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Forest Insect and Disease Leaflet 191

Coconut Rhinoceros Beetle

Introduction

Coconut rhinoceros beetles (CRBs) (fig. 1), *Oryctes rhinoceros* (L.) are major pests of coconut, oil, and ornamental palms. Native to south and southeast Asia, the CRB has invaded many islands across the Pacific. U.S.-affiliated islands invaded by the CRB include American Samoa, the Republic of Palau, Guam, Oahu (Hawaii), and Rota (Commonwealth of the Northern Mariana Islands). Except for American Samoa, these islands have recently been invaded by a newly discovered variant of CRB referred to as the CRB-G biotype. This highly invasive biotype is problematic because it is resistant to *Oryctes rhinoceros* nudivirus (OrNV), a classical biological control agent that historically controlled CRB on Pacific Islands. Throughout this leaflet, CRB-G refers to the virus-resistant biotype and CRB-S refers to virus-susceptible biotypes, which can be readily controlled by OrNV.

Figure 1. Male coconut rhinoceros beetle head and pronotum. Photo by Michael Bohne, USDA Forest Service.

Biology

Taxonomy

The coconut rhinoceros beetle, *Oryctes rhinoceros* (L.), is a member of the scarab beetle family, Scarabaeidae, in the subfamily Dynastinae. Taxonomic expertise is required to differentiate *O. rhinoceros* from several other similar *Oryctes* species, some of which also attack coconut and other palms.

Life Cycle and Reproduction

A coconut rhinoceros beetle has four life stages: egg, larva, pupa, and adult, with the larva having three stages called instars (fig. 2). The lifespan depends on environmental conditions, varying between 9 and 18 months. Generation time varies between 5 and 9 months. The CRB sex ratio is usually close to 50:50 and females lay about 65 eggs during their lifetime. Under optimal environmental conditions with an unlimited food supply, CRB populations have the potential to grow rapidly.

Larval Feeding Behavior

Larvae feed on decaying vegetation. They develop in breeding sites which are primarily dead standing and fallen coconut trees. Beetles also breed and develop in piles of organic material such as green waste, dead trees of any species, sawdust, and manure. CRB larvae have been found in commercially bagged soil purchased from hardware stores. Active breeding sites contain all CRB life stages.

CRB individuals are at their heaviest during the prepupal stage (third instar grubs which have finished feeding). Thus, almost all the biomass in a CRB population comes from conversion of decaying vegetation consumed during the larval stage.

