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DEVELOPING AN ASIA-PACIFIC STRATEGY FOR FOREST INVASIVE SPECIES: THE COCONUT BEETLE PROBLEM – BRIDGING AGRICULTURE AND FORESTRY

Report of the

Asia-Pacific Forest Invasive Species Network Workshop
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Edited by

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Acronyms and abbreviations

APAFRI	Asia-Pacific Association of Forestry Research Institutions
APCC	Asia and Pacific Coconut Community
APFISN	Asia-Pacific Forest Invasive Species Network
APHCN	ASEAN Plant Health Cooperation Network
APPPC	Asia and Pacific Plant Protection Commission
ARCBC	ASEAN Regional Centre for Biodiversity
ASEAN	Association of Southeast Asian Nations
BAP	Biodiversity Action Plan
BIPM	Bio-intensive Integrated Pest Management
CABI	CAB International
CBD	Convention on Biological Diversity
CDB	Coconut Development Board
CLB	Coconut leaf beetle
CoC	Code of Conduct
COP	Conference of the Parties
CPB	Cocoa pod borer
CPC	Crop Protection Compendium
CPCRI	Central Plantation Crops Research Institute
DAALI	Department of Agronomy and Agricultural Land Improvement
DENR	Department of Environment and Natural Resources
DoA	Department of Agriculture
ENAC	Emergency Notification and Assistance Convention
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmers Field School
GISD	Global Invasive Species Database
GISIN	Global Invasive Species Information Network
GISP	Global Invasive Species Program
GMO	Genetically Modified Organism
IAS	Invasive alien species
IPM	Integrated Pest Management
ISPM	International Standards for Phytosanitary Measures

ISSG	Invasive Species Specialist Group
IUCN	World Conservation Union
MAFF	Ministry of Agriculture, Forestry and Fisheries
MARDI	Malaysian Agricultural Research & Development Institute
MDAE	Municipal Department of Agricultural Extension
MDAFF	Municipal Department of Agriculture, Forestry and Fisheries
MPOB	Malaysian Oil Palm Board
MRB	Malaysian Rubber Board
NACA	Network of Aquaculture Centres in Asia-Pacific
NBSAP	National Biodiversity Strategy Action Plan
NPPO	National Institute of Plant Protection
PDAE	Provincial Department of Agricultural Extension
PDAFF	Provincial Department of Agriculture, Forestry and Fisheries
PPPIO	Plant Protection and Phytosanitary Inspection Office
PRA	Pest risk analysis
RAP	Regional Office for Asia and the Pacific
SBSTTA	Subsidiary Body on Scientific, Technical and Technological Advice
SCOPE	Scientific Committee on Problems of the Environment
TCP	Technical Cooperation Programme
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
USDA	United States Department of Agriculture

Foreword

Graceful coconut palms are a fixture of the tropical landscape, they dot the shoreline like tall posts, ubiquitous in every tropical village, and represent an important cash crop in the Asia-Pacific region. But a mysterious pest began ravaging the palms, scorching and browning the leaves, and ultimately killing the towering individuals. It turned out that the mysterious pest is the palm leaf beetle which previously occurred only in the Pacific islands. If the menace is not halted, it is likely to cause major economic problems especially for rural folks dependent on the crop, not withstanding the ugly scars that would dot the environment.

Obviously the natural barriers, the wide seas and mountain ranges, cannot be effective anymore in a shrinking globe where plant material is moved freely around the region. When FAO became aware of the problem, it took immediate measures to control the spread of the leaf beetle. While chemical control measures can generally be applied, in this case the height of the palm and costs of chemicals have both proven to be prohibitive. FAO took several steps to bring about effective control using biological control methods. Experts were dispatched to several countries to introduce the biological control methods – which include rearing the natural parasites and releasing them in the affected areas, and monitoring subsequent developments. But this remains only one measure among a series of activities needed if proper control is to be brought out. FAO, under the aegis of the Asia Pacific Forest Invasive Species Network (APFISN), has been exploring the range of activities which have to be put in place for effectively controlling the coconut leaf beetle from spreading further.

This proceedings represents the results of a workshop of agricultural and forestry experts from across the region. They call for a need to develop a regional programme to investigate the coconut leaf beetle problem so the status of infestation and effectiveness of the eradication programme can be systematically monitored. The experts also point out the critical need to work between sectors: it is increasingly evident that problems in one sector, for example those in agriculture, can also affect the forest sector in due time. It is therefore extremely desirable that multidisciplinary approaches are adopted to halt the spread of invasive species.

The proceedings also goes beyond the coconut leaf beetle problem to look at the broader issues of invasive species in the region such as technology transfer, policies, institution building, and the importance of farmers' education, all of which are integral parts of pest management.

Finally, I must point out that in FAO's longstanding tradition, the work was undertaken in collaboration with the United States Department of Agriculture Forest Service, Asia Pacific Association of Forest Research Institutes, the Commonwealth Agriculture Bureau International, and APFISN. This publication represents an important starting point for systematic and multidisciplinary approaches to solving problems of invasive species in the region.

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Assistant Director-General and
Regional Representative for Asia and the Pacific

Background and introduction

Recognizing the dangers of invasive species in the sustainable management of forests in Asia and the Pacific, the Asia-Pacific Forest Invasive Species Network (APFISN) was established at the 20th Asia-Pacific Forest Commission Session in Fiji. The network's substantive activities began with a workshop on the development of an Asia-Pacific Regional Strategy for *Eucalyptus* rust in October 2004.

Recently, the network has noted with concern the rapid spread of an invasive species, *Brontispa longissima* (coconut leaf beetle) in Asia. Many member countries of the Asia-Pacific Forestry Commission (APFC) have been hard hit by outbreaks of the coconut leaf beetle. An Expert Consultation on coconut beetle outbreak in Asia and Pacific Plant Protection Commission (APPPC) member countries, organized in October 2004 by FAO Regional Office for Asia and the Pacific (RAP) recommended further regional collaboration in combating the coconut beetle problem.

The experiences and successes in handling the outbreaks of *B. longissima* provide valuable lessons for multidisciplinary approaches to managing invasive species whether in agriculture or forestry. It is increasingly evident that activities, whether with forestry or agriculture, are intimately connected and have profound effects on each other – whether with the movement of invasive species into an area, or solutions to the problems. This reinforces the view that such problems cannot be solved without the active collaboration of both sectors. With this as the background, APFISN together with the USDA Forest Service, FAO and the Asia-Pacific Association of Forestry Research Institutions (APAFRI) jointly organized this workshop.

