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DEALING WITH RHINOCEROS BEETLE INFESTATION THROUGH BIOLOGICAL AND NATURAL APPLICATIONS AND METHODS

Using the fungus *Metarrhizium anisopliae* as part of an integrated pest management system

By Catherine Dallaire and Dr. Margret Rueffler

Oryctes Rhinoceros L. is an endemic pest of Asia that causes devastating damages to coconut palm tree plantations. What is an effective method to organically and naturally modify the number of the coconut beetles? Jiwa Damai, a permaculture garden located in Bali, Indonesia, has been under the attack of the *Rhinoceros* beetle (*Oryctes Rhinoceros L.*) for a period of two years. This pest infestation has highly endangered the coconut palm tree population and reduced the coconut oil production. This paper presents the integrated pest management system, composed of several layers of actions, that has been applied by this farm in order to face this issue. This control method is based on ecological principles that aim to strengthen the coconut palm trees and reduce the beetle population to a level that no longer treathens the tree's survival. This method relies heavily on the utilization of the fungus *Metarrhizium anisoplia* as a biocontrol agent for *Oryctes Rhinoceros L*. One month after the application of the fungus, the number of insects has reduced by 50% in the upper part of the trees and the number of larvae, pupae and insects has reduced by 90% in the compost piles. However, monitoring the effects of this control method on a long term basis is essential to pursue a good assessment of its effectiveness.

1. Introduction: our local situation

Jiwa Damai, permaculture garden and retreat center is located in the center of the island of Bali, Indonesia (www.jiwadamai.net). The garden is based on permaculture principles; therefore, only fully organic methods are used. Any chemical products - pesticides, insecticides, conventional fertilizers - are not applicable. The garden is surrounded by a vast natural forest containing 180 coconut palm trees scattered throughout the area. Signs of damages on coconut palm trees appeared 2 years ago, with leaves turning brown, falling down and dying, as well as fronds appearing on coconut tree branches. These symptoms allowed us to identify the presence of a possible pest infestation. Discussion with other local farms informed us about the appearance of *Rhinoceros* beetles in our region. Inspecting the coconut palm trees afterwards revealed the presence of numerous adult insects located in the tree crowns. About 80% of all our coconut palm trees exhibited insects in their upper part. The number of visible beetle holes on branches (see annex 1), varied from 1 to 8 per tree.

However, trees with only 1 visible hole in a branch still showed a high number of damaged leaves. No physical damages appeared on tree trunks. Six months later, some larvae were also discovered in our compost piles. Since that time, four coconut palm trees were already dead and had to be cut down, the trunk heavily infested, due to beetle attacks. From then on damages appeared on almost all of our trees. Moreover, large numbers of *Rhinoceros* beetle larvae, pupae and adults have now been discovered in our compost piles in the past few months. Up to hundreds of larvae and adults were discovered in the biggest compost pile (2 x 4 x 1 cubic meters) (see annex 2). This pile was composed of sugar palm trunks and it seems to

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be a favorite place for the beetle to place the larvae. Digging the soil around the coconut palm trees also revealed some larvae in the earth scattered close to the tree roots. From 1 to 5 larvae could be found around the roots in average. We discovered that dead sugar palm trees and our organic compost were major breeding sites for the larvae. The common knowledge presumes that the beetle breeding in the sugar palm trunks was a different kind of beetle. However, our own experience indicates that coconut palm *Rhinoceros* beetles will use dead, decaying or damaged sugar palm trees as breeding sites. These signs of damages lead us to the conclusion that the beetle population was excessive and was a real threat to the coconut palm trees and our coconut oil production was reduced due to a lesser coconut harvesting.

