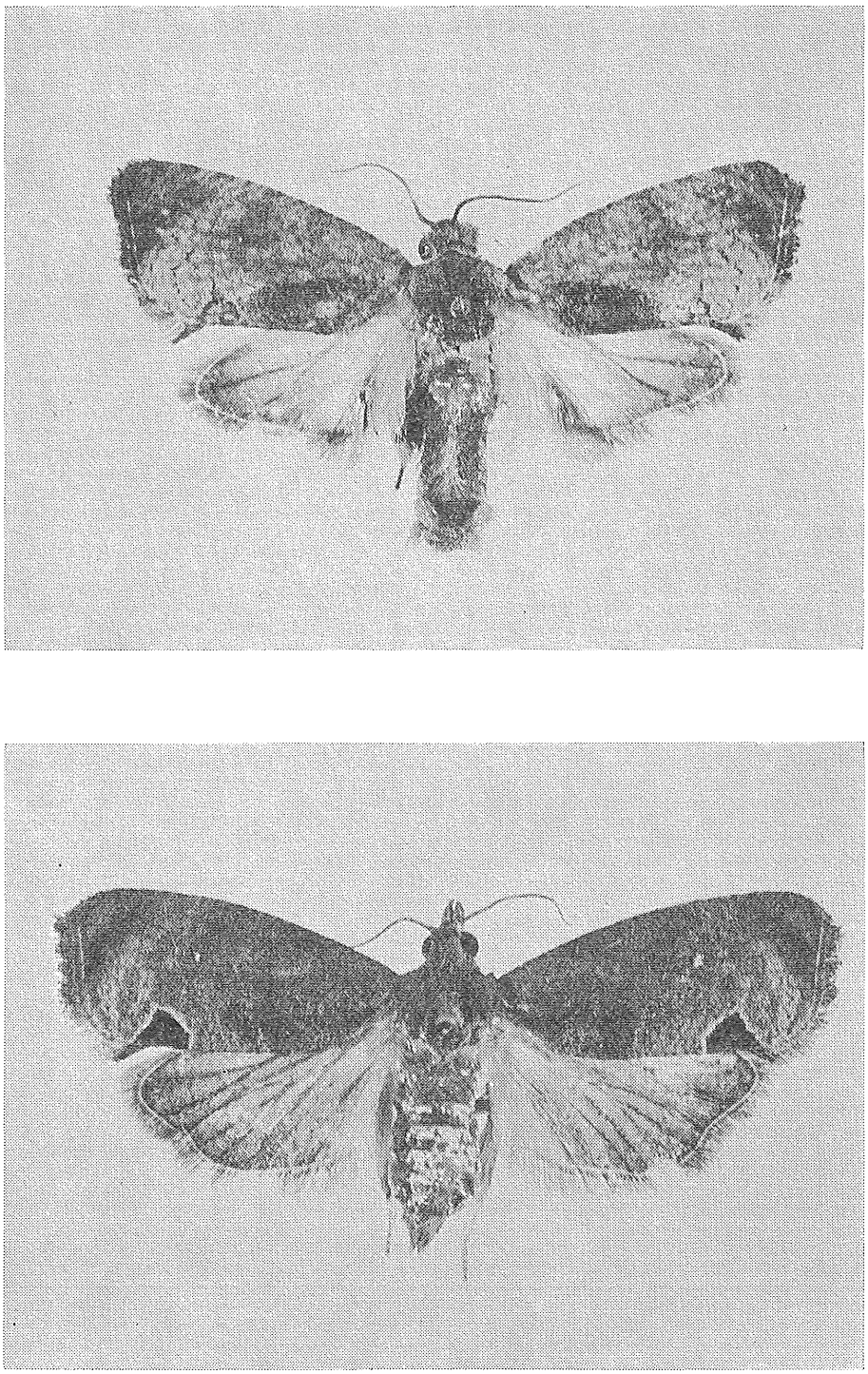

Fig. 1.—Male (upper) and female *Cryptophlebia ombrodelta* (Lower).