The workshop was held from 22 to 25 February 2005 at the Que Huong Liberty 4 Hotel, Ho Chi Minh City, Viet Nam. The purpose was to share experiences among forestry and agriculture specialists in handling invasive species and to develop an Asia-Pacific strategy to work in a multidisciplinary manner to address invasive species management. This workshop comprised three days of technical presentations and discussions. One day was spent visiting a laboratory for rearing biological control agents and a field visit was conducted to observe the impact of biological control in bringing invasive species under check.

Participating countries and participants

Participants came from 12 member countries of the APFISN: Bangladesh, Cambodia, China, India, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Sri Lanka, Thailand and Viet Nam. Resource persons were invited to enrich the discussions and learning experiences during the workshop.

While the workshop was of particular importance to those who deal with coconut pest problems, it was open to all individuals working in policy, research and operations relating to forest biosecurity, agriculture, quarantine and protection, including government officials, scientists, industry representatives and private-sector companies with significant forestry trading operations in the Asia-Pacific region.

Current status of the coconut beetle outbreaks in the Asia-Pacific region

P. Rethinam and S.P. Singh[*]

Abstract

Approximately 1 000 species of insects are associated with coconut worldwide. Over 40 species of coleopteran pests have been recorded – most are under effective natural control but some require interventions. Brontispa longissima *is native to Indonesia and also to Papua New Guinea, including the Bismarck Archipelago, where it seldom causes serious problems. It has now migrated to Asia, Australasia and the Pacific Islands attacking not only coconut palm but also cultivated and wild palms. Recently, it has spread to Singapore, Viet Nam, Nauru, Cambodia, Lao PDR, Thailand, Maldives, Myanmar and Hainan Island (China). In the absence of natural antagonists it has become a devastating pest. It is feared that* Brontispa longissima *will find its way from Maldives to Sri Lanka and southern parts of India, thus derailing the economy of these important coconut-growing regions. In this context, emergency operations are necessary to try to destroy it in the Maldives and in other invaded countries. A number of natural enemies have been recorded. Biological control via the introduction and enhancement of parasitoids has been very effective. Similarly spraying of improved strains of the entomofungal pathogen* Metarhizium anisopliae *has met with success. Exploratory surveys for parasitoids in the original home of* B. longissima *are suggested.*

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Chemical control has been recommended, but most of the insecticides recommended earlier have been phased out owing to their harmful side effects. Though difficult to implement, use of tolerant cultivars, adoption of phytosanitary measures and imposition of strict quarantine measures are also recommended. In addition, relatively safer pesticides could also be used to combat the pest before biological control becomes operative and effective. An international network project is required to develop effective management, raise awareness and to train the coconut growers in implementing Bio-intensive Integrated Pest Management (BIPM) of B. longissima.

Introduction

The coconut palm (*Cocos nucifera* L.) has many uses and is an important crop in the tropics, supporting the livelihoods of millions of people. Global production of coconut is around 61.16 billion nuts from an area of 12.06 million hectares. It is grown in over 93 countries and India ranks first in terms of productivity. Nearly 88 percent of annual production occurs in APCC (Asia and Pacific Coconut Community) countries – the Federated States of Micronesia, Fiji, India, Indonesia, Kiribati, Malaysia, Papua New Guinea, the Philippines, Solomon Islands, Sri Lanka, Thailand, Vanuatu, Viet Nam, Samoa and Marshall Islands. Approximately 78 percent of global production is contributed by Indonesia, the Philippines, India and Sri Lanka. Generally, coconut growers are small and marginalized with holdings of less than one hectare. The average productivity of coconut-growing countries is 4 930 nuts/hectare, which could be enhanced to more than 10 000 nuts/hectare through optimum plant and soil health management. About 1 000 species of insects worldwide are associated with coconut. In several cases insect pests are major constraints to enhancing productivity. Coleopteran pests cause varying degrees of damage in different countries.

Coleopteran pests

The major coleopteran pests are listed in Table 1.

Table 1. Major coleopteran pests of coconut

Name of the pest	Geographical distribution	Pest status
Family: Scarabaeidae		
Oryctes boas Fabricius (Rhinoceros beetle)	Confined to Africa	Major
Oryctes monoceros (Olivier) (Coconut beetle)	Widespread in Africa; Middle East	Major
Oryctes rhinoceros (Linnaeus) (Asiatic rhinoceros beetle)	Endemic to South and Southeast Asia; Oceania; Africa	Major
Scapanes australis Boisduval (Melanesian rhinoceros beetle)	Southeast Asia; Oceania	Primary/major
Strategus aloeus (Linnaeus) (Coconut cockle)	Western Hemisphere	Primary
Strategus anachoreta Burmeister	Trinidad and Tobago; Cuba	Primary
Strategus jugurtha Burmeister	Western Hemisphere (Guyana)	Primary
Strategus quadrifoveatus (Palisot de Beauvois)	Western Hemisphere (Haiti; Dominican Republic; Puerto Rico)	Primary
Leucopholis coneophora Burmeister	India	Major, occasionally serious
Family: Chrysomelidae		
Brontispa longissima Gestro (Coconut hispine beetle)	Southeast Asia; Oceania; Australasia	Major
Plesispa reichei Chapuis (Coconut hispid)	Southeast Asia; Oceania	Primary
Promecotheca caerulipennis Blanchard (Fiji coconut hispid)	Oceania (mainly Fiji); Hawaii	Major
Promecotheca cumingii Baly (coconut leafminer)	Sri Lanka; Southeast Asia	Major
Promecotheca papuana Csiki (coconut leafminer)	Indonesia; Oceania	Major

Name of the pest	Geographical distribution	Pest status
Family: Curculionidae		
Cholus zonatus (Swederus)	Western Hemisphere	Primary
Rhinostomus barbirostris (Fabricius) (Bearded weevil)	South America; West Indies	Primary
Rhynchophorus bilineatus (Montrouzier) (black palm weevil)	Indonesia; Oceania	Primary
Rhynchophorus ferrugineus (Olivier) (Asiatic palm weevil)	South and Southeast Asia; Middle East; Oceania; Africa	Major
Rhynchophorus palmarum (Linnaeus) (South American palm weevil)	Confined to New World	Major
Rhynchophorus phoenicis (Fabricius) (African palm weevil)	Widespread in Africa	Major
Family: Cleridae		
Necrobia rufipes (De Geer)	India; Southeast Asia; Africa	Serious in storage
Family: Silvanidae		
Oryzaephilus mercator (Fauvel) (Merchant grain beetle)	Widely distributed in warm temperate and tropical regions	Major in storage
Family: Bruchidae		
Pachymerus nucleorum (Fabricius) (Coconut borer)	Western Hemisphere	Primary

Most coleopteran pests are under effective natural control but some require interventions. Controls for *Oryctes rhinoceros* include baculovirus, habitat management (cover crop and destruction of breeding sites), introduction of *Metarhizium anisopliae* in breeding grounds, mass trapping of adult beetles in pheromone/coconut sawdust/castor cake slurry traps, use of naphthalene balls in young plantations and application of safer pesticides (CFC/DFID/APCC/FAO 2004; Singh and Rethinam 2004 a;b). This paper considers the coconut hispine beetle, *Brontispa longissima* (Gestro).