2. History of *Rhinoceros* beetle

Oryctes Rhinoceros (L.) (commonly called *Rhinoceros* beetle) is now endemic to Asia; India, Maldive Islands, Taiwan, Thailand, Vietnam, Malayan Peninsula, the islands of Java, west Pakistan, Sumatra, Bali, Lombok and the Philippine Islands (Bedford 1980). The beetle is autochthonous from South-east Asia and was introduced in the South Pacific in the 50s, causing devastating damages to coconut palm tree plantations (Huger 2005). Chemical products were used as a first resort solution at that time, leading to massive utilization of pesticides in an attempt to eliminate the beetle (Huger 2005). Due to the physiological characteristics and the living habits of the adult beetle and the larvae, insecticides showed no conclusive effectiveness in reducing the beetle populations (Huger 2005). For this reason, a new interest was developed for using biological control methods. Some research programs attempted to apply biocontrol methods worldwide, including the *Oryctes* virus that was distributed in several countries in order to reduce the population in the 70s and 80s (Jackson 2005). This baculovirus showed impressive success in reducing the number of beetles at that time. However, recent devastating outbreaks of the beetle show that this control method is no longer as effective as before. Furthermore, the virus has demonstrated genetic variation, which leads to doubts about its characteristics and effects in the long term (Jackson 2005). As declared by the FAO, strategies based on the use of chemical products are unsustainable and inefficient (FAO 2004). These factors contribute to the need for exploring new techniques for controlling pest outbreaks in the coconut growing regions of Asia.

As these insects attack not only the adult trees, but also young trees and seedlings, their impact can be very damaging to a plantation. When invading a site, their widespread and multiple breeding sites are difficult to destroy or remove completely. Dead trees, killed by adult insects or other sources (disease, physical damage, lightning strikes, …) serve as breeding sites for the larvae (Bedford). Other locations for *Rhinoceros* beetle larvae may be compost, decaying wood, heaps of sawdust, animal manure or any decaying material (Bedford 1980). Larvae show strong negative phototaxis behaviors, select high humidity (85-95%) areas and prefer temperatures between 27-29 celsius degres (Bedford 1980). The main factors affecting the density of a beetle population on a site is the availability of breeding sites in the area and the density of accessible food supplies. Adult beetles are usually located in the crown of palm trees for feeding and larvae are found at the ground level in the breeding sites (Hallet et al 1995). The adult beetle attacks the trees on multiple areas, which makes it hard to evaluate the scope of an infestation. Feeding on unopened leaves and tissue juices, the adult beetles get inside the tree by the growing points of the tree (Bedford 1980). This causes damages to inflorescences which reduces the general photosynthetic activity of the tree and

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diminishes or completely stops fruit production. As said by Bedford (1980), a tree with 50% of its fronds damaged is likely to produce only one fifth of its normal fruit production, as coconut palm trees react with a drop-off of immature button nuts when loosing inflorescences. Damages to opened leaves and defoliation can lead to death of young and mature trees. Moreover, opened fronds and damaged growing points enhance the risks of pathogen attacks and the wounds provide entry points for other insect pests (Hallet et al 1995). Asian palm weevil infestations, which is another important pest for coconut palm trees, can then become a major risk to the trees (Hallet et al 1999).

Moreover, as the damages of a *Rhinoceros* beetle infestation are irregular and located on various tree parts, different control methods need to be implemented in order to be effective on each area. This complexity reinforces the need for a multi-approach control method, with effective techniques that focus on reducing the number of beetles without injuring the tree and the surrounding environment. As total eradication of the beetle in Asia was shown to be impossible for the last decades (Bedford 1980), implementing efficient population control methods is imperative to stop the decline in coconut palm tree number. Knowing that females can lay from 49 to 60 eggs on average (Bedford 1980), we can expect this already excessive population to grow even bigger in the next few months if nothing is done in our garden.

3. Our action plan

Working in cooperation with local specialists and reading other case studies allowed us to develop a plan of action based on the utilization of multiple control methods simultaneously. This integrated pest management system focuses on using ecologically based methods that reduce the number of beetles and larvae on our site without damaging the surrounding environment and creating any negative feedback effects. Our approach does not aim to completely eradicate the beetle from our environment, but only to control the population in order to achieve a state of balance that no longer threatens coconut palm tree survival.

3.1 Monitoring

Monitoring tree damages and symptoms is an important part of this system. In order to assess the efficiency of our control method, we numbered each coconut palm tree from 1 to 160 and separated the land in three distinct areas. This was done with the aim of keeping track of the beetle population evolution and change. Sketching a map of the area is our next goal in order to precisely locate the beetle's hotspots and movements through time.