In Queensland, it occurs generally throughout coastal areas (unpublished Queensland Department of Primary Industries records). During this research, most observations and recordings were made in the coastal area from Beerwah to Gympie. In south-eastern Queensland the species is less prevalent in areas with elevations above 1 000 feet, such as on the Blackall range, where it is an unimportant pest.

Populations of the moth appear to be sedentary, as new macadamia plantations not in the immediate vicinity of established infestations have remained free of the pest for several years.

III. PLANT HOSTS

The hosts for *C. ombrodelta* include a few economic food plants and numerous species commonly grown as ornamentals. Hosts recorded in the literature as well as those from the current study are listed in the appendix.

Froggatt (1897) found that *Acacia farnesiana* was severely infested. In India fruit of *Litchi chinensis* was reported to be a favourite host (Fletcher 1920.). *Filicium decipiens* and *Indigofera suffruticosa* were found to be severely infested and damaged in Hawaii—by Davis (1962) and Nakao (1966). The author has recorded severe infestations in the pods of *Bauhinia* spp., *Cassia* spp., *Delonix regia* and *Poiciana pulcherrima* as well as in nuts of *Macadamia* spp. Tunnelling in young shoots has been recorded on some hosts but on *Macadamia* spp. damage has been confined to the nuts.

IV. DESCRIPTION AND HABITS

IMAGO. The female moth has a wing span of up to 25 mm and body length up to 12 mm. The distinctive features have been described by Bradley (1953). Both sexes are illustrated in Figure 1.

EGG. The egg is almost flat, oval-shaped and about 1·0 x 0·8 mm in size (Figure 2). The surface of the chorion is finely reticulate. It is ivory white to pale yellow in colour with pale orange to red spots appearing as incubation progresses. Before hatching the spots coalesce to form a reddish suffusion, and the outline of the head capsule becomes clearly visible. Up to 15 eggs may be laid on the green husk of one nut. They may be placed singly or in groups with individual eggs slightly overlapping.

LARVA. The newly-hatched larva is slightly more than 1 mm long, light orange in colour with a dark brown head capsule. After eating its way out of the chorion, which is left mainly intact, the larva soon begins to tunnel into the husk. The entry hole is barely visible to the unaided eye and may be filled with sap exudate. As the larva grows, a larger hole is made allowing for the disposal of excess frass from the feeding area.

The head capsule and prothoracic shield of later instars are a dark brown and the remainder of the thorax and the abdomen are mainly whitish with a distinct pattern of infuscate pinaculae. Before each moult, the larva enters a short quiescent stage.