Distribution of *Brontispa longissima*

Figure 1. *Top*, *Brontispa longissima*, adult and damage *Bottom*, Severly damaged coconut tree

Brontispa longissima is native to Indonesia (Aru Islands, Maluku Province and possibly Papua Province, formerly Irian Jaya) and also to Papua New Guinea, including the Bismarck Archipelago, where it seldom causes serious problems (Figure 1). It is now distributed in Asia, Australia and Pacific Islands attacking not only coconut palm but also several other palm species (Figure 2). *Brontispa longissima* has reached Ari Atol in Maldives from where it could easily spread to Sri Lanka and southern parts of India, if not contained. In Australia it has been recorded in 27 native and exotic palms. Lack of strict quarantine on the movement of palms (particularly ornamentals) is considered as a major factor in the spread of *B. longissima.*

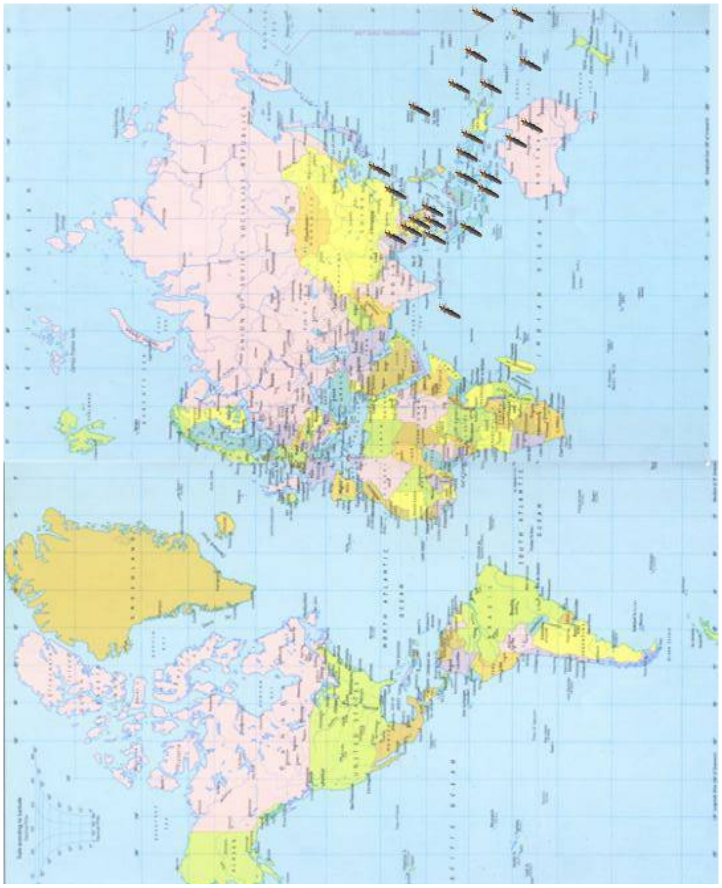

Figure 2. Distribution of *Brontispa longissima*

Development of *Brontispa longissima*

Brontispa longissima is one of the most thoroughly studied pests in Indonesia, with work undertaken in Bogor, as well as Bulukumba and Manado (Franssen and Tjoa 1952).

Adult females lay their 1.4 mm long and 0.5 mm wide brown flat eggs in the still-folded leaflets of both young and mature coconut palms. The eggs are surrounded by debris and excrement, and laid longitudinally in rows of an excavated area of leaf tissue. They hatch in a minimum and maximum period of 3 - 4 and 4 - 7 days respectively.

The whole cycle from egg to adult occupies about five to seven weeks in Java and Sulawesi (Kalshoven 1981; Lever 1969), but can extend to nine weeks in other (presumably cooler) places.

The adult beetle (7.5 to 10 mm long and 1.5 to 2 mm wide) matures two weeks after emergence from the pupa. It lives for two to three months. The female on average lays 120 eggs in the course of several weeks (Kalshoven 1981), which produce 40 larvae. The beetles are nocturnal and fly well. They always live in the still-folded leaflets and move outside only to infest the nearby palms or for mating.

Nature and extent of damage

The larvae and adults of *B. longissima* shun light. They feed on the mesophyll of both surfaces of the closely oppressed leaflets and both stages gnaw long incisions in the tissues, parallel to one another and in the veins of leaflets leaving longitudinal white streaks. Light attacks result in minor leaf injury, and a slight decrease in fruiting at the axils of the damaged leaves. Fruit production is significantly reduced, if eight or more leaves per palm are destroyed.

When the insects are numerous, the incisions are so close to one another that whole of the attacked part of the leaflets is similarly injured and photosynthesis is reduced to zero.
As noted earlier, *B. longissima* has spread to a number of different countries. In the absence of natural antagonists it has become a devastating pest. For example, in parts of Viet Nam, production loss for related industries is approaching 50 percent and there are many dead trees.

It is feared that the beetle will also attack other palm species and may reach Sri Lanka and southern parts of India where it will derail the economy of these important coconut-growing regions. Thus emergency operations are necessary to try to eradicate it in the Maldives and other invaded countries.

The spread of *B. longissima* and other coconut pests in Oceania is mainly attributed to human activities (Dharmaraju 1984).

Factors governing abundance

Dry periods favour the development of *Brontispa* populations (Bariyah and Baringbing 1987; Tjoa 1953; Kalshoven 1981).

Two- to three-year-old young palms attract the pest. The heartleaves of older trees are firmer and become less suitable as breeding grounds and are not penetrated by the beetles.

Stunted palms with less compact hearts are more susceptible to *Brontispa* attacks. Strong monsoon winds reduce the abundance of parasitic wasps, which trigger pest attacks.

Natural enemies of *Brontispa longissima*

The natural enemies of *B. longissima* are presented in Table 2.