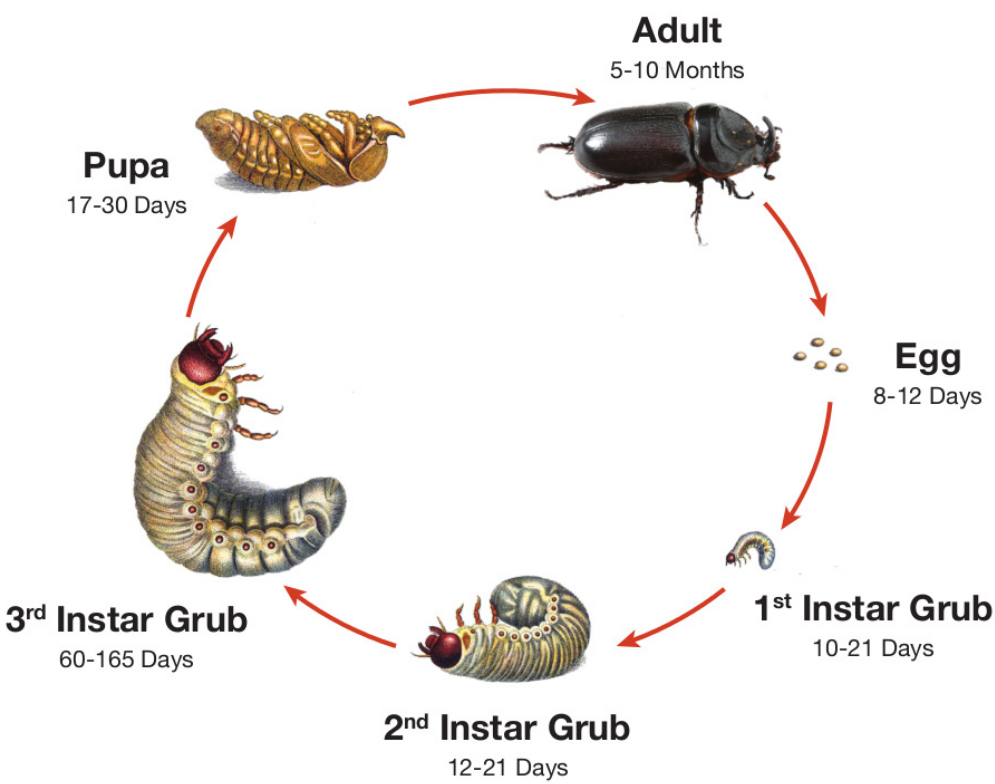

Figure 2. Coconut rhinoceros beetle life cycle. Illustration by Aubrey Moore, University of Guam.

Adult Feeding Behavior and Damage Symptoms

CRBs cause plant damage only in the adult stage. Both sexes burrow into the stems of tropical monocot plants and feed on sap liberated by maceration of soft tissues. Primary host plants are coconut, oil palms, and other palms. They will feed on other monocots such as banana, sago, pandanus, taro, pineapple, sugarcane, papaya, and agave, but CRBs are not reported to be major economic pests of these secondary hosts.

In coconut and oil palms, CRB adults fly into the crown and force their way down between the leaf axils until they find a position where they can bore a horizontal hole into the crownshaft towards the white tissue at the center of the stem. When boring this hole, they will pass through one or more developing fronds. As these damaged fronds emerge from the crownshaft several days to weeks later, the damage presents itself as boreholes and V-shaped cuts, which are distinctive signs of CRB damage (figs. 3 and 4). Similar V-shape leaf cuts appear in palms that have been trimmed to prevent trees from contacting power lines or to remove nuts. In these cases, there are no boreholes associated with the damage. If a CRB caused a V-shaped cut, this can always be confirmed by the presence of a borehole (figs. 5 and 6).

Adult beetles feed for only a few days in the crown before exiting the borehole to fly to a breeding site for mating and oviposition. Adults feed every few weeks during their adult lifespan. Thus, a single adult can damage several trees.

V-shaped cuts reduce production of nuts and degrade the aesthetic appeal of ornamental palms. However, the damage is not necessarily permanent. Even severely damaged palms can be nursed back to full health if all further attacks from adults are prevented. If the meristem has not been damaged, the tree will be able to generate new fronds.

A CRB can cause palm mortality if it bores into the single apical meristem (growing tip) within the base of the crownshaft. Mature palm mortality caused by CRBs is rare unless the adult population and the associated attack rate is very high.

Figure 3. Coconut palms severely attacked by coconut rhinoceros beetles. Photo by Aubrey Moore, University of Guam.

Figure 4. V-shaped cuts caused by adult coconut rhinoceros beetles. Photo by Aubrey Moore, University of Guam.

Figure 5. Coconut rhinoceros beetle boreholes through petioles. Photo by Aubrey Moore, University of Guam.

Figure 6. A coconut rhinoceros beetle borehole in a stem, made visible by removing petioles. Photo by Aubrey Moore, University of Guam.

Population Dynamics

With unlimited food and no control from natural enemies, CRB populations can grow at a rate of about 3,250 percent per generation. Devastating, uncontrolled CRB outbreaks are often triggered by tropical cyclones, massive land clearing, or military activity which generate large amounts of dead and decaying vegetation over a large area. Within a few months, this plentiful food supply produces massive numbers of adults that emerge and then feed in the crowns of surviving palms. The high rate of attack results in high palm mortality. These dead palms quickly begin to rot and become ideal CRB breeding sites, generating even higher numbers of adults, which kill even more palms. In the absence of natural enemies, green waste management, or introduced biological control agents, this self-sustaining feedback cycle may result in the loss of most palm trees on an island.