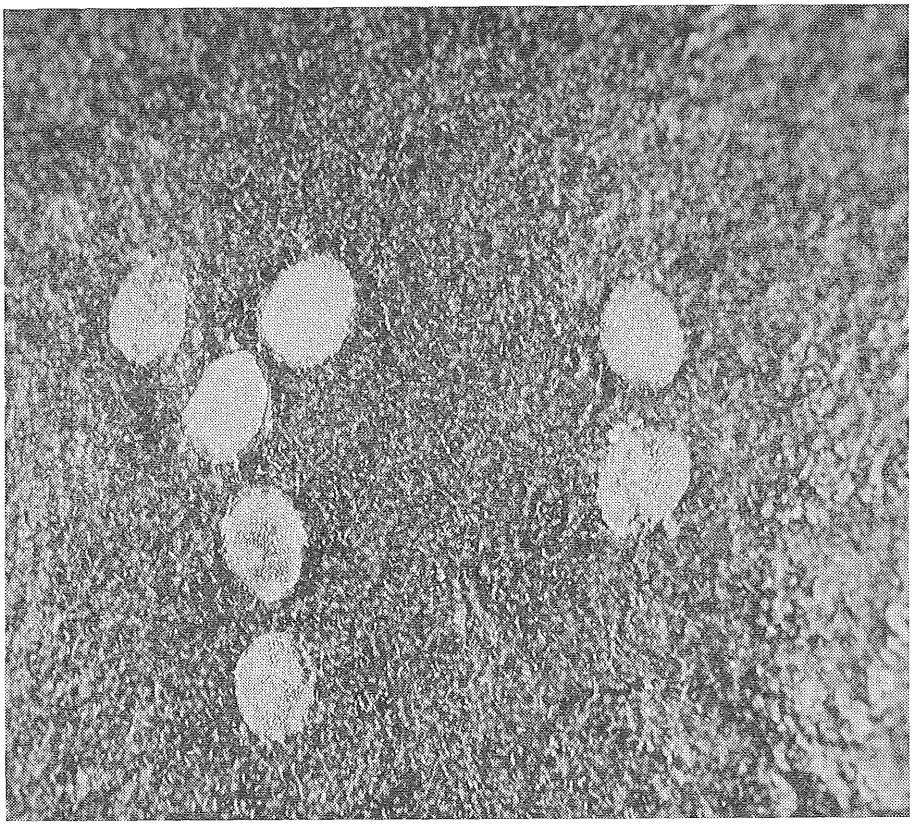

Fig. 2.—Eggs of *Cryptophlebia ombrodelta* (Lower).

The fully grown larva (Figure 3) is stout-bodied and up to 20 mm long. The head capsule and prothoracic shield are light brown except for a light median stripe. Thoracic segments are light greenish-grey and abdominal segments are light pink. The round or slighly oval, dark-greenish pinaculae are more prominant than in earlier instars. Some larvae have a dark internal hue dorsally in the abdomen.

When the macadamia nut shell or testa is light in colour and still soft, the larva will tunnel through the shell and feed on the kernel. Except for the entry hole there is often no external sign that a nut is infested. As the nut matures the shell hardens and becomes a dark brown colour. It then 'resists' entry by the larva and feeding is mostly confined to the inner layer of the husk. Infestations are then made obvious by splitting of the husk and/or protrusion of larval excreta. Excavations are often seen on the surface of nut shells after a larva has failed in attempts to bore through to the kernel. The hilum and micropyle ends are more readily entered than other parts of the hardened shell.

The larva seeks dark narrow places and little webbing is associated with its feeding, but in clusters of nuts it may move to contiguous nuts webbing them together at the point of contact. The spaces between the nuts can become filled with brown pellet-like excreta of the larva.

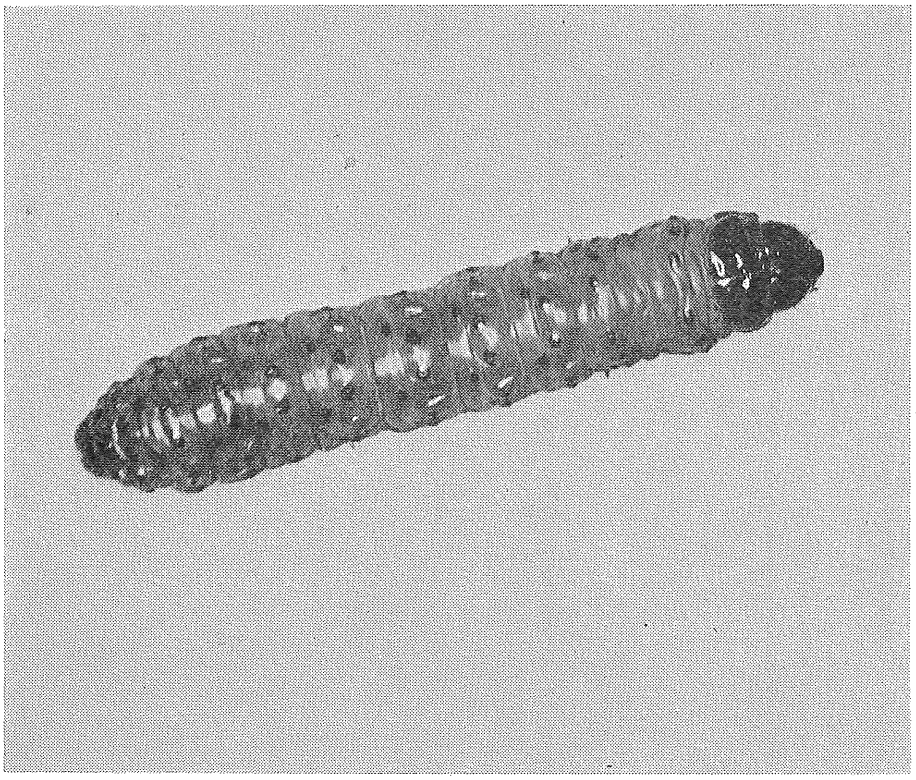

Fig. 3.—Larva of *Cryptophlebia ombrodelta* (Lower).

