

PROSPECTS FOR BIOLOGICAL CONTROL OF TARO BEETLES, *PAPUANA* SPP. (COLEOPTERA: SCARABAEIDAE), IN THE SOUTH PACIFIC

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Abstract

Adults of taro beetles, *Papuana* spp. (Coleoptera: Scarabaeidae), damage corms of taro (*Colocasia esculenta*) and other aroids and, less seriously, a range of other crops in five countries in the South Pacific (Papua New Guinea, Solomon Islands, Vanuatu, Kiribati, and Fiji).

Previous control measures were based on the use of pesticides, which is inappropriate in subsistence agriculture. The present project (South Pacific Commission/European Community (SPC/EC) Project for the Biological Control of Taro Beetles in the South Pacific, part of the Pacific Regional Agricultural Program) aims to develop cultural and biological control of the beetles. Studies on taxonomy, distribution, biology, ecology, and cultural and biological control are in progress; the latter focus on the use of pathogens.

Introduction

Taro beetles (Coleoptera: Scarabaeidae: *Papuana* spp.) are shiny black scarab beetles, ranging from 15 to 25 mm in size. The males of most species have horns or tubercles on the head and depressions on the pronotum. The adults attack taro and a number of other plants in five countries in the Pacific.

Taro (*Colocasia esculenta*) is a traditional and preferred root crop staple of many Pacific Island countries. In Kiribati, the giant swamp taro (*Cyrtosperma chamissonis*) is grown instead, but this, too, is attacked by taro beetles. In Kiribati, Papua New Guinea, Solomon Islands, and Vanuatu, taro is primarily a subsistence crop, whereas in Fiji, Tonga, and Samoa, it is a major commercial crop.

Previous studies in Papua New Guinea, Solomon Islands, and Fiji have investigated chemical control methods, but the only effective insecticides had long term persistence in the soil and lindane was the only one recommended. Indeed, pesticide use is inappropriate in subsistence agriculture and particularly so in the atoll environment of Kiribati. A method based on cultural and biological control methods would be much more appropriate for these situations.

Taro beetles are closely related to coconut rhinoceros beetle (Coleoptera: Scarabaeidae: *Oryctes rhinoceros*). In the 1970s, following many years of research into and introductions of biocontrol agents (Waterhouse and Norris 1987), this insect was successfully brought under control in several Pacific island countries using a baculovirus from Malaysia, the area of origin of the beetle (Bedford 1980 1986, Young 1986).

Tests with this virus in Fiji on *P. uninodis* gave positive results (Zelazny et al. 1988). A project to look in more detail at this and other pathogens was therefore proposed. This led the development of a regional project to consider biological control of these beetles in the South Pacific.

SPC/EC Project on Biological Control of Taro Beetles in the South Pacific

The project is being implemented by the South Pacific Commission as part of the Pacific Regional Agricultural Program funded by the European Community. It is based at Dodo Creek Research Station, Honiara, Solomon Islands where four scientists (two ecologists and two pathologists) work in a newly constructed and equipped laboratory designed for insect pathology studies. The project is regional, involving Fiji, Kiribati, Papua New Guinea, Solomon Islands, and Vanuatu.

The aims of the project are to develop biological and cultural control techniques for reducing crop losses caused by taro beetles (*Papuana* spp.), to assist with the distribution of agents found to be successful, to disseminate information on other control methods, and to develop control measures for other beetle which are serious pests in the region.

This paper describes some of the work in progress since the start of research in January 1991.

Taxonomy

There are 19 known species of *Papuana* (Endrodi 1971, 1985), of which eight are recorded as major pests of taro. Accurate identification of these species is important so that the distribution of each can be determined. For

biological control, it is likely that not all of the species will be susceptible to the same biocontrol agents and there is evidence that different species breed in different habitats. Specimens have been collected from each of the project countries, and specimens in other collections, usually in government agricultural research sections, have been examined. Some species are very variable and are difficult to determine using the keys given by Endrodi (1971, 1985), but extra distinguishing characters have been found and are being studied further.