An example of this positive feedback cycle occurred in the Palau Islands as a result of massive destruction of palms and other vegetation during the Second World War. Prior to the war, CRBs were very rare in Palau; shortly afterwards, about 50 percent of coconut palms were killed by the CRB throughout the archipelago, and some islands lost all of their palms.

Uncontrolled outbreaks of CRB-G are currently happening on Guam and areas of Solomon Islands and Papua New Guinea (PNG).

Geographic Distribution

Islands in the Pacific and Indian Oceans were invaded by the CRB during three waves of movement (fig. 7). The first wave started in 1909 when the CRB was accidentally transported from Sri Lanka to Samoa with a shipment of rubber tree seedlings. A second wave of invasions introduced CRB to the offshore islands of PNG during World War II. These waves ended during the 1970s. All of the CRB range expansion during this period was south of the Equator except for the invasion of the Ryuku Islands (Japan) starting in 1921 and invasion of the Palau Islands prior to 1943.

A third wave of CRB invasions started in 2007 with discovery of the CRB on Guam, followed by invasion of Oahu (Hawaii); Port Moresby (PNG); Guadalcanal, Savo, and Malaita (Solomon Islands); and Rota (Commonwealth of the Northern Mariana Islands). Beetles in the third wave of invasions are genetically different from those in the earlier waves and these are being referred to as the Guam biotype or CRB-G.

Control Tactics

Eradication

In theory, eradication of a CRB population from a newly invaded area can be attained by blocking invasion pathways coupled with finding and destroying all breeding sites. In practice, eradication has proven to be very difficult after initial establishment of a CRB population, despite early detection and rapid response.

Only one of many eradication attempts has succeeded. This was accomplished on Niuatoputapu Island (also known as Keppel Island), a tiny island (36 km^2) that lies between Samoa and Tonga. From 1922 to 1930, all CRB breeding sites were located and destroyed.

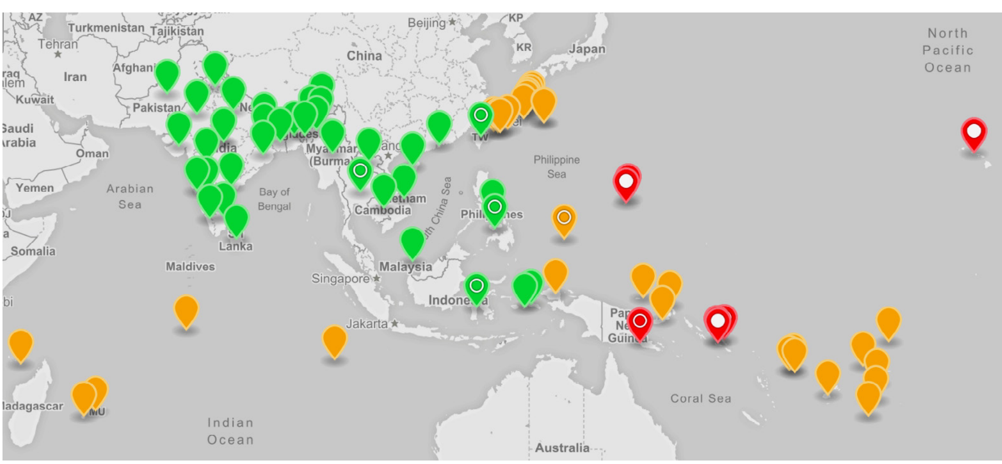

Figure 7. Screenshot of an online interactive web map showing the geographic distribution of the coconut rhinoceros beetle. Green markers signify native range; orange markers signify first detection during the 20th century; red markers signify first detection during the 21st century. An open circle means the population includes CRB-G biotype; a filled circle means the population is exclusively CRB-G biotype. Map by University of Guam.

Sanitation

Sanitation includes detection and destruction of active and potential CRB breeding sites.

