MASS REARING OF THE COCONUT HISPINE BEETLE (*Brontispa longissima*)

AND ITS NATURAL ENEMY (*Asecodes hispinarum*)

FAO TCP/VIE/2905

Wilco Liebregts
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THE AUTHORS

The authors have implemented Coconut Hispine beetle bio-control FAO projects in Viet Nam, Lao PDR, Cambodia, Thailand, Naru and the Maldives. They have also provided advice to other countries and the Asia/Pacific coconut community on control strategies and quarantine vigilance of this devastating, invasive species in the Asia/Pacific region.

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PREFACE

The Coconut Hispine (or Leaf) Beetle (*Brontispa longissima* Gestro) has in the past 5 years become a very serious and damaging pest of coconut in the Asia and Pacific region with recent outbreaks in Viet Nam, Lao, Thailand, China, Maldives, Indonesia, Cambodia, Myanmar, Philippines and Nauru. In Viet Nam alone the pest causes losses of US 40 million per year and up to 5 percent of trees died each year.

In all of these countries FAO is either assisting or has assisted in the bio-control of this Coconut Hispine Beetle, using the parasitic wasp *Asecodes hispinarum.*

In most instances control of the beetle with the *Asecodes* parasitoid has been spectacularly effective and recovery of coconut palm health has been complete with no significant re-infestation.

During the first of these many recent interventions, Viet Nam via the FAO-TCP/VIE/2905 (A) project entitled, 'Integrated Pest Management of Coconut Hispine Beetle (*Brontispa longissima* Gestro)', has succeeded in very effectively controlling the pest.

The project was led by Dr. Tran Tan Viet, (Chief Project Researcher from Nong Lam University of HCMC) with support from his team, Wilco Liebregts (International Technical Team Leader and Specialist in Classical Biological Control of Coconut Hispine Beetle), and the Plant Protection Department of Ministry of Agriculture and Rural Development. The project team developed a range of methodologies for mass-rearing, releasing and monitoring of field establishment of *A. hispinarum* (parasitoid of the beetle) and its impact on the pest population and damage levels sustained by coconut trees. These methodologies have been documented and presented in this publication as a record for future assistance in bio-control of any further outbreaks of this serious pest in other countries.

FAO is proud to have been associated with this highly motivated team who has so successfully achieved control of the Coconut Hispine Beetle in Viet Nam and other countries. FAO can recommend this publication.

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February 2006

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INTRODUCTION

The scourge of the coconut – The Coconut Hispine Beetle

The Coconut Hispine beetle, *Brontispa longissima* Gestro (Coleoptera: Chrysomelidae) is potentially one of the most serious pests of coconut palms. Both larvae and adults of the beetle inhabit the developing, unopened spear leaves of the coconut palm where they feed on leaf tissues. When the leaf opens it quickly dries out and the leaf tissues die. A severe attack can lead to complete defoliation of the palm and, if prolonged will result in death of the tree. With other palms productivity and appearance is severely affected by sub-lethal attacks. Up to 17 species of palms including oil palm, betel palm, nipa palm and several ornamentals may be attacked.

A farm shed in a poor farming area. The destructive effect of the pest on the tree is clearly seen which translates to huge loss of income and livelihood

Close-up of damaged spear

Close-up of damaged young leaf

Dying palm tree due to heavy *Brontispa* damage

Close-up of damaged crown

Dead stem

Many species of ornamental palms are also attacked

Damaged leaflets

Brontispa longissima is believed to be endemic to Indonesia and possibly also to Papua New Guinea. In the 20th century the beetle was accidentally introduced into several other countries in South East Asia and Pacific, and as a result has now become widespread there. However, the pest was not recorded from continental Southeast Asian countries until the late 1990s when it was first detected in the Mekong delta in Viet Nam.

Specialists suspect that this species was introduced into southern Viet Nam in shipments of ornamental palms. The pest rapidly spread west and north, causing very significant

losses to smallholder farmers in the coconut industry in Viet Nam and also in nearby Cambodia and Lao PDR and Thailand.

***Brontispa* beetles on leaf spear folded away**

***Brontispa* adults on leaf**

The introduction of the beetle into Hainan Island in southern China, is believed to have occurred in a similar way to that of Viet Nam. At around the same time, the pest was introduced into the Maldives by means of imported ornamental palms originating from Indonesia or Malaysia. The pest was first noticed in Thailand in February 2004, and several months later in Myanmar, followed by the Philippines in 2005. Singapore and parts of Indonesia have also reported damage by the pest, but it is unclear if this is a new incursion. With no significant physical barriers such as mountain ranges or seas, it is expected that the pest will continue its spread westward.