Table 2. Natural enemies of *Brontispa longissima*

Species (Order: Family)	Reported locations	Remarks and references
Egg parasitoids		
Hispidophila (*Haeckeliana*) *brontispae* Ferriere (Hymenoptera: Trichogrammatidae)	Java, Indonesia	Described in 1931, one wasp/*Brontispa* egg; parasitized 15 percent eggs in the field (Kalshoven 1981).
Ooencyrtus podontiae Gahan (Hymenoptera: Encyrtidae)	Java, Indonesia	Parasitized 10 percent eggs (Kalshoven 1981). In 1941, *Brontispa* eggs, parasitized by Ooencyrtus were introduced from Bogor. Introduced to several countries for evaluation, recorded in Malaysia.
Trichogrammatoidea nana Zehntner (Hymenoptera: Trichogrammatidae)	Java, Indonesia	Described in 1896, a successful egg parasitoid of *Brontispa* and several other coconut pests. Native to Java (Indonesia); introduced to Fiji, Papua New Guinea and Solomon Islands.
Larval/pupal parasitoids		
Tetrastichus brontispae Ferriere (Hymenoptera: Eulophidae)	Java, Indonesia	Found in 60 - 90 percent of the pupae and 10 percent of the larvae (Kalshoven 1981). Considered a most effective species, widely introduced in the Pacific Islands for the control of *Brontispa*.
Asecodes hispinarum Boucek (Hymenoptera: Eulophidae)		Larval parasitoid of *Brontispa*, collected from Samoa and released in Nauru, Thailand, Viet Nam and Maldives.
Chrysonotomyia sp. (Hymenoptera: Eulophidae)	Samoa	The parasitoid was the most important cause of larval mortality, parasitizing 75 percent of the fourth instar larvae collected from Samoa.

Species (Order: Family)	Reported locations	Remarks and references
Entomopathogenic fungi		
Metarhizium anisopliae (Metchnikoff) Sorokin (Moniliales: Moniliaceae) (Figure 3)	Samoa	Widely distributed soil-inhabiting entomopathogenic fungus. Isolated from *Brontispa* in several locations and successfully used for control in Samoa and Taiwan.
Beauveria bassiana (Balsamo)Vuillemin (Moniliales: Moniliaceae)	Samoa	Common fungus, spraying of coconut trees with 5 x 105 conidia/ml was effective against adults and larvae.
Predator		
Chelisoches morio Fabricius (Dermeptera: Chelisochidae)	Java, Indonesia	Important predator of *Brontispa*, available in most of its distribution zones.

Tetrastichus brontispae–based biological control for Brontispa

Tetrastichus (*Tetrastichodes*) *brontispae* was described from *Brontispa longissima* (Ferriere 1933). It is its main natural enemy and parasitizes the larval and pupal stages (Figure 3). It is native to Java, Indonesia. It has been widely introduced in the Pacific Islands for control of *Brontispa.*

Indonesia

Leefmans propagated the use of biological control of *B. longissima* in 1920. His investigations on parasitoids, demonstrated that *T. brontispae* was the most effective (Leefmans 1935).

The introduction of *T. brontispae* against *B. longissima* in Sulawesi started in 1932 and within three years a total of 37 500 parasitized pupae were sent from Bogor to Makassar (Ujung Pandang).

Figure 3. (Top to bottom)

Tetrastichus brontispae, the most important pupal parasitoid, widely introduced in the distribution zone of *Brontispa*; established successfully, it provides relief from the pest.

Chelisoches morio, important predator of *Brontispa*, available in most of its distribution zones.

Metarhizium anisopliae, isolated from *Brontispa* in several distribution sites and successfully used to control the pest in Samoa and Taiwan Province of China.

M. anisopliae: A simple method for producing *M. anisopliae* in empty wine bottles with coconut water from the copra industry evolved in India; it is an excellent example of the utilization of industrial waste and converting it to a valuable product.

Eventually ten rearing stations were established over South Sulawesi and a total of about 13 million parasitized pupae were reared and released between 1935 and 1941 in various locations. The rate of parasitism among field-collected pupae typically was between 70 and 90 percent. In 1946 it was between 20 and 40 percent.

In 1948/49 the rate of parasitism was on average about 40 percent in the 20 1ocations surveyed. The establishment of *Tetrastichus* brought *Brontispa* under control and the remaining anomalies improved (Franssen and Tjoa 1952).

The earwig, *Chelisoches morio*, is an important predator of *Brontispa* but also feeds on coconut flowers and other organic materials (Figure 3). Its life cycle lasts 75 to 94 days and adults live for three to five months. It is commonly associated with *B. longissima* in most coconut plantations and complements *T. brontispae* and other parasitoids.

Papua New Guinea

Tetrastichus brontispae was imported from the Solomon Islands (origin, Java). Large numbers have been released near Rabaul (New Britain) and parasitized pupae have been recovered. The native egg parasitoid, *Trichogrammatoidea nana*, the larval parasitoid *Chrysonotomyia (Achrysocharis)* sp., two mites associated with the beetles – one identified as *Anoplocelaeno* sp. – and a larval bacterial disease also complement *T. brontispae* and have already been established (O'Connor 1940; Froggatt and O'Connor 1941).

Mariana Islands

Tetrastichus brontispae and *Haeckeliana brontispae,* obtained from Java, were released in 1948 on Saipan and Rota Island for the control of *Brontispa. T. brontispae* appeared to be well established by 1954, sometimes providing parasitism of up to 90 percent.

Solomon Islands

Before *T. brontispae* was released in 1936 against *B. longissima* in Banika Island (Russell Group) (Lever 1937), the red Gasmasid mite (*Celaenopsis* sp.) was introduced in the Russell Islands (Lever 1933). *T. brontispae* was again introduced into the Solomon Islands in 1938, but the outcome was negative. Another introduction in 1968 succeeded. The parasitoid spread over 100 acres by the end of 1969 and was affording parasitism of at least 70 percent, which was sufficient for effective control. The parasitoid spread rapidly and greatly reduced infestation (Stapley 1973; 1979).

The rearing and release of the pupal parasitoid *T. brontispae*, the removal of ants of the genus Pheidole from coconut palms, and the establishment of *O. smaragdina*, which drives out *Brontispa* and other pests has been recommended (Stapley 1980).

New Caledonia

Tetrastichus brontispae was introduced into the Noumea Peninsula, New Caledonia and became established. The rate of parasitism did not exceed 24 percent and even a combination with fungal diseases and the dermapterous predator *C. morio* did not reduce the incidence of the pest to a satisfactorily low level (Cochereau 1969).

Guam

Tetrastichus brontispae was introduced into Guam in 1974 with shipments from Saipan, New Hebrides, New Caledonia and the Solomon Islands. The parasitoids became established and in the early 1980s, rates of parasitism ranging from 2 to 72 percent in different locations were reported (Muniappan *et al.* 1980).

Tahiti

In Tahiti, *T. brontispae* was reared from *B. longissima* (Gourves *et al.* 1979).