Distribution

The center of origin of *Papuana* spp. is the island of New Guinea where 14 species occur. There are two species in Philippines, one in the Moluccas, one in northern Australia, four in the Solomon Islands, and two in Vanuatu. Kiribati and Fiji both have one species, which became established in 1934 and 1984, respectively, and the beetles are of quarantine significance to other Pacific island countries.

Life Cycle

Taro beetles breed in soil. For laboratory cultures, previous studies on taro beetles (Perry 1977) and coconut rhinoceros beetles (Bedford 1976) have used a 1:1 mixture of cowdung and sawdust. This method has been successfully used in the present study.

Cultures of several species of taro beetles have been set up for life cycle studies. For *P. uninodis*, the life cycle lasts for 19 weeks in the laboratory in Solomon Islands. This compares with other studies on *P. uninodis* in Fiji which found a life cycle of 22 to 25 weeks (Autar and Singh 1988) and for *P. huebneri* and *P. woodlarkiana* in Papua New Guinea which found a life cycle of 20 weeks and 28 weeks, respectively (Perry 1977). A mass culture of *P. uninodis* has also been set up to provide insects for tests of pathogens.

Breeding Habitats

Several species of scarab larvae can be collected from soil and rotting vegetation in the Solomon Islands. To enable breeding habitats to be identified, it was necessary to be able to distinguish between these larvae. Bedford (1974) provides keys and descriptions for some of the larger Dynastine beetles, but no information was available for smaller species which could be confused with taro beetles.

Larvae were therefore collected, drawn, described, and preserved while some were bred through to adult for identification. Seven species from the subfamilies

Dynastinae, Cetoniinae, Rutelinae, and Melolonthinae have now been bred, and it is now possible to identify taro beetle larvae in the field in the Solomon Islands without the need for further breeding.

Breeding occurs in the soil. Larvae are rarely found in taro gardens, and do not themselves feed on taro, but are often found in suitable habitats around the edge of the gardens. There is evidence for two species that breeding habitats are different. *P. uninodis* larvae have been found in light soils with low weed or grass cover or, in some cases, with no vegetation (e.g., weeded edges of gardens). *P. uninodis* larvae have often been found in small numbers, but up to 17 have been found in one square meter in the Solomon Islands. *P. woodlarkiana* have been found in stands of *Phragmites* weeds in the Solomon Islands and in *pitpit* (*Saccharum spontaneum*) (Perry 1977) and large scale sugar cane plantations (L. Kuniata, pers. comm.) in Papua New Guinea. The density of larvae in breeding sites would have significance for the development of diseases.

Damage

The adults of taro beetles burrow into corms of taro (*Colocasia esculenta*) and other aroids (*Xanthosoma sagittifolium*, *Cyrtosperma chamissonis*) making smooth sided tunnels with the same diameter as their width. In severely damaged plants, the tunnels run together to form large cavities and secondary rots often develop. Damage to other root crops (sweet potato, yams, and potato) is of a similar form. The beetles occasionally ring bark young tea, cocoa, and coffee plants in the field and bore into seedlings of oil palm and cocoa. Other recorded hosts include Canna lily (*Canna indica*), pandanus (*Pandanus odoratissimus*), a fern (*Angiopteris evecta*), betel nut (*Areca catechu*), and cabbage (Thistleton 1984, Macfarlane 1987, Sar et al. 1990).

Two methods are used for assessment of damage to taro. One assesses the number and weight of corms in each of five damage categories, ranging from undamaged and saleable to completely damaged and not even suitable for animal consumption, and is useful for determining qualitative and economic loss. This method is very similar to ones used by previous studies in the Solomon Islands and Papua New Guinea.

A second simple assessment method has been developed which allows the calculation of weight of taro consumed and hence the calculation of the yield loss per plant or per unit area. For surveys and experimental studies, this allows more accurate comparisons of actual intensity of damage between areas and treatments.