Three or 4 days before pupation, the final instar larva enters the prepupal phase. If necessary, a circular or oval hole 3 to 4 mm across is made in the shell or husk to allow the imago to escape. A tightly woven silken cocoon incorporating frass is spun and sealed with an unobtrusive flap at the exit hole. The larvae remains quiescent in the cocoon for about 2 days and then pupates (Figure 4).

The number of larvae reaching maturity in one nut is usually not more than two or three. This is probably because of the limitations of the food supply and the tendency of the larvae to be cannibalistic. Larval mortality can also result from food deterioration after damaged nuts have fallen.

PUPA. The pupa is at first light brown and darkens to a dark brown before the moth emerges. At emergence, the pupa moves about two-thirds of the way out of the cocoon and the moth emerges leaving the pupal case protruding from the exit hole (Figure 5).

V. DURATION OF STADIA

At the Nambour Field S'ation, adults, which had been reared from field-collected larvae, were fed on a 10% honey solution and mated in a cloth-covered half-gallon metal ice-cream container. The wall of the container was lined with

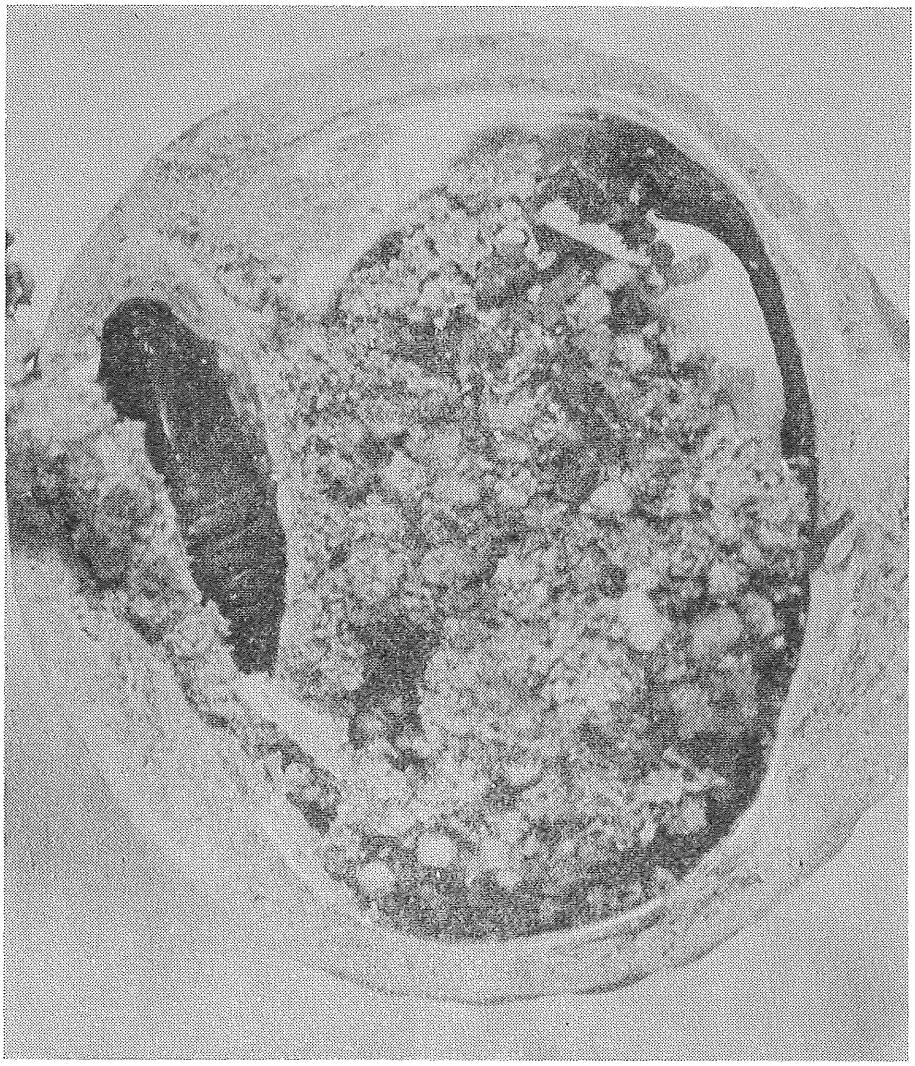

Fig. 4.—Pupa of *Cryptophlebia ombrodelta* (Lower) in damaged macadamia nut.

wax paper. One female began oviposition 3 days after emergence and continued for 11 days, laying about 230 eggs on the wax paper. Incubation times were noted for about 200 eggs.