Australia

Tetrastichus brontispae was imported from New Caledonia and released in Darwin. *Brontispa longissima* first appeared in Darwin in 1979. *Tetrastichus brontispae* was first introduced into Darwin to control *B. longissima* in 1982. The initial introduction did not establish, but a new introduction in 1984 established for five years and then died out. *Tetrasticus brontispae* was re-introduced into Darwin in 1994 and established in moderate numbers for two years. Between October 1994 and March 1997, the beetle damage to the coconut palms at the release sites was reduced by 20 percent. The parasitoid established in higher numbers at sites that were irrigated with overhead sprinklers. After November 1996, the numbers of *T. brontispae* diminished and it could not be collected from any of the release sites or nearby areas. The climate at the tip of the Northern Territory may be responsible for the parasitoid's failure to establish, as it is probably suited to a milder tropical climate (Chin and Brown 2001). Only in North Queensland did the release of *T. brontispae* demonstrate effective control of *B. longissima*. Successful release is dependent on the initial release of large numbers of the parasitoid (Halfpapp 2001).

Samoa and American Samoa

For long-term control of *B. longissima* in Samoa, *T. brontispae* has been mass-released since 1981. From 1984 to 1987, a steady decline in damage from 42.4 percent in 1984 to 15.4 percent in 1987 was noted following the release of *T. brontispae* as well as the larval parasitoid, *Asecodes* sp. (1981 - 1986). The incidence of palms damaged by *B. longissima* in plantations and villages was 4 and 22.9 percent, respectively. In American Samoa approximately 74 percent of all palms were infested, compared with only 14.3 percent in Samoa. In American Samoa and Samoa, damage to coconut by *B. longissima* was 10 and 1–2 percent of the total leaf area. In Samoa, *Asecodes* sp. was an important cause of larval mortality. No parasitoids were found in American Samoa (Vogele and Zeddies 1990). An extensive survey of damage to 37 000 trees in Western Samoa showed that *B. longissima* was under control and did not cause any significant yield losses (initial production losses were estimated to be as high as 50 - 70 percent). Biological control has been one of the primary methods of managing pest problems in American Samoa since 1954 (Tauili'-ili and Vargo 1993).

Taiwan Province of China

Ten releases of a total of 11 456 *T. brontispae* adults were made from January to July 1984 in Chenchinhu, and seven releases of 4 881 parasitoids were made from February to June 1984 in Linbien. The percentage parasitism of pupae recorded from field recoveries at the two sites was 21.2 - 79.2 and 9.3 - 36.2, respectively. The parasitoid prevented most host larvae from developing into adults at Chenchinhu, whereas at Linbien, chrysomelid populations were not effectively suppressed. The parasitoid has established at distances of 2 - 8 kilometres from the release site at Chenchinhu (Chiu *et al.* 1985) and provided good control of the chrysomelid (Chiu and Chen 1985). The establishment of *T. brontispae* as a biological control agent of *B. longissima* in Taiwan Province of China has been confirmed (Chiu *et al.* 1988).

Other control options

Quarantine measures

The key issue is to stop people carrying palms of any kind from one country to another and from one area to another, as the beetles, eggs, larvae and pupae reside inside the tightly folded leaves. Quarantine measures that can be taken to prevent the entry of such pests are needed (Shiau 1982). In fact a rigid quarantine of plant pests has been highly recommended (Dharmaraju 1984). In Hainan Province of China, measures such as blockading and cutting down coconut palms up to three kilometres from the infestation spot; hanging insecticide bags on the infested palms and banning the transportation of palms from other provinces to or from infested areas have been implemented. Check points were established to enforce this quarantine regulation (FAO 2004).

Cultural control

As far as possible phytosanitary measures should be adopted in plantations. All plants leaving and entering a nursery should be checked for obvious signs of infestations. Infested plants should not be sold – only properly managed; pest-free healthy plants should be removed from the nursery. Old and dead plantation fronds should be removed and destroyed at regular intervals to destroy adult beetles, which hide under the leaf bases during day.

Chemical control

At the beginning of the twentieth century, it was common practice to combat *B. longissima* by applying manually a concoction of lead arsenate and bordeaux mixture or of tobacco and soap, but the results were poor (Pagden and Lever 1935). The lead arsenate and Bordeaux mixture was too toxic for the foliage (Lever 1933). Later, infested trees were sprayed every 4 - 6 weeks with a solution of 0.15 percent dieldrin via low-volume knapsack sprayers. DDT at 0.2 percent and chlordane at 0.16 percent were effective, but less persistent than dieldrin.

Chemical control of *B. longissima* was recommended for young palms, followed by biological control with *T. brontispae* on three-year-old palms when spraying became more difficult (Stapley 1973). Chemical control measures while the palms were still in the nursery became routine (Stapley 1980).

During the twentieth century a number of insecticides were used in different concentrations and combinations to combat *B. longissima*, these included: dieldrin, aldrin, phosdrin, DDT, aldicarb, dichlorvos, methidathion, fenthion, quinalphos, azinophos methyl, tetrachlorvinphos, monocrotophos, chlorfenvinfos, idiofenphos, trichlorphon, deltamethrin, dimethoate, endosulfan and lindane.

Brontispa longissima has developed resistance to aldrin and dieldrin. Moreover, most of the aforesaid insecticides have been phased out owing to their harmful side effects. Chemical control may be required in outbreak areas, but from the literature it is clear that very little effort has been made to find safer chemicals. It should be feasible to evaluate pesticides of plant origin, which are ecofriendly and compatible with biological control.

Initiatives of the Asia-Pacific Coconut Community on *Brontispa longisimma*

From 5 to 18 April 2004, Dr S.P. Singh, Project Coordinator-IPM, visited the following centres in India: The Central Plantation Crops Research Institute (CPCRI), Regional Station, Kayamgulam, Kerala; University of Agricultural Sciences, Bangalore, Karnataka; Coconut Development Board (CDB), Kochi, Kerala and Regional Office, Bangalore, Karnataka and the Project Directorate of Biological Control, Bangalore. At each centre, Dr Singh talked with staff members and warned about the possible danger of *B. longisimma* entering India. Dr. Singh requested the CDB to make reprints of the paper published in *Cord* 2004, 20(1): 1 - 20 and disseminate the details of the pest to all concerned to maintain vigilance.

Dr P. Rethinam, Executive Director, APCC visited the CPCRI in August 2004. He briefed the scientists about *B. longissima* and advised them to carefully monitor the pest and enforce strict quarantine measures. He urged them to disseminate the details of this pest to stakeholders to maintain vigilance.

Dr S.P. Singh visited Madang and Tavilo Centers of Cocoa and Coconut Research, Papua New Guinea in July 2004 and Davao Research Center, Philippine Coconut Authority, Philippines in September 2004 and discussed *B. longissima* and its natural antagonists.