It was originally intended to carry out surveys to

determine baseline damage levels to compare with the levels following biological control. Initial surveys were carried out in Papua New Guinea, the Solomon Islands, and Vanuatu. It was often not possible to obtain large enough samples due to small garden size, different plant ages, and different varieties. However, the information has shown that in many areas damage levels are high with large losses of weight. In addition, it has been shown by this work and by other studies in Papua New Guinea (Gaupu et al. 1990) that even a small amount of damage substantially reduces the value of the taro corms. In addition, in some areas farmers have ceased to grow taro due to the intensity of beetle attack or to a combination of this and the effects of fungal and virus diseases (Solomon Islands).

To obtain more accurate base-line data, plots of taro have been planted by the project in various areas of the Solomon Islands and regular samples made of populations and damage.

Cultural Control

Cultural control methods which have been used by farmers include tolerant varieties, wood ash, flooding, trap cropping, mulching, intercropping, repellent plants, and time of planting. Trials are in progress to test some of these.

Biological Control

Two parasites of taro beetles have been recorded--a scoliid wasp (Lever 1934, Smee 1965) and a tachinid fly (Perry 1977), but they are uncommon and their use for biological control is not promising. The biological control studies have therefore concentrated on the use of pathogens, based on the success of the earlier coconut rhinoceros beetle project.

There is one important difference between the two projects which affects the strategies chosen. The coconut rhinoceros beetle (*O. rhinoceros*) is an insect which had been introduced into the Pacific. In the area of origin, this insect was not a pest, and it was possible to find and introduce pathogens which were keeping it under control there.

For taro beetles, it is necessary to control the insect in the area of origin. In this case, any pathogens will already be present, although at present not giving adequate control.

Surveys of these naturally occurring pathogens are important for two reasons: 1) it is good biological control practice to know what is already present before new releases are made, and this is recommended in recently

published guidelines (Waterhouse 1991); 2) the strains of diseases isolated from taro beetles are likely to be more effective than the same diseases isolated from other insects.

There are also a number of diseases of other scarab beetles which are being used for biological control (Glare and Jackson 1992), and the project has imported a number of these into the Solomon Islands for testing. Preliminary tests in the laboratory of these pathogens on larvae and adults of *P. uninodis* are currently in progress.

Virus

The virulence of the baculovirus, *Baculovirus oryctes*, for *Oryctes* species in other parts of the world has led to its successful introduction into the South Pacific as a biological control agent for the coconut rhinoceros beetle. The virus is self perpetuating. Infected adults are released and transmit the disease to adults and larvae in their breeding habitats.

This success was the basis of the tests of the virus on adult taro beetle in Fiji (Zelazny et al. 1988). Positive results of these tests were indicated by a white swollen midgut which is the most diagnostic symptom of infection. Infection was confirmed by feeding these midguts back to healthy *Oryctes rhinoceros* adults.

Six strains of this virus were supplied by Paul Scotti of the Department of Scientific and Industrial Research, Auckland, New Zealand. Tests of these strains showed positive symptoms on a few adults fed with one strain only. Tests will be repeated for these strains and fresh virus material from either Fiji or Western Samoa will also be tried.

Fungi

There are relatively few species of entomopathogenic fungi that are active against scarab species. These include common entomopathogenic fungi that are currently under investigation for use as biological agents of scarab pests in several countries. These fungi have also been selected for our tests.

Metarhizium anisopliae

This is a common fungus that attacks many soil insects, and it is the only species of *Metarhizium* that has been found attacking scarabs (Glare 1992). For example, it is an effective control agent for the pasture scarab, *Acloryphorus couloni* (redheaded cockchafer) in Tasmania, Australia. This has led to its formulation as granules that are being developed as a commercial product known as DAT F-101 which has reduced the pest population by 94

percent (Rath 1992). In Samoa, *Metarhizium* has long been established as a second main biocontrol agent to the baculovirus for the coconut rhinoceros beetle (Waterhouse and Norris 1987). In fact, it was proposed as a candidate to control the coconut rhinoceros beetle before the success of the baculovirus.