3.2 Collecting the adult beetles and larvae

The next step is to ensure adult beetles and larvae are removed from the garden as often as possible. Each compost pile is a prominent breeding site for the female *Rhinoceros* beetle to lay eggs. Therefore, each one of our compost piles must be opened, turned and scrutinized attentively on a regular basis to remove all the beetles. A deep cleaning of the compost piles must be done at least every 30 days in order to ensure a good diminution in the number of new eggs (see annex 3). Depending on the type of surface your compost piles are on, any vegetative or soil surface needs to be dug up and inspected too. Larvae were found as deep as one foot buried in the compacted soil under our compost piles. Insects and larvae can be collected and placed into a bucket with high borders, and afterwards filled with water

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to drown the beetles. Burning the insects and larvae is also a possibility. All possible breeding sites need to be clean or removed from your garden. Dead trees, decaying organic matter, piles of vegetation or soil, compost and animal manure, have to be inspected and cleaned and the beetles and larvae burnt if possible. Sanitation measures are crucial to an efficient integrated pest management plan. Counting the number of insects discovered in each area is an important step for monitoring the population changes at this step.

3.3 Cleaning the trees

The coconut palm trees need to be cleaned as well. Adult beetles are often located in the crown of the trees (Bedford 1980). We then decided to employ professional coconut climbers to reach the upper part of the trees and collect the adult beetles located in this area (see annex 4). After collecting the beetles, any dead or heavily damaged branches are taken down and burned. These leaves are draining unnecessary energy from the trees. Any fragments of old leaves stuck in the crown and dead palm tissue need to be cleaned (see annex 5). These scraps have to be collected and burned. The climber also checked each leaf for possible holes where beetles had eaten themselves into the leaves and cleaned each leaf meticulously by either removing or if too deep using a knife to kill the beetle in its hole.

3.4 Feeding the trees

Feeding the tree roots is crucial to ensure an optimal protection against the beetles and a good recovery process after their damages. By providing the tree with nutrients, they can invest more energy in fighting the beetle infestation, which tremendously weakens them (Bedford 1980).

1.To achieve that goal, we cut bamboo trees in pieces of approximately 40 centimeters -the bamboo must be cut on the joints in order to prevent water logging- which we use as a tube to reach the tree roots. The bamboo pieces must be dug into the soil 20 centimeters deep and placed vertically with a slight angle on the side. Several tubes can be placed around the coconut palm trees, at a distance of 2 to 3 feet away from the trunk (see annex 6). We decided to use compost tea as the nutrient mixture to feed our coconut trees. Our compost tea is a mixture of 10 % worm compost, 10% fine compost, 1 cup of molasses and 5 litres of water. These ingredients are mixed together in a bucket for 48 hours with an air pump that adds oxygen to the mixture to promote microorganism action. 10 litres of water can then be added to the compost tea before pouring the diluted solution into the bamboo tubes. Approximately 2 to 5 litres of solution was given to each tree every two months. We also replaced the soil surrounding the tree with high quality compost to ensure optimal soil conditions for the roots.

2. Opening the earth to about 20 cm depth around the trees at about 1 ½ m distance to get to the feeder roots and using compost and earth mixture to get to surround the tree to strengthen the roots and the tree to better cope with the beetle infestation.

3.5 *Positive energy*

Even though this practice has not been demonstrated by any scientic evidence for now on, our personal values make us believe sending positive energy to our trees is essential to their recovery. For that matter, we hugged each of our coconut palm trees and sent them love and positive toughts. We also played some classical music

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to them, as we believe positive sounds and vibrations can also help in the recovery process.

3.6 *Using natural biocontrol agents*

Our system, based on several steps, is vastly supported by the utilisation of biological pest control techniques that propose to integrate natural enemies of *Oryctes rhinoceros* L. in our environment in order to act as control agents. For this purpose, we decided to introduce the fungus *Metarrhizium anisopliae var. anisopliae* (also called Green Muscardine Fungus) in our garden as a biocontrol agent for *Oryctes rhinoceros* (L.), as proposed by some researchers (Bedford 1980; Hosang et al; Walstad et al 1970; Zimmerman 1993). The fungus is generally isolated from a variety of infected insects, soils and parasites by laboratories across the tropics and temperate regions (Bischoff et al 2009). It was not easy in bli to find this. We eventually did and made sure that this fungus is not damaging to other insects. We were assured that it is not and will not harm bees and butterflies.