The XLI Cocotech Meeting held in Santo, Vanuatu from 5 to 9 July 2004 recognized the recent threat of *B. longissima* in reducing productivity and production and the urgent need to educate coconut growers and development workers. It was recommended that the APCC with the support of FAO will jointly follow up with USAID on the organization of a seminar on *B. longissima* with funding from USAID. This seminar will be organized by the APCC to develop strategies for limiting the impact and spread of this devastating pest in the Asia-Pacific region. The need for enforcing strict plant quarantine measures by member countries will be stressed.

The threat of *B. longissima* was discussed at the Annual Review Meeting of the CFC/DFID/APCC/FAO Project on Coconut Integrated Pest Management held in Manila, Philippines in late 2004 and FAO and APCC decided to work together for the management of *B. longissima*.

At the XLI APCC Session held in Tarawa, Kiribati from 19 to 22 October 2004 the problem of *B. longissima* was highlighted. The Department of Agriculture, Thailand, has introduced the larval parasitoid *A. hispinarum* from Viet Nam; once established and spread, the pest problem will be reduced within the next two years.

The threat of *B. longissima* was discussed at the Farmer Field School (FFS) Curriculum Development Workshop held at Kochi, Kerala, India from 3 to 5 February 2005. The need for management of the pest in invaded countries and for vigilance in countries where the pest has not been recorded so far was stressed.

Apart from visits and use of electronic media, APCC staff participated in meetings and exhibitions at Vanuatu, Manila (Philippines), Manado (Indonesia), Kiribati and India. A complete set of colour charts on *B. longissima* was displayed and discussions were held on management aspects. The information was put on CD ROM and sent to Sri Lanka and India.

Projects pursued and proposed by FAO

The FAO Regional Office for Asia and Pacific is implementing Technical Cooperation Programme (TCP) Projects on Integrated Pest Management of Coconut Leaf Beetle in Viet Nam, Nauru, Maldives, Thailand and in Hainan Island of China. The main thrust is classical biological control (FAO 2004). The larval parasitoid *Asecodes hispinarum* was collected in Samoa in 2003 and introduced, reared and released in Viet Nam, Maldives and Nauru to combat the beetle (Figure 4). The parasitoid is established in all the three countries, with promising prospects for achieving control of the beetle.

Initial results from Viet Nam confirm the establishment of the parasitoid in provinces where it was released and observations at and near release sites indicate that beetle damage has been reduced considerably. Surveys have shown that the dispersal rate of the parasitoid is rapid.

In Maldives and Nauru, field establishment of the parasitoid was confirmed after two and five months after initial field releases in February and November, respectively. In Viet Nam, a recent cost-benefit study showed a return of US$11 for every dollar invested.

Figure 4. Adult *Asecodes hispinarum* – a larval parasitoid of *Brontispa longissima*

What will APCC do in collaboration with FAO?

For raising awareness and capacity building, training programmes on *B. longissima* will be organized. Insectaries will be developed and mass-rearing of the larval parasitoid *Asecodes hispinarum* will be implemented.

Future needs

- Raising awareness and capacity building through training programmes
- Adoption of strict quarantine measures on the movement of all types of *Brontispa*-infested palms
- Introduction/enhancement of the parasitoids *A. hispinarum* and *T. brontispae*
- Development of insectaries at selected places for mass production of parasitoids
- Use of improved strains of *M. anisopliae*
- Adoption of phytosanitary measures
- Exploratory surveys in Papua Province of Indonesia and adjoining Papua New Guinea
- Taxonomic revision of the genus *Brontispa*
- Use of safe/plant-based chemicals for controlling sudden serious infestations
- Adoption of measures to stop *Brontispa* entry into Bangladesh, India and Sri Lanka

Acknowledgement

This paper has been modified from the paper published earlier in *Cord* 2004 which in turn was prepared to serve as a preliminary note to APCC country members to gear up for meeting any eventuality regarding the management of this fast-spreading pest. We are grateful to FAO for expressing the need for documentation and closer interaction.

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Effective methods for controlling coconut hispine beetle outbreaks – lessons learned from FAO regional projects

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Abstract

The incursion of B. longissima *into Southeast Asia exemplifies the invasion of a new area by invasive alien species where no or few natural enemies exist. Quarantine and surveillance are the best prevention methods. If incursion occurs, the distribution of the pest and the feasibility of eradication should be determined and measures, such as sourcing natural enemies, should be studied. Collaboration with pesticide lobby members should remain close and the community should be kept abreast with the activities of the control programme. Lessons learned from regional projects are provided.*

Introduction

The incursion of the coconut hispine (leaf) beetle, *B. longissima*, into Southeast Asia is a typical example of what can happen when an exotic pest arrives into a new area where no or few natural enemies exist. The damage inflicted by the pest is dramatic, as it initially affects the central crown and slowly, as the leaves become older and young emerging leaves continue to display damage symptoms, progresses to include all of the tree leaves.

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In the absence of natural antagonists in the region where it is endemic, the pest can multiply very rapidly. This has led to high damage levels, and death of trees at an estimated 5 percent *per annum*. The pattern of the outbreaks displayed over Southeast Asia is very similar to the one experienced in Samoa in the early 1980s.

The assistance provided by FAO to help affected countries achieve control of the beetle has been progressively fine-tuned to incorporate the results of projects in other countries. During this process, a number of lessons have been learned from the *Brontispa* incursion into Southeast Asia; these are briefly described hereunder. Accurate identification of the pest is of key importance and information on control measures should be studied.

Prevention is better than cure: keep it out!

Quarantine

Quarantine is the first step in blocking a pest. On the Asian mainland, this is not so much a national responsibility, but rather a regional responsibility. If a pest becomes established in one tropical Southeast Asian country, it is highly likely that it will eventually spread to others, where it will in turn necessitate control efforts.

Surveillance

Surveillance not only depends on surveys for pests and diseases in areas at risk, it also should involve extension agents and farmers. Information on known pests in the region and abroad should be made available and should include good photographs of the adults, immature life stages and damage symptoms.

Upon incursion

Identification – taxonomic capacity

Accurate identification of the pest is of key importance. Taxonomic capacity should be on hand, or rapidly available. This, of course, requires the availability of and access to up-to-date taxonomic information. However no single taxonomist can identify every arthropod/insect pest. Thus, a wide range of taxonomic skills is required, necessitating regional cooperation.