Breeding Site Detection

Local searches for breeding sites are usually initiated in response to visible damage to palms or capture of adults in pheromone traps. In Guam and Hawaii, dogs trained to detect CRB grubs have been deployed to assist human searchers. Recent research suggests that CRB adults fitted with miniature radio transmitters or harmonic radar tags may be a cost-effective way of detecting cryptic breeding sites. The essential idea is that the radio transmitters and tags will accumulate at breeding sites where adults aggregate. These tags can then be detected by ground and/or aerial surveys using radio receivers or harmonic radar transceivers.

Removal of Standing Dead Palms

CRB adults are attracted to standing dead palm trees that have begun to rot from the crown. Females will lay their eggs in the rotting palm trunk and the developing larvae will feed on the decaying fibers near the top of the trunk, which starts to decompose in the center forming a protective tube for larval development. As the larvae increase in size and their mandibles strengthen, they can penetrate further down the trunk leaving a column of frass and cut fibers. Dead standing palms should be felled, cut flush to the ground, and cut into pieces that can be burned, buried, or processed via active composting to prevent development of breeding sites.

Larvae may develop in the crown of live palms if organic matter accumulates in the frond bases. The organic matter should be removed where possible.

Disposal of Dead Felled Palms

Mature palm trees will fall after being weakened by fungal diseases (*Ganoderma*), after strong winds during tropical cyclones, or after the felling of senile palms prior to replanting. Dead palms on the ground should be cut into manageable lengths or chipped prior to disposal by burning, deep burial, or active composting.

Covering of Palm Stumps

Felled palms leave a stump that is suitable for development of larvae as it rots. In management of palm plantations in Asia, where a zero-burning policy is in operation, ground cover is planted shortly after felling to cover the debris and make it less attractive to the flying beetles. The legumes *Mucuna* spp. and *Pueraria javanica* are ground cover plants that are commonly used, as they will add nitrogen to the soil and cover decaying stumps and trunks.

Management of Organic Matter and Compost

Heaps of organic matter, particularly palm debris, provide excellent food material for development of CRB larvae. Any deep piles of organic material will be attractive to egg-laying females. Heaps of fronds or empty oil palm fruit bunches are particularly attractive. Sawdust from sawmills that process palm timber is also a favorable resource for beetle development. General compost, farmyard manure, and even organic garbage can provide sites for development of the larvae.

The first step in reducing the threat of beetles emerging from composts is management of the organic matter. Palm debris should be spread among the palms to break down rapidly and release nutrients rather than being piled in heaps. Compost or farmyard manure should be turned regularly, and larvae removed, or pigs and chickens can assist by eating exposed larvae. In urban environments, organic material is often gathered during environmental cleanup and composted, but this may provide a center for reinfestation of the locality. Compost can be sterilized or fumigated to kill larvae; however, this process is energy-demanding and expensive. Sterile compost will also be susceptible to reinvasion. Where feasible, compost heaps can be covered with netting to trap emerging beetles.

Burning CRB breeding material is the most dependable method for removing the food source for CRB grubs. In Hawaii's CRB sanitation programs, breeding site material is being burned onsite using air-curtain burners, and some is being trucked to a waste-to-energy electrical power generation plant.

Trapping

CRB trapping can be used for different purposes, including surveillance for early detection, monitoring growth and spread of a population over time, and population suppression by mass trapping. In all cases, the trap needs to be attractive enough to draw in beetles from a distance and strong enough to contain them once they are captured. Olfactory and visual attractants can be used to increase trap catch.

Simple Traps

One of the first traps to be developed was the Hoyt trap made from a metal can set on top of a coconut trunk or wooden post (fig. 8). The can was capped with a length of coconut stem with a hole in the center large enough for a beetle to enter. The trap system was used extensively and functioned because it mimicked a standing, decaying coconut stem, which is attractive to CRB adults.

Artificial Breeding Sites

An artificial breeding site trap can easily be constructed simply by laying coconut log sections on the ground (fig. 9). Trap catch can be enhanced by covering the logs with netting (see section on netting below) and/or providing a pheromone source.