The use of the fungus *Metarrhizium anisopliae* has shown conclusive reduction effects on *O. Rhinoceros* beetle populations in some studies. Bedford (1980) showed that when spraying the fungus on *O. Rhinoceros* adult beetles at concentrations of 1 x 10^{5} and 1x 10^{6} spores/ml, half of the adults died. Total mortality was obtained when spraying the adults with a 10 ml solution at 1 x10^{7} spores/ml. When spraying the fungus solution on breeding sites, *O. Rhinoceros* larvae are killed for a 3 month period. Reapplication of the spore solution on the breeding site is unnecessary for a period of up to 24 months. It has been shown to be highly effective on *Brontispa longissima* as well, which is another major coconut palm tree pest (Hosang et all). It is used for reducing grasshopper, mosquito, locust and Acridoidea populations as well (Bischoff et al 2009).

The fungus has to be spread on all possible breeding sites; compost piles, the soil surrounding coconut palm trees, dead vegetation and manure piles. Coconut climbers also pour down the fungus on the crown of the tree to protect this part of the tree. If no possible breeding sites seem obvious, an artificial one can be created to attract the female beetles (Coconut Development Board). We used the fungus *Metarrhizium anisopliae var. anisopliae* (Green muscardine fungus), as local specialists indicated that this variety is known to be safe for other insects as well as for bees. There seems to be confusion in the literature about the taxonomy of the fungus. Recent studies by Bischoff et al (2009) now propose a taxonomy of the fungus based on four different varieties, but their distinction in morphology and effects remains unclear and without general acceptance. The fungus is known to be safe for human handling and other animals. This entomopathogenic control method causes mortality of larvae and adult beetles on which it is sprayed by infection (Hosang and all). The spores of the fungus germinate on the body wall of the adult beetles when in contact with it. Fungal growth causes mortality of the beetle. Beetles entering in contact with contaminated insects or sites will be infected by the fungus (Walstad 1970).

We mixed 20 grams of fungus powder in 15 litres of water, which we put into bottles of 1 litre (annex 7). Coconut climbers pour down 1 litre of the solution where the upper branches meet together (crown). We applied the solution once on every possible breeding site and on each of our coconut palm tree's crown. Local specialists advised us to apply the fungus twice a year, as its effect is supposed to

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last for a period of six months. The fungus has to be applied in the evening, as intensive sun makes the solution ineffective. The fungus needs to be stored in a dry and dark place.

4. Results of our control plan

Assessing the pathogenicity of the fungus M*etarrhizium anisopliae var. anisopliae* on *Oryctes Rhinoceros (L.)* in our local garden is still precocious. It is still too soon to evaluate extensively the long-term effectiveness of our pest management system, as it only fully took place in our garden one month ago. Knowing that damages can appear up to 113 days after the first day of insect penetration in a tree (Bedford 1980), it is crucial to keep track of tree's physical symptoms in the next years to assess the real efficacy of the fungus. Monitoring the infection rate of the beetle by the fungus will necessitate detailed surveys for a longer time period. Moreover, quantifying the reduction in coconut production will call for constant monitoring of the fruit production of each tree for the next few years in order to perform good statistical analysis. It is however possible for us to estimate the number of adult insects, pupae and larvae diminished approximately by 50% in the upper part of the tree in one month after the application of the fungus. A reduction of approximately 90% in the number of insects has been assessed in our compost piles after cleaning and spraying the fungus for a period of one month after the application. The infected beetles showed physical signs of fungus propagation on their exterior wall tree days after the application. Five to six days after the application, the fungus caused death of the beetle. These early observations allow us to believe the fungus is for now on effective in reducing the beetle population and is a good prospect for long-term population control. However, information concerning this biological control method is limited and no major extensive studies have been done to evaluate the potential of such predators on *Rhinoceros* beetles (Hosang et al). Therefore, definitive results from the use of this biocontrol agent remain uncertain.