Biological control

Complete control of *B. longissima* with high benefit/cost ratio (approaching 100:1 /year) has been achieved in several countries by importing and establishing parasitoids that attack immature stages of the pest. One of the most successful species to control *Brontispa* is the larval parasitoid *Asecodes hispinarum* Boucek (Hymenoptera: Eulophidae), which is believed to originate from the Solomon Islands / Papua New Guinea region. This natural enemy was successfully introduced into Samoa in the early 1980s to control the *Brontispa* incursion. With assistance from FAO, the parasitoid was collected from Samoa and introduced into Viet Nam in 2003 for host testing, mass rearing and field release. Other countries in Asia have since been provided with the parasitoid from the Nong Lam University lab in HCMC to help control *Brontispa* outbreaks.

Asecodes hispinarum is a larval parasitoid that attacks 3rd and 4th instar larvae of *Brontispa*. It has only been recorded from *B. longissima*, but there is a possibility that its host range may also include closely related species such as *B. palauensis* and *B. mariana*, which are also pests of coconut and several other palm species. In any case, more than 20 years after its introduction into Samoa and American Samoa the parasitoid has not shown to have any adverse effects on other species. Despite this, further host testing on several other insect species including silkworm (*Bombyx mori*), was carried out in Viet Nam prior to the release of *A. hispinarum*, but all yielded negative results.

This manual on mass rearing has been developed for research staff and field workers to help establish mass rearing of *Brontispa longissima* and its parasitoid *Asecodes*

hispinarum in a field-laboratory environment. Cheap materials are used which should be readily available in rural towns. The rearing techniques are simple and can be applied by farmers, students and field workers after a training demonstration by experienced and trained research staff.

The parasitoid, *Asecodes hispinarum*

Caution

Whilst this manual provides information for rearing of *A. hispinarum*, strict safety protocols and procedures must apply for rearing of beneficial insects under **quarantine conditions**.

Some of the methods described in this manual may not be in full compliance with protocols and procedures of some countries. It is therefore strongly recommended to review these procedures in detail for each country to minimize any risk before commencing rearing of the natural enemy under **quarantine conditions** and to ensure compliance with national and international protocols and guidelines.

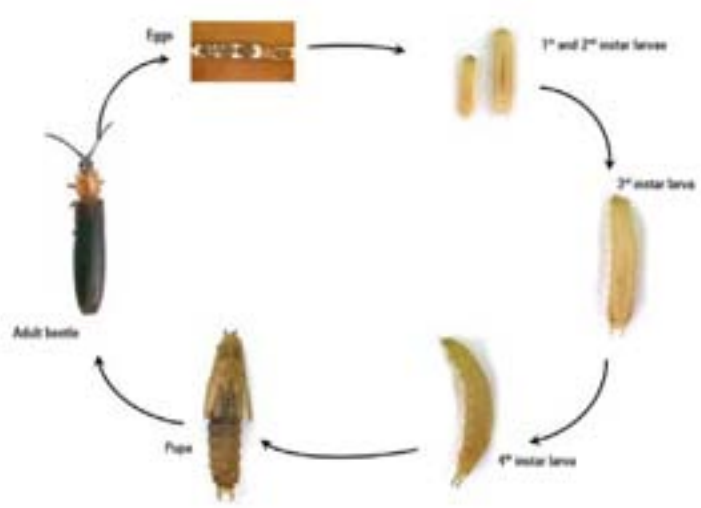
TAXONOMY OF *BRONTISPA LONGISSIMA*

The Coconut Hispine Beetle belongs to the order of Coleoptera, in which the beetles and weevils are grouped together.

Phylum	Arthropoda
Order	Coleoptera
Family	Chrysomelidae
Subfamily	Hispinae
Genus	*Brontispa*
Species	**longissima**

Biology of *Brontispa longissima*

Brontispa longissima and all other species belonging to the order of Coleoptera have a complete (perfect) metamorphosis, i.e. the immature life stages – larvae or grubs – are very different in appearance from the mature (reproductive) life stages. Their development life cycle starts with the egg phase followed by the larval (grub) phase. After going through several instars, the larva develops into a pupa from which the beetle emerges. Only beetles can reproduce and lay eggs.