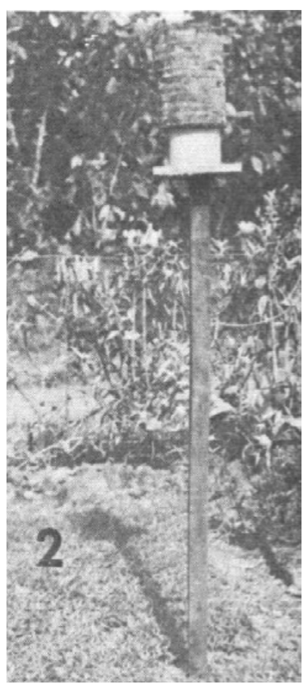

Figure 8. A Hoyt trap for capturing coconut rhinoceros beetle adults. Photo courtesy of Trevor Jackson, AgResearch.

Figure 9. Traps for capturing coconut rhinoceros beetle adults constructed using coconut logs shrouded with tekken netting. Photo by Kenneth Puliafico, Colorado State University.

Pheromone Traps

Design and utility of traps changed with the discovery of ethyl chrysanthemate as an attractant. This was rapidly superseded by ethyl-4-methyloctanoate (E4-MO), the male-produced aggregation pheromone of CRB that attracts both sexes. E4-MO can be synthesized and has been used for more than 30 years in commercial products—known as oryctalure—from several companies.

Pheromone traps for surveillance need to be robust, inexpensive, attractive to beetles, difficult to exit, and simple to service. Simple bucket traps are used extensively for monitoring throughout the Pacific Islands and Southeast Asia (fig. 10). Vaned bucket traps (fig. 11) and panel traps (fig. 12) have been used in surveillance trapping in Guam and Hawaii where thousands of traps have been deployed to monitor the spread of CRB populations and success of control activities.

Efficacy of Pheromone Traps for Population Suppression

Trapping removes adults from the population and may contribute to pest and damage reduction. Bucket traps baited with pheromone have been reported to reduce CRB populations in Malaysia and the related *O. monoceros* in West Africa.

However, efficacy of pheromone traps for populations of CRB-G is in question. Mass trapping was performed on Guam shortly after detection of the CRB in the Tumon Bay area in 2007. There was no indication of population suppression and trapping did not reduce damage to palms in the mass trapping areas. During 2010, the trap catch rate in Tumon Bay was only 0.006 beetles per trap day, but CRB damage was visible in 100 percent of coconut palms. In contrast, a similar mass trapping program in Samoa trapped 0.150 beetles per trap day, 25 times the Guam trap-catch rate, but the proportion of damaged coconut palms was only 30 percent. Note that the Guam population is the CRB-G biotype and the Samoan population is the CRB-S biotype.

Figure 10. A bucket trap for capturing coconut rhinoceros beetle adults. An oryctalure dispenser is hung from the lid, inside the bucket. Beetles enter through holes in the top and sides of the bucket. Photo by Trevor Jackson, AgResearch.

Figure 11. A vaned bucket trap for capturing coconut rhinoceros beetle adults. An oryctalure dispenser is visible at the center of the vanes. Photo by Aubrey Moore, University of Guam.

Figure 12. A commercially manufactured panel trap for capturing coconut rhinoceros beetle adults. An oryctalure dispenser is hung in the rectangular hole at the center of the vanes. Photo courtesy of Darek Czokajlo, Alpha Scents, Inc.

Three possible explanations have been suggested to account for these observations:

1. Traps baited with oryctalure are more attractive to CRB-S than CRB-G.

2. CRB-G individuals do far more damage than CRB-S individuals.

3. At very high population levels and trap densities there is so much pheromone in the air that beetles cannot navigate to pheromone sources.

In mark-release-recapture experiments on Guam only 64 of 567 (11 percent) marked beetles were recaptured in a grid of traps baited with oryctalure, indicating that oryctalure is not highly attractive to the CRB-G biotype. Unfortunately, there are no comparative data for the CRB-S biotype.