Newly-hatched larvae were placed on fresh fragments of macadamia husk in petri dishes. Larvae were examined daily and transferred to fresh food as necessary. A number of individuals was reared to adult at laboratory ambient temperatures in February-March 1968, and a small series was reared in a constant temperature unit at 26°C. Both five and six larval instars were recorded. Data on the duration of the development periods are given in Table 1. Inconsistencies in the number of individuals recorded under various stadia resulted from failure to recover all the exuviae and because of death of one of the pupae.

TABLE 1

DURATION IN DAYS OF IMMATURE STADIA OF *C. ombrodelta* AT LABORATORY AMBIENT TEMPERATURE AND AT 26°C

Development Stage	Ambient Temperature, February and March				Constant Temperature 26°C			
	Mean	S.E. of Mean	Range	No. of Insects	Mean	S.E. of Mean	Range	No. of Insects
Egg	4	..	..	200+	4·6	0·24	4–5	5
Instar I	3·4	0·12	3–4	18	4·1	0·40	3–6	7
Instar II	2·8	0·24	2–5	15	3·9	0·51	2–6	7
Instar III	2·6	0·18	1–3	13	3·3	0·29	2–4	7
Instar IV	3·2	0·13	2–4	17	4·0	0·77	3–7	5
Instar V (Instar VI absent—see text)	11·4	0·38	10–14	16	..	..	..	..
Instar V (Instar VI present)	3·8	0·48	3–5	4	4·3	0·25	4–5	4
Instar VI	8·3	0·95	7–11	4	12·6	0·24	12–13	5
Pre-pupae	2·2	0·14	1–3	20	3·3	0·33	2–4	6
Total for larvae (Includes pre-pupae)	23·7	0·38	21–27	20	32·6	1·17	29–36	6
Pupae	9·3	0·15	8–10	19	11·4	0·24	11–12	5
Total time (eggs to adult)	36·9	0·43	24–40	19	48·5	1·01	46–52	5