***Brontispa* life cycle**

The approximate duration of various instars under an ambient temperature of 26 to 28°C and relative humidity of 70 to 80% is:

Egg	4 days
1st instar larvae	3 days
2nd instar larvae	4 days
3rd instar larvae	5 to 6 days
4th instar larvae	9 to 10 days
Pre-pupa	2 to 3 days
Pupa	4 to 6 days
Adult beetle	150 days (range 120 to 260 days)

Procedures for mass rearing of *Brontispa longissima*

Mass rearing of *Brontispa* is aimed at providing sufficient numbers of hosts (4th instar larvae in particular) over a prolonged period to enable an optimum and sustained production of the parasitoid *A. hispinarum*. The continued success of this first step is therefore an important contribution to the overall objective of bringing *B. longissima* under sustainable biological control.

Cleanliness and hygiene are very important. Decomposing leaf materials, faeces and frass should be removed every 2 days to prevent build up of moisture and pathogens. New leaves need to be added at similar intervals. The amount of leaves should be sufficient to provide an adequate food supply for the host, and maintain moisture, but should not be excessive, as too many leaves prevent adequate air circulation. This increases moisture levels, which promote the development of fungi and bacteria that will affect the quality of the leaves and encourage the growth of lethal pathogens.

Rearing boxes with developing fungal infections

Cleanliness and hygiene are very important!

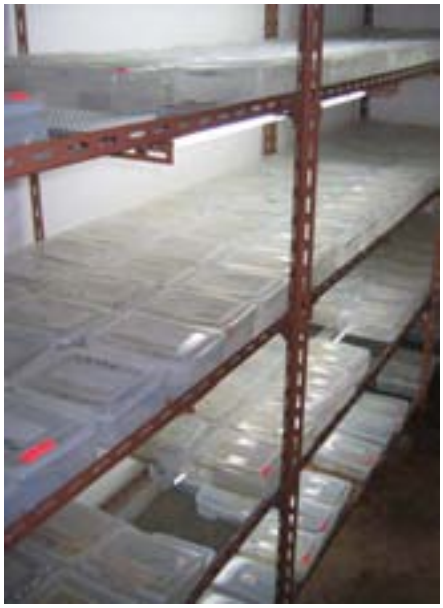
Decomposing leaf materials, faeces and frass should be removed every 2 days to prevent build-up of moisture and pathogens in the fresh leaves.

Larvae (top photos) and beetle (lower photo) killed by fungus

Equipment required

- Plastic boxes (approximate size: 20 cm long, 10 to 15 cm wide, 5 to 8 cm high). Boxes should have tight sealing lids preferably with a double seal. A large opening should be cut in the lid in the form of a rectangle or an oval, about 2 to 3 cm from the edge. A fine mesh (cloth or plastic) should be glued on the inside of the lid to cover the opening. The mesh size should be small enough to prevent the beetles from escaping.
- Fresh, young coconut leaves (coconut leaf spear)

- Pruning scissors, or secateurs
- A small, fine, soft haired paint brush
- Sticky labels or sealing (masking) tape
- A pencil and a marker pen
- Scissors
- A book or notepad for record keeping
- A table, bench or shelf. Keep ant-free by placing the table legs in small tins of water or oil.
- A room or shaded shelter with sufficient light in the daytime. Alternatively, light could also be provided from fluorescent tubes. Rearing under ambient temperatures is preferred, but if an air-conditioned room is used, make sure that the humidity remains above 80% RH to avoid drying out the leaves.



Room with appropriate shelving for containers in which to raise *Brontispa*

Rearing of *Brontispa longissima*

Under optimal rearing procedures, the individual developmental stages of *Brontispa* are kept separate to produce a maximum number of 4th instar larvae, and to make it easier to maintain the host culture.

Eggs

The adult beetles lay their eggs on the leaflet in the unopened leaf spear, mostly in a single row of up to 7 eggs.

Eggs on a leaf

***Brontispa* adult with eggs on a leaf**

Segments of leaves with eggs are cut out and placed within the folds of young leaves (see top photo next page). This placement of eggs will allow young larvae to commence feeding on the young soft tissue immediately after they hatch. Also, the folded leaves maintain humidity and reduce the risk of dehydration of the eggs.