Emergency response

The distribution of the pest and the feasibility of eradication should be determined. For example, a case occurred in April 2004 at Hulhule Island, the location of Maldives' international airport. Surveys showed that the beetle infestation appeared limited to some 6 - 8 trees near the jetty. An immediate campaign was started to eradicate the beetle. Regular monitoring has failed to detect any signs of the beetle to date, and it is now assumed that the eradication has been successful.

Information on control measures

A literature study and web search on the pest and related specimens should be conducted to obtain information on control measures that can be applied if the pest becomes established.

It should not be assumed that all published information is up to date. Whilst preparing the project document for FAO support to Viet Nam in 2001 and 2002, we assumed that there were three parasitoids and one predator in Samoa, where *B. longissima* was recorded about 20 years earlier. Work on *Brontispa* stopped in 1985/1986, when it was decided that classical biological control of the pest had been achieved, and no further studies or surveys were conducted. We therefore assumed that at least two parasitoid species would be found that we could consider for introduction into Viet Nam, as well as a predatory mite, but field surveys only found one species of parasitoid.

After establishment

Reduce the rate of dispersal

Once it is determined that the pest is present in a certain area, measures should be taken to reduce its spread. This may include restrictions on the movement of plant hosts from the infested area. However, this should always include a major effort to increase community awareness about the pest and how it spreads, and seeking help from the public to prevent this. The smaller the infested area, the easier it will be to achieve biological control more quickly.

Duration of projects

Classical biological control often takes considerable time (5 - 10 years), and in many cases any significant result should not be expected during the initial years. For *Brontispa*, we were lucky to have expertise in *Brontispa* control and sources of parasites. The pest had spread earlier in the Pacific, and in particular in Samoa it has remained an insignificant pest since it was brought under sustainable control more than 20 years ago.

Biological control capacity

Capacity requirements for classical biological control projects involving arthropods should, besides extensive skills and experience in entomology and plant protection, also include population ecology, population dynamics and integrated pest management (IPM). Knowledge of pesticide application is useful, but often less necessary.

Climate

The climatic conditions in the region where *Brontispa* is endemic parallel those in Samoa and southern Viet Nam. In Hainan, the climate is significantly different, and prolonged cold spells are experienced during the winter season, which may have an effect on the survival and effectiveness of the parasitoids there.

Sourcing the natural enemies

Although we anticipated finding three parasitoids and one predatory mite in Samoa, we could only find one species of parasitoid during surveys from April to June 2003. Moreover, *T. brontispae*, a pupal parasitoid of *Brontispa* that was imported and released in large numbers in Samoa in the early 1980s was not found at all.

Monitoring

Monitoring of damage and pest abundance is important to help demonstrate the impact of natural enemies. It should be noted that when commencing releases of parasites in the field, there is little time to study decreases in host abundance and damage, particularly if the parasite is highly effective.

Pesticide lobby

There is a very strong pesticide lobby in most countries of Southeast Asia. Although this lobby inevitably is oriented towards profitability, it has provided short-term relief of the pest in several cases. Lobby members should be viewed as partners, and collaboration should remain close where possible.

Visibility – community awareness

Keeping the community abreast with the control programme is essential to ensure continuous support for activities. This should be done at any opportunity, and include the press, TV and radio. Whenever possible, community leaders and policy-makers should be informed about a project and its progress.

In Tables 1 and 2, additional information on lessons learned from regional projects and the effect of release of parasitoids on *Brontispa* beetle (2 possible scenarios) are given.

Table 1. Lessons learned from regional projects

The problems	The solutions	The moral
Increasingly strong pressure from civil society and policy-makers at national, provincial and town levels to control the pest immediately, asking for wide-scale pesticide applications, and proposals that offer "quick fix" solutions.	This is the most difficult issue. Pesticides generally do not work well and if they appear to provide some cosmetic relief, this is not sustainable owing to costs, environmental impacts and the scale of the problem. Moreover, the application of pesticides will impede the successful establishment and effectiveness of natural enemies. Classical biological control is no quick fix – but once established, it is a lasting one. We have worked with government authorities to increase awareness on biological control. Indeed, for some of us it was a leap of faith to put trust in a small animal that is hardly visible. Some provinces – initially those that were the most desperate – had few other alternatives but to trust us. In particular it was difficult to convince some clients that time was needed before any signs of improvement could be seen.	Work with policy-makers and civil society – keep them updated on progress, and provide details and examples of classical biological control projects in the country and abroad.

The problems	The solutions	The moral
Following extensive surveys for *Brontispa* and parasitoids, we only found one parasitoid species – one that had never been recorded from Samoa before. The other species, and the mite, could not be found.	Out of necessity, we imported the parasitoid to Viet Nam – particularly because the parasite was doing a very good job in Samoa: *Brontispa* was maintained at very low population densities – damage to palm trees was very low, and tree infestation rates were perhaps 0.5 - 0.1 percent. Also, the climate in both countries (Samoa and Viet Nam) was quite similar. This made our work easier, since we could dedicate all our efforts to the rearing of a single species. In fact, it facilitated everything….for Viet Nam at least.	You cannot comfortably assume that the same situations that existed (more or less) 20 years ago are still the same – especially when no recent data are available. It is highly recommended that a visit is made to (1) assess the extent of the problem; and (2) determine the current status of the pest and its natural enemies.
The FAO TCP project facility has quite a rigid structure – and some forms of support are kept to a minimum (e.g. international specialist and vehicles).	We were fortunate to have very good support from officers and offices (national, regional and headquarters) and partner organizations which allowed us to have considerable flexibility in the planning and implementation of the project.	Cooperation between and support from various departments in an organization, and with external partners, greatly helps the implementation of the project, and ultimately in achieving success.

The problems	The solutions	The moral
How to rear and distribute many parasites in as short a time as possible.	Viet Nam established decentralized rearing centres in various provinces. Parasite releases were made according to a grid pattern based on observed dispersal rates, to optimize natural spread of the natural enemies. The grid pattern identifies large areas of coconut, and splits these into quadrants of approximately 10 x 10 km. Based on a natural dispersal rate of 5 - 8 km over 2 months, 1 (in the centre) to 4 (each 2.5 km from any 2 borders) releases are made of 5 - 6 mummies (approx. 250 parasitoids) in each of these quadrants – depending on production levels.	If parasitoid production levels are limited (which they always are early in the project), it is better to make as quickly as possible – many releases of small numbers of parasitoids in many widely distributed sites, as opposed to few releases of large numbers in nearby sites.
FAO TCP support is limited to amounts of US$500 000, and a duration of two years. In general, this is insufficient funding to seriously implement biocontrol projects, and the time is too short to obtain results.	In the case of Viet Nam, it was fortunate that biocontrol agents were already known, and a source had been identified. This allowed the parasites to be introduced 4 -5 months after the start of the project, and field releases to commence after six months. However, at the conclusion of the project – 1½ years after the first releases – sound results	When planning a biological control project, one should take into account that they generally take many years and may appear costly – but the results are sustainable over the long term, and highly cost effective. When planning a biological