The fungus occurs naturally in the field under favorable conditions. Adults, pupa, and larvae of the taro beetle were found in our insect mass culture being infected by the fungus. Isolates from these specimens are in culture. Five strains of *Metarhizium anisopliae* were supplied by the International Mycological Institute (IMI), United Kingdom, and 21 by Andrew Rath of the Department of Primary Industry, Tasmania, Australia. A number of local *Metarhizium* isolates and one of the introduced strains from IMI have been tested. Tests using fungal isolates from our mass culture applied in an oil suspension on larvae are in progress.

***Beauveria* spp.**

Two species of this fungus, *Beauveria bassiana* and *B. brongniartii*, are active against scarabs. *Beauveria bassiana* is the more common of the two and is one of the most common fungi found throughout the world, but *Beauveria brongniartii* is more commonly found in Scarabaeidae (Glare 1992). It has been used for approximately 100 years to control white grubs and adults in Europe (Zimmerman 1992). Cultures of these are to be supplied by the International Rice Research Institute.

Bacteria

Bacterial pathogens are also utilized in some scarab biocontrol programs in the world today. In the United States, the bacteria, *Bacillus popilliae*, that causes milky disease has been used for the suppression of the Japanese beetle larvae for more than fifty years (Klein and Jackson 1992). It was the first pathogen to be developed commercially and registered as a microbial product. Other bacterial pathogens that were found being associated with scarabs are *Bacillus thuringiensis* and *Serratia* spp. These bacteria have also been considered for testing.

Bacillus thuringiensis

This bacteria has often been isolated from a number of dead and dying scarabs (Klein and Jackson 1992). The bacteria produces toxic parasporal bodies or crystals that break down the gut of an invaded insect leading to its death. A strain of this bacteria was reported to have been isolated from the grass grub, *Costelytra zealandica* in New Zealand (Wigley and Chilcott 1990, quoted by Klein and Jackson 1992). The strain when fed to actively feeding

grub larvae caused cessation of feeding and growth.

Five strains of *Bacillus thuringiensis* have been obtained from Plant Genetic Systems, Belgium. Tests on first and second instars showed high mortality. These tests indicated strain 1 (Cry 3 A) to be more effective than other strains. However this did not show up with the test on third instars where the mortality was very low. These tests will all be repeated.

***Serratia* spp.**

Some of the most facultative bacterial pathogens of scarabs belong to this genus. These have been isolated from different scarabs in many parts of the world. For example, in New Zealand, *S. entomophila* and *S. proteamaculans* were isolated from field populations of the grass grub (*C. zealandica*), causing the amber disease (honey disease) (Jackson et al. 1992). The bacteria *S. entomophila* was developed as a commercial biocontrol agent under the trade name Invade.

Seven strains of *Serratia* have been obtained from MAF Technology, New Zealand.

Nematodes

Nematodes have been reported to be associated with scarabs. Important pathogens of scarab larvae in the soil are nematodes in the family Steinernematidae. A number of Steinernematids have been recovered from Scarabaeidae world wide. An up-date list is presented in Poinar and O'Callaghan (1992). Williams and others (unpublished) conducted a small preliminary experiment in the insectary to test the effect of three species of nematodes on the survival of taro beetle in the Solomon Islands and found 100 percent mortality by *Steinernema glaseri*. It is proposed to test three species--*S. glaseri*, *S. carpocapsae* and *S. feltiae*.

Future Work

Our testing program for these pathogens aims at selecting those that will be most appropriate in keeping the taro beetle population under good control in the field.

The strategies developed for field control will depend on the types of diseases selected and the results of the ecological studies. The most suitable form of control would be a self-sustaining biological control similar to that obtained for the coconut rhinoceros beetle. This beetle has high aggregations of larvae in the breeding sites and the baculovirus is dispersed between these sites by infected adults. Evidence at present suggests that taro beetle larvae are less aggregated and virus dispersal may not operate in the same way.

Some of the other pathogens (fungi, bacteria, and

nematodes) will not be dispersed with the adults. In this case, they will need to be applied to each plot of taro. This will be less satisfactory since it relies on continued supplies of the pathogens and it may not be so suitable for implementation in a subsistence system.

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