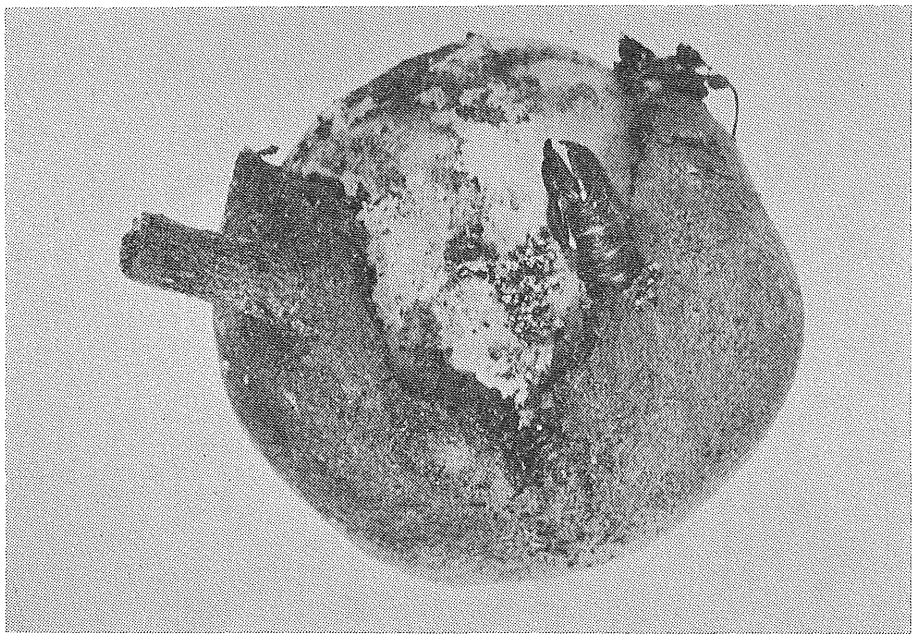

Fig. 5.—Empty pupal case of *Cryptophlebia ombrodelta* (Lower) protruding from damaged Macadamia nut.

VI. SEASONAL INCIDENCE

In most older *M. integrifolia* plantings, nuts suitable for infestation by larvae are present throughout the year. Successive generations occur in such orchards, larvae being found in the nuts during every month of the year. Populations are at the lowest level during the winter months when nuts are not as plentiful, and when lower temperatures depress development. Numbers increase during spring and early summer, and the most severe infestations occur from December to April. Light to moderate damage to early-set nuts can occur in spring, but severe damage to the main crop on varieties Keauhou and Kakea does not usually begin until early to mid December. By the end of February, such nuts can be sufficiently mature to give commercially acceptable kernels even though the husks are damaged.

VII. NATURAL ENEMIES

In Queensland, the following species have been recorded (D.P.I. records) from *C. ombrodelta*: *Apanteles briareus* Nixon, *Apanteles* sp. (? *ater* group), *Apanteles* sp. (*myoecenta* group), (Braconidae); *Echthromorpha insidiator* Smith, F., *Gotra bimaculatus* Cheesman, (Ichneumonidae); *Pristhesancus papuensis* Stål, (Reduviidae).

In Nambour *G. bimaculatus,* reared from larvae in the pods of *Delonix regia,* was more numerous than any other parasite. However further investigation is needed to determine the importance of natural enemies.

Namba (1956) lists 10 parasites of *Cryptophlebia illepida* (Butler), (a pest of macadamia in Hawaii) and considers them important in keeping the population down. It may therefore be possible to improve biological control of *C. ombrodelta* in this country by introducing suitable parasites.

VIII. DAMAGE

Most crop losses occur when nuts are approaching full size and maturity during the period December to February. However, nuts as small as 10 mm in diameter may be destroyed.

Nuts not in contact with others readily fall after they are damaged. In clusters, however, damaged nuts supported by other nuts or held by larval webbing may remain on the tree long after the adults have emerged.

Damage to nuts in clusters is not all caused by *C. ombrodelta*. The yellow peach moth (*Dichocrocis punctiferalis* (Guenee)) causes similar damage and it is more attracted to clusters of nuts than to single nuts. Larvae of both species can be found in one cluster of nuts.

Premature nut fall as a result of husk damage is the most important cause of crop loss after the shells have hardened. The kernels, though not injured are spongy, low in oil content, of poor flavour and unsuitable for commercial use.

Husk damage is relatively unimportant once the kernels are sufficiently mature for commercial acceptance. Nuts with husk damage are then marketable even though they are shed before the natural drop of mature nuts begins. It is therefore desirable to evaluate kernel quality to determine when marketing fallen, husk-damaged nuts can commence.

Larvae which tunnel through hard shelled nuts do not always destroy the kernels, but they provide access for secondary infestations by such insects as *Cateremna* sp., *Pheidole megacephala* (Fabricius) and *Carpophilus dimidiatus* (Fabricius), and for fungal infections. These render the kernels unmarketable.

Much of the *C. ombrodelta* damage is not detected until nuts are cracked. Consequently, the pest not only reduces the yield of quality kernels but also increases sorting and grading costs during processing.