Remember, that in the field eggs are deposited between the young, unopened, leaflets where humidity is close to 100%.

Leaves may have to be replaced after 2 to 3 days to ensure their freshness when the young larvae hatch. With a set-up for large production of *Brontispa*, it is best to keep each day's egg collection in separate boxes so the eggs will hatch within 1 to 2 days of each other in each box. For smaller rearing units, eggs collected from the 'beetle' boxes over a period

of up to 3 days can be placed in the same box, so that similar developmental stages of the larvae are kept together. Keeping eggs and larvae of a similar age together in one box makes the later extraction of the 4th instar larvae for parasitoid rearing much easier.

Field collected eggs

It is difficult to seek out live eggs among the many old, hatched and dead eggs that can be found when collecting in the field. Therefore, unless there are exceptional circumstances such as starting a mass rearing, or if few larvae are present in the field, it is of little use to collect eggs from the field for rearing purposes, since many eggs would be dead or have the larvae already emerged.

The egg developmental stage takes 4 to 5 days under ambient temperature (28°C) before larvae hatch. Below is the procedure to be followed.

Cut out the eggs including leaf strip or place leaf strip with eggs into a fresh young leaf

Place the leaf strips with eggs in a box with fresh young leaves

Label the box

Larvae – 1st and 2nd instar

Newly emerged 1 day old larvae can be maintained in the box for further rearing, but more young, fresh leaflets (preferably the soft, yellow leaflets) must be added. Once the larvae are larger (2nd instar stage), other leaflets from the coconut 'spear' can be used.

> Leaves must be replaced regularly (every 2 to 3 days) to avoid build up of excessive moisture and the development of fungi that may kill the larvae. Up to about 500 of the 1st and 2nd instar larvae can be kept in one container.

If egg collection in the laboratory is carried out regularly and eggs of similar age are kept together in separate boxes, the age variation would not be more than a few days.

Larvae should always have fresh young coconut leaves available for optimal feeding and growth. This requires careful inspection every 2 to 3 days and replacement of old rotten leaves with new fresh turgid ones.

Field collected larvae

When starting rearing, or if for some reason the number of larvae in the rearing has declined, it can be useful to collect larvae from the field. Field-collected larvae should be

kept separate from laboratory-reared ones to avoid any contamination or cross-infection. It is better to separate the young larvae (1st and 2nd instar) from the older ones (3rd and 4th instar), which will make it easier to extract 4th instar larvae for exposure to parasitoids at a later date.

Larvae – 3rd and 4th instar

As they grow, the larvae will consume more plant materials, therefore the density should be reduced to 200 to 300 larvae per container. About 2½ weeks (16 to 20 days) after hatching, the larvae will have reached the most suitable stage (4th instar) in their development and can be used for exposure to parasitoids.

> Remember to leave a quarter of these 4th instar larvae to develop into pupae and beetles that are needed to continue the mass rearing process.

Larvae on a leaf (above) and transferring larvae to a clean, new box (right) with new leaves. The old, brown leaves are discarded after carefully removing the larvae.

Remember to check between the leaf folds for larvae.

Pupae

Once the remaining 4th instar larvae have developed into pre-pupae and pupae, they have become unsuitable for parasitoid rearing. They are then transferred to a smaller container where they are incubated for emergence of adults. Since they do not feed, there is no need to place any leaf material in the container. However, a few leaflets placed on top of the pupae will help extract the beetles after they have emerged, as these often move into the folded leaves. All pupae can be kept in the same container, and do not have to be segregated according to the date of pupation.

At this stage, both field and laboratory reared pupae can be placed in the same box. New pupae can be added to the box anytime, but any emerging beetles should be removed every 1 to 2 days.

Under ambient temperature (28°C), the pupal stage takes 4 to 6 days to complete.

Pupae

Beetle emerging from pupa

Young beetle after emerging

Adult beetles – holding boxes

Young, newly emerged beetles are collected from the pupae box every 1 to 2 days. When collecting large numbers, beetles could be placed in separate boxes. However if only a few beetles are collected over a short (4 to 5 day) period, they may be placed in the same box.

The pre-oviposition period (the period before adult female beetles begin to lay eggs) of *B. longissima* is approximately 3 weeks. Although the beetles will require fresh leaves every 3 days, no inspections for eggs are needed for at least 2 to 3 weeks. Once egg production has started, the beetles may be added to the boxes with other, older and egg-producing beetles.