Netting

Tekken, a gill net used by Chamorro fishermen on Guam, has proven to be an effective trapping tool for coconut rhinoceros beetles. Beetles are captured when a strand of the netting falls into the gap behind a beetle's pronotum, in the same way that fish are caught when a strand falls into a gill slit (fig. 13). In Guam, heaps of organic waste are covered with tekken, which traps outgoing beetles emerging from the pile and incoming beetles attracted to the heaps for mating and oviposition (fig. 14).

Cheap and simple pheromone traps, called DeFence traps, can be made by attaching pieces of tekken to fences and placing an oryctalure dispenser at the center of each piece (fig. 15).

Figure 13. An adult coconut rhinoceros beetle captured by tekken fish netting. Photo by Aubrey Moore, University of Guam.

Figure 14. Tekken fish netting used to cover a pile of green waste. Photo by Aubrey Moore, University of Guam.

Figure 15. A DeFence trap for trapping coconut rhinoceros beetle adults, constructed by attaching a piece of tekken fish netting to a fence and hanging an oryctalure dispenser near the center. The dispenser shown here has the oryctalure covered by a cup to protect it from the sun and wind. Above the cup is a solar-powered, ultraviolet light emitting diode, which can increase trap catch by a multiple of 3 compared to traps without a light emitting diode. Photos by Aubrey Moore, University of Guam.

Chemical Control

Chemical control of CRBs is difficult because all life stages live in protected habitats: grubs and adults may be found inside dead logs or buried in or under heaps of decaying vegetation, and adults may be found boring into palm crowns only briefly, for a few days during feeding bouts.

Federal and State pesticide regulations should be checked before planning any chemical control activities.

Foliar Application

Foliar insecticide application is aimed at preventing palm damage or mortality caused by adults. The pyrethroid cypermethrin has been used to successfully protect coconut palms and oil palms. A high enough volume should be applied so that the pesticide runs down the midrib and pools at the base of the petiole where it meets the crownshaft. This is the location where CRB adults initiate boreholes. Foliar sprays may be applied by hydraulic sprayers or by pesticide applicator drones.

Trunk Injection

Trunk injections of systemic insecticides have been applied to oil palms and coconut palms with variable success.

Treatment of Breeding Sites

Cypermethrin applied as a drench controls all life stages in heaps of loose breeding site material but may not kill adults and grubs living inside logs.

Biological Control

Biological control is the use of natural enemies (predators, pathogens, parasites) to suppress pest populations. In its native range, the CRB is attacked by a community of coevolved natural enemies, including pathogenic viruses and fungi, predatory carabid and elaterid beetles, and parasitic *Scolia* wasps. The relative impact of each natural enemy species within this native community is poorly known, with additional control strategies often needed to complement biological control in coconut and oil palm plantations.

When CRB-S invaded the Pacific, it was the focus of a substantial biological control program. The aim was to find one or more natural enemies in the native range that could be introduced to the invaded range to suppress CRB-S populations. This process is known as classical biological control. Among many natural enemies introduced to the Pacific, very few predators or parasites became established. Incidental predation by pigs and chickens on CRB larvae may assist with control of this pest and can be useful for control of larvae in household or community waste piles. Local species of generalist arthropod predators (centipedes, beetles, ants) may feed on CRB larvae; however, there is little evidence that this contributes significantly to CRB control.

Only one pathogen provided significant control of CRB-S: the *Oryctes rhinoceros* nudivirus (OrNV) discovered in Malaysia by the German scientist Dr. Alois M. Huger in 1963. This virus infects CRB-S larvae and adults, causing death after 6–30 days. Infected adults are weakened prior to death so that they stop feeding, their mobility is reduced, and females stop laying fertile eggs. Once established in countries invaded by CRB-S, the virus significantly reduced CRB populations and the damage they caused. OrNV persists in CRB-S populations and has effectively suppressed damage and population levels for decades after introduction.