IX. EFFECT OF HOST VARIETY ON DAMAGE

Both time of maturity and shell type were found to be important factors influencing nut susceptibility to damage. Samples of approximately 100 nuts harvested during 1967 from different varieties grown on Maroochy Horticultural Research Station were examined for kernel damage. Data on the percentage of damage for the various varieties are given in Table 2.

TABLE 2

EFFECT OF TYPE AND VARIETY OF MACADAMIA ON PERCENTAGE OF KERNELS DAMAGED BY *C. ombrodelta*

Species	*M. integrifolia*				*M. tetraphylla*
Variety	R1 Seedling	Rickard	Teddington	Pahau	N7
Shell Type	Medium Shell Evenly Thick		Thin Shell and/or Open Micropyle		
Time of Maturity	Early			Late	
Harvest Dates—	%	%	%	%	%
20 Mar 67	1	2	9	28	16
10 Apr 67	1	1	11	17	18

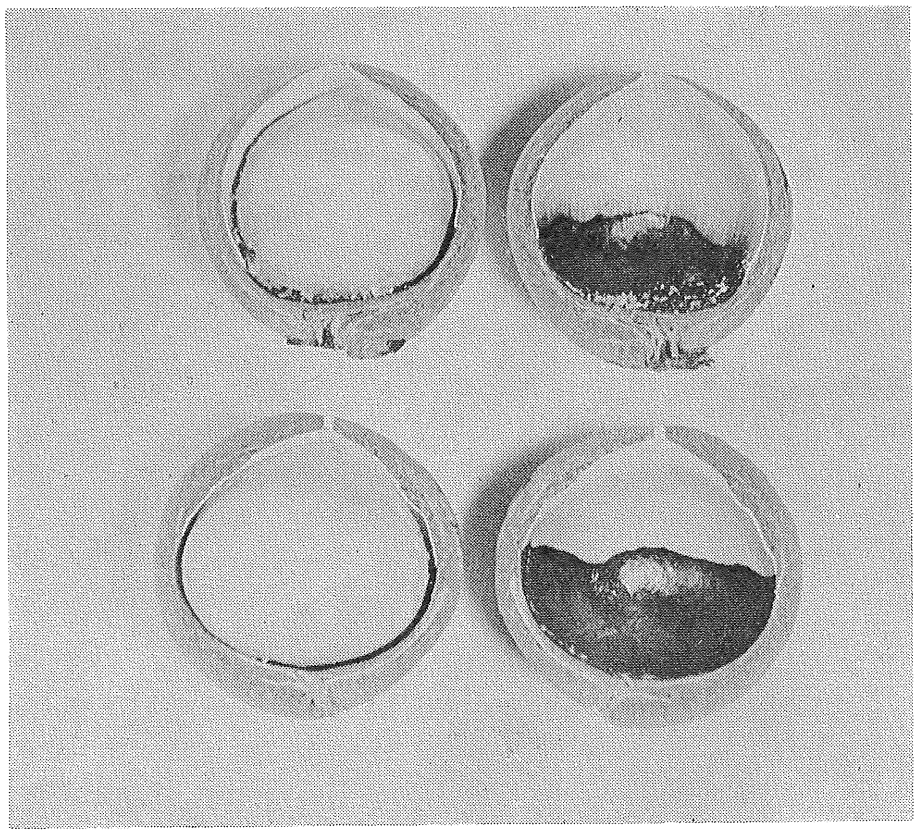

Fig. 6.—*Macadamia integrifolia* nuts cracked open. Upper: thin apical end and open micropyle nut of 'Teddington' variety. Lower: medium evenly thick shelled nut of 'Rickard' variety.

Early maturing varieties avoid exposure to peak *C. ombrodelta* numbers as the nuts are mature during this peak and so kernel loss is minimized. However it is noted that nuts of the variety Teddington, although early maturing, sustained a high level of damage because of the thin apical end and open micropyle of the shells (Figure 6). When nuts are close to maturity, shells of even medium thickness and with closed micropyles (Figure 6) are not as readily entered by larvae as are thin-shelled nuts, or nuts with open micropyles. The effect of shell type on nut susceptibility to damage was also noted by Leverington (1962) who reported that thin shelled nuts were more prone to insect injury than thicker shelled nuts.