Adult beetles / egg production containers

Beetles that have reached the egg production stage can be combined in one or several boxes with about 300 beetles per container. Once the beetles have commenced laying eggs, the boxes must be inspected, preferably every 1 to 2 days, but at least every 3 days. Any eggs should be collected and placed in a separate box with very young and tender coconut leaflets, to allow hatching larvae to commence feeding immediately.

> Remember that the objective of the mass rearing is to produce *as many eggs for larvae production as possible*, and inspections should therefore take place as often as possible.

Adult beetles have been recorded as living up to 260 days under ambient temperatures, and a single female can lay more than 430 eggs during her lifetime.

Transferring beetles from an 'old' to a 'new' box

Field collected beetles

Field collected beetles can be placed together in one or more boxes, at densities of up to 200 to 300 beetles per box. Inspection and collection of eggs are required at least every 3 days, and old, rotting leaves replaced with new spear leaves of coconut palms.

PROCEDURE FOR MASS REARING OF THE PARASITOID, *ASECODES HISPINARUM*

Taxonomy of *Asecodes hispinarum*

The parasitoids, *Asecodes hispinarum*, belongs to the order of Hymenoptera, which consists of the wasps and bees:

Phylum	Arthropoda
Order	Hymenoptera
Family	Eulophidae
Genus	Asecodes
Species	**hispinarum**

Biology of *Asecodes hispinarum*

Asecodes hispinarum is a gregarious endoparasitoid, which means that many (*'gregarious'*) parasitoids will develop inside ('*endo*-') each host larvae of *B. longissima*.

The female parasitoid only lives up to 5 days, but in that short lifetime can produce many eggs; in the laboratory some females have produced as many as 210 offspring!

During their short life, the parasitoids need only a source of carbohydrates for food; in the field this is nectar from flowers, but in the laboratory you need to provide honey or sugar. They also need moisture in the form of water. It is therefore important that both are available to the parasitoids when they emerge from the mummy. You can supply both by dissolving some honey in water, and apply the solution to a small strip of tissue paper, which is then stuck to the inside of the box.

Mating takes place shortly after the females emerge from the mummy. The females then seek out suitable hosts – mostly 3rd and 4th instars of *Brontispa*, to lay their eggs. A female can lay more than 100 eggs into one larva. The size of the larva determines the number of eggs the female parasitoid lays, and consequently the number of parasitoids that will emerge. It is therefore important that a good and constant supply of 4th instar *Brontispa* larvae is maintained so that optimum production of parasitoids can be assured.

The development of the parasitoid from egg to adult takes about 2½ to 3 weeks (17 to 20 days), depending on the temperature and other factors in their environment. Except for the adult stage, the whole life cycle (egg to larvae to pupa) takes place within the host larvae.

Parasitoid rearing

Care must be taken not to utilize too many 4th instar larvae for the rearing of the parasitoids, since this may jeopardize the continuity of the rearing of the beetles. Keep a quarter of the 4th instar larvae to develop into beetles.

Rearing the parasitoids

You will need boxes of a similar or smaller size to those used for rearing *Brontispa*. However, the gauze used to cover the hole in the lid will need to be of much finer mesh size to prevent the parasitoids from escaping. Also, you will need to make a small hole (1 cm diameter) in the side of the box – this is needed to insert the adult parasitoids into the box.

Place approximately 20 *Brontispa* 4th instar larvae with several coconut leaf cuttings in a box of about 15 x 8 x 5 cm. Attach a small (4 cm by 1 cm) piece of tissue paper soaked in a 10% honey solution to the side wall of the box. Close the lid and make sure it seals tightly. Through the small hole in the side of the box introduce some 60 newly emerged adult parasitoids (see picture).

Introducing parasitoids into a box with *Brontispa* larvae

Close the hole firmly with a cotton wool plug. Keep the boxes preferably in a room with ambient temperature. If an air-conditioned room is used, the temperature should remain above 25°C with high humidity (over 70% RH) to prevent the mummies from drying out. A simple way to do this is to place buckets or trays with water in the room so the water can evaporate and maintain humidity at acceptable levels.

Do not introduce too large a number of parasitoids into a single box with limited hosts. As a rule of thumb, 5 parasitoids should be introduced for each larva.