In order to increase our success rate, other control methods should be added slowly to our system. Many ideas have been proposed by previous case studies that could be implemented in our garden in the next months. Using a heavy vegetative ground cover at the base of coconut palm trees has been shown to reduce breeding of beetles. Ground cover restricts the movement and flight of adult *Rhinoceros* beetles, which reduces their effectiveness in attacking the trees. Grasses, ferns and creepers, as well as planted leguminous covers would be suitable for this task (Coconut Development Board). Because beetles can fly, a vegetative vertical barrier can be useful in acting as a physical protection around the trees. The utilization of vegetation as a barrier to the expansion of *Rhinoceros* beetles is one of the cheapest methods to reduce their attacks.

Neem oilcakes can also be placed on the mature trees to repell the beetles. This natural insecticide is produced from the seeds of neem trees and is effective in repelling insects from plants and trees. The oil form can be applied directly on leaves and the oilcakes can be suspended close to the trunk of the trees (Coconut Development Board). Attractive trapping can also be used in a small field. However, this method, if used to eradicate an entire population of beetles, must be sustained on a long-term basis and at a high concentration of traps in order to be successful (Hallet et al 1995). This technique uses different kinds of traps built from 1-9 litres buckets buried in the soil or located above ground level in order to catch the adult beetles flying around the trees.

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Discussing with an organic farm owner facing the same issue in India revealed to us that spraying a solution of salt in the crystal form mixed with turmeric powder at the base of coconut palm tree's branches each year is a treatment that showed conclusive results in reducing the incidence of beetle attacks.

5. Conclusion

Our control method plan has for now shown impressive results in diminishing the number of insects on our site. However, knowing that the *Rhinoceros* beetle is now endemic to the South-east Asian region, it is imperative to understand that no total eradication of the beetle on our site will ever be possible. The applied pest management system must be focused on controlling and reducing the number of insects to a tolerable level and not on the complete extermination of the insect population. As we cannot control the outer environment, our system must take in account that beetles coming from outside will enter our garden. Neighbouring forests or monoculture plantations that do not use proper pest management systems, for example, add to the complexity of monitoring the evolution of the beetle population on our site. The control method must then be based on a multi-year plan, that is sustained on a long-term basis and continuous efforts to reduce the insect propagation.

The multiple control techniques applied should then be able to sooth possible pest outbreaks triggered by the outer environment or any environmental changes and imbalances. The low value of this crop adds a major challenge to the implementation of these labor intensive methods. Therefore, discovering new simple and inexpensive control techniques is imperative to the resettlement of balanced ecosystems in the coconut growing regions of Asia. As declared by the FAO, relying on insecticides is unsustainable and applying effective biocontrol agents at regional, national and worldwide levels is now necessary to ensure ecologically sound coconut ecosystems (FAO 2004). To this effect we share and teach our findings with the neighbours and other farms that face the same issue. We hope, in comminucating our recommendations to others, to help improving the collective knowledge about organic control of the *Rhinoceros* beetle and foster improvement in this field of study.

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Annex

Annex 1	Annex 2
	
Holes made by the beetles in a tree crown. Picture taken at our farm in central Bali, Indonesia 07/03/15.	Beetle found in our biggest compost pile. Picture taken at our farm in central Bali, Indonesia 05/05/15.

Annex 3	Annex 4
	
Our biggest compost pile opened to find all the beetles and larvae in it. Picture taken at our farm in central Bali, Indonesia 05/05/15.	Coconut climber cleaning a coconut palm tree. Picture taken at our farm in central Bali, Indonesia 07/03/15.

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Annex 5	Annex 6
	
Two coconut palm trees side to side. The one on the left has not been clean as opposed to the tree on the right which has been cleaned by the coconut climbers. Picture taken at our farm in central Bali, Indonesia 07/03/15.	Bamboo pieces dug up into the earth to feed the coconut tree by the roots. Picture taken at our farm in central Bali, Indonesia 06/15/15

Annex 7	Annex 8
	
Beetle larvae. Picture taken at our farm in central Bali, Indonesia 07/03/15.	Beetle larvae. Picture taken at our farm in central Bali, Indonesia 06/15/15

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Annex 9	Annex 10
	
Beetle larvae. Picture taken at our farm in central Bali, Indonesia 07/03/15.	Beetle larvae. Picture taken at our farm in central Bali, Indonesia 06/15/15

Annex 11

Solution of water and the fungus *Metarrhizium anisopliae* in its powdery form. Picture taken at our farm in central Bali, Indonesia

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