Large yield differences apparently due to the time of flowering and maturity have been observed in mixed seedling plantings. On a farm where *C. ombrodelta* had not been controlled, the early flowering and early maturing *M. integrifolia* trees consistently produced satisfactorily. Attacks by *C. ombrodelta* on nuts of late flowering and maturing *M. tetraphylla* trees usually resulted in almost complete crop loss.

To minimize losses caused by *C. ombrodelta,* it is essential to select and grow varieties with early-maturing crops and with nuts that have shells of even, medium thickness and closed micropyles.

X. ACKNOWLEDGEMENTS

The author is grateful to the Commonwealth Institute of Entomology for providing parasite identifications and to the Colonial Sugar Refining Company Limited for financial assistance with macadamia pest investigations. Officers of the Department of Primary Industries Entomology Branch gave much helpful criticism during preparation of this manuscript.

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(Received for publication 1 May 1974)

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APPENDIX

Plant Host List for *C. ombrodelta*

The following list of names of host plants are arranged in alphabetical order under family and generic names. The part of the plant attacked is indicated where this information is available. All names marked with an asterisk are known to be host plants in Australia. Where a plant is only recorded as host in another country, the name of the country or State is indicated (where available) and also the authority for the reference. 'Hawaii' refers to the State of Hawaii and not necessarily the island known by that name.

LEGUMINOSAE
* *Acacia farnesiana* (L.) Willd.; pods and seeds.
Acacia spp; pods and seeds; Bradley (1953).
Adenanthera pavonina L.; seeds; Guam; Davis (1962).
* *Bauhinia galpinii* N. E. Br.; pods and seeds.
Bauhinia purpurea L.; pods; Bradley (1953).
* *Bauhinia* sp.
* *Cassia fistula* L.; pods and shoots.
* *Cassia coluteoides* Collad.; pods.
Cassia occidentalis L.; pods; Bradley (1953).
* *Delonix regia* (Bojer ex Hook.) Raf.; pods, seeds and shoots.
Indigofera suffruticosa Mill.; terminal stems and seed pods; Hawaii; Nakao (1966).
Parkinsonia aculeata L.; pods and leaves; Bradley (1953).
Phaseolus limensis Macf. var. *limenanus* Bailey; Hawaii; Sherman (1962).
Phaseolus vulgaris L.; Hawaii; Hamilton (1964).
Pithecellobium dulce Benth.; seeds; Guam; Davis (1962).
* *Poinciana pulcherrima* L.; pods and seeds.
Prosopis pallida H. B. K.; pods and seeds; Hawaii; Shiroma (1965).
* *Schotia brachypetala* Sond.; pods and seeds.
Sesbania cannabina (Retz.) Poir.; pods; Bradley (1953).
Sesbania formosa (F. Muell.) N. T. Burbidge; seeds; Bradley (1953).
* *Tamarindus indica* L.; fruits.

PALMAE
Cocos nucifera L.; stem end of immature fruit; Hawaii; Shiroma (1965).

POLYGONACAE
Coccoloba uvifera L.; Hawaii; Davis (1962).

PROTEACEAE
* *Macadamia integrifolia* Maid. & Betche; fruit.
* *Macadamia tetraphylla* L. Johnson; fruit.

RUTACEAE
Aegle marmelos (L.) Corr.; fallen fruits; Bradley (1953).
Citrus sinensis (L.) Osbeck; fruit; Bradley (1953).
Feronia sp.; fruit; Bradley (1953).

SAPINDACEAE
* *Cupaniopsis anacardioides* (A. Rich.) Radlk; fruit.
Euphoria longan Steud.; Hawaii; Hamilton (1964).
Filicium decipiens Thw.; young terminal growth; Hawaii; Davis (1962).
* *Litchi chinensis* Sonn.; fruit.
Sapindus saponaria L.; terminal branches; Hawaii; Bianchi (1968).