Check the box every 2 days. The larvae that have been parasitized will gradually change to a dark brown colour — an indication that the parasitoids have killed the larvae. The parasitized larvae will turn into mummies after about 10 days. When the mummies have become dark brown (see third image from the left in the picture), they should be extracted and transferred to individual tubes.

Box with mummies and pupae

Two mummies on a leaf

Use a plug of cotton wool to tightly close the tubes to prevent the emerging parasitoids from escaping. The parasitoids emerge after approximately 17 days. The parasitoids can be used immediately after emergence for parasitization of *Brontispa* larvae.

Mummies on tissue paper

Transferring mummies to tubes

Mummies placed in individual tubes for parasitoid emergence

Parasitoids that have emerged from the single mummy

Close-up of mummy with emergence holes

Large number of mummies

Release of parasitoids in the field

The parasitoids can be introduced into the field as live, adult parasitoids or in the mummy stage. The introduction of parasitoids into the field in the mummy stage is the preferred option, as it allows the introduction to take place any time during the day. It is best to do this a few days before the parasitoids are expected to emerge, as it will allow the parasitoids to become acclimatized so that they are better adapted to the local environment when they emerge from the mummy. It also enables the parasitoids to start seeking suitable *Brontispa* hosts immediately after their emergence when they are fit. You would need to protect the mummies with a mummy shelter.

Mummy shelters

There are many designs for mummy shelters for releasing the mummies into the field (see pictures). One of the easiest methods is to release them in a small ‘bag’ made of mosquito netting. The mesh size of the mosquito netting must be small enough to prevent the mummies from falling through, and large enough to allow the parasitoids to escape. A cover made from a plastic cup or preferably cardboard, can be applied on top of the ‘bag’ to provide shelter from direct sunlight and rain.

Placing mummies in release shelter (cup)

Make sure that the 'bag' or other mummy shelter is hung in a shady place protected from sun. Direct exposure to the sun will not only increase the heat but also cause the mummies to dry out and make it more difficult for the parasitoids to chew holes in them when they are ready to emerge.

Do not apply any honey or sugar to the mummy shelter, as this will attract ants, which will prey on the mummies.

Release of adult parasitoids

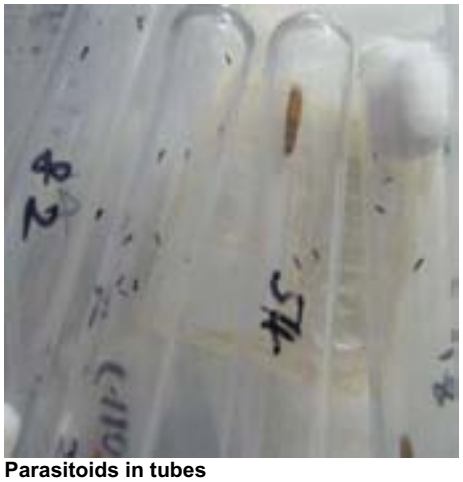
It is also possible to release adult parasitoids in the field. However, they must be released early in the morning, at or shortly after sunrise when it is cool. This is the time that the parasitoids naturally emerge and coincides with the time when most flowers are open and nectar is available. Often dew is on the plants to provide water for the parasitoids. Do not release them around noon or in the early afternoon when it is hottest and driest, as the parasitoids will have little chance of surviving.

Before field release, the parasitoids should be given access to water and honey to allow them to feed and enhance their fitness.

Care must be taken when transporting mummies or live parasitoids to the field for release, since they are very susceptible to heat and direct sunshine. At all times, keep the tubes or boxes out of direct sunlight. Do not leave them in a parked vehicle where the temperature increases very quickly and will kill the parasitoids.

Mummies are very susceptible to heat and direct sunshine. It is best to transport the parasitoids in an insulated icebox with an ice element in the box to keep them cool. However, make sure that the box is not too cold, or freezing, as this may also kill the parasitoids.

Various release methods for mummies



Parasitoids in tubes

Tubes on a palm trunk

Releases over extensive coconut growing areas

If releases are to be made over large areas, a 'grid' release pattern should be used. This method was developed after findings in Viet Nam showed that the parasitoids dispersed at a rate of 5 to 8 km in 2 months from their release sites. To increase the efficiency of releases over large areas, an approach was developed using grids 10 by 10 km, with parasitoid releases made at a small number of sites within the central area of the square (grid). This enables the parasitoids to disperse and cover most of the 10 km grid area within 2 to 3 months.