Another approach to biological control for CRB was to create a biopesticide from a known entomopathogenic fungus. CRB adults and larvae can be infected by *Metarhizium majus* (formerly *M. anisopliae* var. *majus*). This fungus has been developed into a biopesticide that can be applied to CRB breeding sites in both the native and invaded range.

The recent invasion of CRB-G has changed CRB management wherever the new biotype is found. CRB-G is not susceptible to strains of OrNV introduced originally to control CRB-S in the Pacific. A new biological control effort is underway to identify strains of OrNV from the CRB's native range that are effective against CRB-G. Until an effective OrNV strain is discovered, biopesticides containing *M. majus* are the only option for biological control of CRB-G.

In some jurisdictions, biological control agents are regulated as pesticides. For example, the U.S. Environmental Protection Agency regulates OrNV and *M. majus* as pesticides. Federal and State pesticide regulations should be checked before using biological control agents for CRB.

Figure 16. Damage index 0: Zero damage; no CRB damage visible. Photo by Trevor Jackson, AgResearch.

17. Damage index 1: Light damage; notching or tip damage; less than less than 20-percent foliar loss. Photo by Trevor Jackson, AgResearch.

Damage Surveys

A standardized method has been developed for quantifying CRB damage (for details see Jackson et. al 2020). This method uses a five-level scale as illustrated in the following figures (figs. 16–20).

This method can be applied by direct visual observation or by scoring palms appearing in images. Research is underway to develop automated detection and mapping of CRB damage by applying computer vision techniques to images recorded during ground-based and aerial drone surveys.

Figure 19. Damage index 3: High damage; greater than 50-percent foliar loss. Photo by Trevor Jackson, AgResearch.

Figure 18. Damage index 2: Medium damage; multiple fronds damaged; notching and breakage; 20- to 50-percent foliar loss. Photo by Trevor Jackson, AgResearch.

Figure 20. Damage index 4: Dead or moribund; meristem destroyed. Photo by Trevor Jackson, AgResearch.

Integrated Pest Management

Integrated pest management (IPM) is a broad-based approach that integrates practices for economic control of pests. The Food and Agriculture Organization of the United Nations defines IPM as: "The careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations. It combines biological, chemical, physical and crop specific (cultural) management strategies and practices to grow healthy crops and minimize the use of pesticides, reducing or minimizing risks posed by pesticides to human health and the environment for sustainable pest management."

IPM for CRBs includes a combination of the tactics described above. For coconut palms planted for subsistence, ornamental purposes, or in commercial plantations, IPM for CRBs involves:

1. Monitoring of palm damage to detect localized CRB outbreaks and to check that control is successful.

2. Biological control with OrNV (in the invaded and native range) and other coevolved natural enemies (in the native range only).

3. Sanitation to remove organic waste, dead palms, and other potential breeding sites.

Sanitation is an essential component of IPM for the CRB that complements biological control. Localized CRB outbreaks will occur when breeding sites are left uncontrolled, especially after cyclones and tropical storms, when palms are often toppled by high winds and large amounts of green waste are created. Historically, outbreaks of the CRB often follow cyclone damage or large-scale land clearing. Larvae will develop in the decaying fronds, the trunk, the roots of felled palms, and in many other forms of decaying vegetation.

Some additional options may be incorporated into IPM programs for coconut, particularly for commercial plantations or ornamental palms. These more costly options include pheromone traps to monitor adult beetle activity and visual surveys of palm damage. Occasionally, trap catches may be high enough to contribute to significant population suppression in coconut plantations, but this strategy is more relevant to oil palm. If a recent CRB invasion is targeted for eradication, insecticides may be necessary for success.

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Author Credits

Aubrey Moore, Professor of Entomology, University of Guam

Trevor Jackson, Senior Scientist, AgResearch, New Zealand

Roland Quintugua, Extension Associate for Invasive Species, University of Guam

Robert Bevacqua, Extension Associate for Forest Health/Agroforesty, University of Guam

Jonae Sayama, Graduate Research Assistant for Entomology, University of Guam

Ross Miller, Professor of Entomology, University of Guam

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