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The role of *Oryctes* nudivirus in management of the coconut rhinoceros beetle, *Oryctes rhinoceros*

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The coconut rhinoceros beetle (CRB), *Oryctes rhinoceros* L. (Scarabaeidae, Dynastinae) is endemic to South East and Southern Asia where it is traditionally known as a pest of the coconut palm (*Cocos nucifera*) and more recently the oil palm (*Elaeis guineensis*). The insect has a very close association with palms where the adult beetles cause damage by mining into the emerging spear and feeding on the soft developing leaf tissues. In cases of severe attack, beetles will kill the palm and lay eggs within the decaying stem where the larvae feed and develop on the rotting tissue, pupating and emerging as adults to continue the damage cycle. Within the endemic region CRB is a pest following exceptional circumstances, where cyclones, volcanic activity or palm plantation clearance lead to an abundance of rotting palm trunks providing an abundance of material for insect development and an outbreak of the damaging adult beetles.

When the beetle was accidentally introduced into the Pacific island of Samoa in 1909 from Ceylon, damage to coconuts was severe and continuous. CRB spread through surrounding Pacific islands and also expanded its range into the Indian Ocean. The vigour of the invasive populations led German scientist Dr Alois Huger to hypothesise that the invasive populations had "escaped" the control of natural enemies from their endemic zone and initiate a search for controlling agents in Malaysia. This led to the discovery of a virus disease that infected both larvae and adults. The causal agent was identified as a non-occluded virus first described as *Rhabdonovirus oryctes* and later *Oryctes* virus until its current classification as *Oryctes* nudivirus.

Preparations of the virus from fresh gut macerates were introduced into the Pacific Island CRB populations with dramatic effects. Virus was first released in Samoa, followed by Fiji, Tonga and the other infested Pacific islands. In all cases, infection was recorded in the target populations and dramatic reductions in damage to palms were noted within 18 – 24 months of virus release. Success of the programme led to releases in other areas of the Pacific, the Indian Ocean and in endemic areas where palm plantation renovation has led to major outbreaks.

The development of a PCR detection method for the virus (Richards et al. 1999) has allowed more detailed study of the epizootiology of the disease. Once introduced, the virus rapidly spreads through the adult beetles and persists through time (Ramle et al. 2011). Success of the simple release method appears to be due to the pheromone-stimulated aggregation behaviour of beetles in the crowns of the infested palms which allows ready transmission from infected to healthy beetles. Once infected, feeding and vigour is reduced leading to a reduction in damage. Virus detection levels in beetles are high in both the endemic areas and zones where virus has been released. A campaign for release of virus into outbreak areas was held through the 1970s and 1980s leading to beetle suppression and since that time there has been little movement of CRB into uninfested areas.

Unexpectedly, a highly damaging outbreak was reported from Guam (2007) that was unable to be controlled by commonly used biocontrol isolates of OrNV. Subsequently, new invasions were also reported from Port Moresby, Papua New Guinea (2009); O'ahu, Hawai'i (2013); and Honiara, Solomon Islands (2015). We identified that all of these new outbreaks were caused by a previously unrecognized haplotype, CRB-G, which appears to be tolerant/resistant to OrNV. PCR analysis shows that OrNV is generally present at high incidence in established populations of CRB, but is absent from the invasive

CRB-G populations. CRB-G from Guam was not susceptible to OrNV infection by oral delivery, but injection of the virus did cause mortality. Further genetic analysis shows that Pacific populations of CRB can be divided into a number of clades that coincide with the endemic and invasive history of the beetle. Analysis suggests that CRB-G originated in Asia, though the precise location remains to be discovered.

It appears that CRB is held in check by OrNV and other natural enemies within its endemic range except following exceptional conditions, like cyclones and felling of standing palms, which provide an abundance of breeding sites. At these times, implementation of IPM, crop hygiene, management of biocontrol agents, is usually sufficient to control the pest. In contrast the newly discovered CRB-G is invasive, highly damaging and does not respond to the virus biocontrol. In addition CRB-G is spreading and poses a threat to the whole of the Pacific region and beyond. A concerted effort is needed to overcome the threat posed by this pest.

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