The problems	The solutions	The moral
	were only available from the southern provinces The budget of US$400 000 was sufficient, as no exploratory surveys for additional natural enemies had to be made in countries where *Brontispa* is endemic.	control project, one should take into account that they generally take many years and may appear costly – but the results are sustainable over the long term, and highly cost effective.
How can we reduce the rate of spread in Southeast Asia, and to nearby countries?	We believe that by the time the project started the pest had already reached Lao PDR and Cambodia. Hence, any parasite releases were too late to reduce its spread there. However, the reaction time was considerably shorter when the pest was discovered in Thailand and Lao PDR, and parasites were released shortly thereafter. Information on the seriousness of the pest incursion in Cambodia only reached FAO in October 2004, and assistance is now being planned. The pest is also present in Myanmar, but so far no request for assistance has been received. A different approach was applied in Maldives where	A network of plant protection agencies, organizations and individual specialists will allow a rapid exchange of information on both the pest's distribution and control methods. For those countries isolated by natural barriers (ocean, mountain ranges), quarantine is of the utmost importance to prevent the pest from entering. If the pest manages to enter, the implementation of an eradication campaign should commence.

The problems	The solutions	The moral
	pest incursion was limited to a few islands in the south of Ari Atoll. Nationwide public awareness campaigns via the media (TV, newspaper, radio, posters, and stakeholder meetings) helped prevent the further spread of the pest to other atolls: Until now, the distribution of the pest remains limited to a chain of nearby islands in the south of the atoll; the nearest islands are some distance from the infestation, probably too far for the beetle to fly. A pest incursion on the airport island was detected early in April 2004 and it is now assumed that the eradication has been successful. The risk of spread of the beetle from Maldives to nearby countries has been recognized, and two awareness seminars were held in Sri Lanka for quarantine and plant protection staff. To date, the pest has not been recorded elsewhere in the region.	

The problems	The solutions	The moral
How to promote the benefits of biological control?	People, and policy-makers in particular, tend to forget quickly about a pest once it has been brought under control. Production losses and costs of chemical controls become a thing of the past, until another pest arrives. After initial promising results from the biocontrol project, an economist was hired to conduct a study on the costs of the *Brontispa* incursion into Viet Nam, and to prepare a cost-benefit analysis. The study showed that damage by the pest to the coconut industry alone exceeded US$35 million *per annum*; as it is typical to measure such impact over a 30-year period, the total damage would amount to well over US$1 Billion.	As early as possible in the control programme, conduct a financial analysis on the losses and the costs of conventional control with pesticides and eradication efforts. This will help support preventive measures (e.g. quarantine) and sustainable (biological) control activities. Classical biological control projects commonly have very high cost-benefit ratios.

Stable population density of Brontispa
Assumptions:
Average Adult Brontispa density: 100 per tree
Average number of trees: 125 per ha (12500 per km^2)
Brontispa adult longevity: 120 days
Brontispa immature life cycle: 30 days
Potential hosts for parasitisation: L3 and L4 stages
Each mummy yields 30 parasitoids (M:F = 1:1)

Parasite generations in field	0	1	2	3	4	5	6	**7**	8	
Days (development time = 20 days)	0	20	40	60	80	100	120	**140**	160	
SCENARIO ONE										
Stable population density of Brontispa										
Total No. adult beetles per 10 by 10 km grid	125000000									
Brontispa abundance (120 days adult life)	125000000	124995500	124950500	124545500	122115500	112395500	92955500	63795500		
Brontispa immature abundance (30 days; 1/4 of adults)	31250000	31248200	31230200	31068200	30096200	26208200	18432200	6768200		
Of which potential hosts (L3 and L4) (0.5)	15625000	15624100	15615100	15534100	15048100	13104100	9216100	3384100		
L3 and L4 abundance per tree	12.5	12.49928	12.49208	12.42728	12.03848	10.48328	7.37288	2.70728		
Multiplier (females produced per female)		15 x	10 x	9 x	6 x	4 x	2 x	**1.5 x**	1.2 x	1.1 x
Number of females released/in the field:										
initially - one	1	15	150	1350	8100	32400	64800	**97200**	116640	128
initially - one hundred (1 per sq km)	100	1500	15000	135000	810000	3240000	6480000	**9720000**	11664000	12830
initially - one thousand (10 per sq km)	1000	15000	150000	1350000	8100000	32400000	64800000	**97200000**	116640000	128304
initially - three hundred (20 mummies per sq km)	**300**	**4500**	**45000**	**405000**	**2430000**	**9720000**	**19440000**	**29160000**	**34992000**	**38491**
Number females released	**300**									
Eff. Parasitisation (ie. ratio that produces offspring) (%)	20									
Number of effective parasites (b29 * b30)	**60**	900	9000	81000	486000	1944000	3888000	**5832000**	6998400	7698
2nd release (30 mummies; +60)		**960**	9600	86400	518400	2073600	4147200	**6220800**	7464960	8211
3rd release (30 mummies; +60)			**9660**	86940	521640	2086560	4173120	**6259680**	7511616	82627
SCENARIO TWO										
Stable population density of Brontispa										
Total No. adult beetles per 10 by 10 km grid	125000000									
Brontispa abundance (120 days adult life)	125000000	124977500	124820000	124032500	121670000	116945000	110330000	103053500		
Brontispa immature abundance (30 days; 1/4 of adults)	31250000	31205000	30890000	29315000	24590000	15140000	1910000	-12643000		
Of which potential hosts (L3 and L4) (0.5)	15625000	15602500	15445000	14657500	12295000	7570000	955000	-6321500		
L3 and L4 abundance per tree	12.5	12.482	12.356	11.726	9.836	6.056	0.764	-5.0572		
Multiplier (females produced per female)		10 x	7 x	5 x	3 x	2 x	1.4 x	**1.1 x**	1.1 x	1.1 x
Number of females released/in the field										
Number females released (3000 mummies)	**45000**									
Eff. Parasitisation (ie. ratio that produces offspring) (%)	5									
Number of effective parasites (b45 * b46)	**2250**	22500	157500	787500	2362500	4725000	6615000	**7276500**	8004150	8804
2nd release (+1000)		**23500**	164500	822500	2467500	4935000	6909000	**7599900**	8359890	9195
3rd release (+1000)			**165500**	827500	2482500	4965000	6951000	**7646100**	8410710	9251

Table 2. Effect of release of parasitoids on *Brontispa* beetle (2 scenarios)