The number of mummies to release in each 10 km grid depends on the extent of the *Brontispa* infestation in the region or country, and the number of mummies that can be produced by the parasitoid rearing. However, as a general guideline, a minimum of 50 mummies should be released in 5 to 10 mummy bags in each square of the grid. It is, of course, better to release more mummies in an area if they are available.

It is more beneficial to introduce and establish the parasitoids in as many locations as possible, than it is to make releases of higher parasitoid numbers at fewer locations. Since the most rapid increase in the parasitoid population will take place shortly after the parasitoid has become established in an area, it is more important to cover an area as large as possible in the shortest feasible time. Therefore, if many mummies are available within a short period (2 to 4 weeks), it is better to release lower numbers of mummies (at a minimum of 50 per grid) in as many grid squares as possible, than to release higher numbers of mummies in fewer grid squares.

Monitoring

It is important to regularly monitor the impact of the parasitoids on the *Brontispa* population, by looking at damage symptoms of the leaf spear and the young leaves in the central crown of the palm. Surveys should include a visual inspection from the ground of individual leaves as well as the whole central crown.

> It will take 6 to 12 months before any clear signs of undamaged leaves can be observed on the palm trees.

These will appear first in the young leaves as they unfold, and will gradually show a reduction in *Brontispa* damage. After a while the central crown will become much greener when compared to the remaining older leaves that will continue to show high levels of damage. It is important to notice this, as it may take up to two years before the old leaves are shed and the palm regains a healthy appearance.

> It may take up to two years before the old leaves are shed and the treated palm tree displays a healthy appearance.

It is useful to select one or a few sites that are representative of the area where the releases are made. These sites should consist of a large number of coconut trees (at least 500 but better still, more than 1000) in a relatively easily accessible area. They should not be planted too close together as the central leaves need to be readily viewed from the ground. Once every 3 to 6 months, the 4 to 5 youngest unfolded leaves of 100 randomly selected trees should be surveyed for *Brontispa* damage from different angles by 2 or 3 observers on the ground. A tree showing damage symptoms to any of the youngest leaves is recorded as 'damaged'. The results shown in numbers or percentage of damaged trees, of successive surveys enable a comparison of damage incidence over time, and should

show a gradual reduction as the parasitoids gain control and the *Brontispa* population decreases.

More detailed monitoring programmes involve cutting of the coconut leaf spears of some 10 randomly selected at monthly or bi-monthly intervals. These procedures include counting and incubation of beetles and larvae, and have the advantage of detecting the establishment and impact of parasitoids at an early stage. They are quite labour-intensive and require the services of a climber and several technicians to assist with the checking and collection. It is also necessary that the leaves are carefully cut, tied together and gently lowered to the ground to prevent beetles, larvae and mummies from falling out of the leaves. Inspection of the leaves is best done on a large white sheet spread over the ground to enable collection and counting of all live stages. Ideally, these detailed programmes should start before the first releases of the parasitoids are made in the area, so that the results will provide information on the dynamics and abundance of the beetle population. Importantly, these data will give a baseline against which any impact of the parasitoids can be measured.

Casual checks for mummies can be made after a few weeks, but detailed studies have shown that the first detection of mummies may vary from 2 to 3 months up to 7 to 8 months. It is often useful to incubate 4th instar larvae collected from the field to check for parasitoids. If mummies are found in the field or after incubation of larvae, then this is an indication that the parasitoids have become established in the area.

Concluding comments

Once there are signs that the parasitoids have become established in an area there is little use in continuing to release more parasitoids. The parasitoids that have now been 'living' in the field for some generations have an advantage over any newly released ones from the laboratory, as they are fitter and better adapted to the local environment and climate. In time they will increase in abundance, and help prevent the *Brontispa* pest from reaching outbreak levels in the future that would result in major damage and losses to coconut and other palm trees.

Palm showing a healthy central crown

Tying a cut palm spear to prevent mummies, larvae and beetles from falling out

In hot dry conditions, parasitoids may be slow to establish parasitization of larvae in the field, as many may die shortly after emergence. Further releases may then be needed in the wet season. In colder regions, *Asecodes hispinarum* may not perform as desired for quantity of *Brontispa* and alternate parasitoids may be required.