2008 IMPACT REPORT

WPTRC

RESEARCH FOR GUAM'S FUTURE

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2008 IMPACT REPORT

MISSION

Excellence in research in support of the land grant mission of discovery, learning and engagement. We excel in the areas of tropical agriculture, environmental and life sciences.

Western Pacific Tropical Research Center
College of Natural & Applied Sciences
University of Guam

WPTRC

RESEARCH FOR GUAM'S FUTURE

Hafa Adai !! This is our second Western Pacific Tropical Research Center Impact Report and we add another great year of productivity from our research faculty. I believe as you read through this report you will realize how important our current activities are to the stakeholders we serve locally, regionally, and internationally. In our second issue we have highlighted some very key projects that demonstrate our usefulness to the community we serve. Our scientists continue to make every effort to secure both contracts and grants that are used to target important issues in both agriculture, aquaculture and our ever-troublesome invasive species issues. I believe our island's sustainability for current and future generations will rely on how much time, effort and resources our current government will allocate to support agriculture, aquaculture and environmental issues. This island has the capability to be one of the showcases of the Western Pacific. We all can make a difference if we are willing to work together for a common goal. I urge our policy makers to allocate more funding for our land and water resources to ensure a brighter economic future for the next generation of this island.

I personally want to thank all the contributing researchers at the Western Pacific Tropical Research Center for a great year of both applied and basic research activities. It will be the combination of their efforts and other research scientists on Guam that will add to the overall sustainability to the place many of us call home. Viva Guam and Viva WPTRC.

Lee S. Yudin, Ph.D.
University of Guam, CNAS
Dean/Director
Western Pacific Tropical Research Center

Lee S. Yudin, Ph.D.

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The dramatic changes in agriculture research provide major challenges and major opportunities for the Western Pacific Tropical Research Center. This past year we continued to develop research strategies geared towards achieving sustainable agriculture and the protection of the environment in this age of globalization.

WPTRC scientists conduct innovative research discovering and implementing novel practices in plant and animal sciences as well as health and sustainability of the natural environment. For this group of scientists located on the remote island of Guam, international collaboration and the exchange of research ideas and results are essential. Cooperation and exchange programs with institutions and countries in our region are particularly important aspects of long-term projects. Cooperative arrangements recently established with China, Japan and other Pacific countries expand our strong ties with U.S. universities.

As a land-grant institution of higher learning, we strive to combine discovery, innovation and research applications in educating our students. We continue to ask questions and encourage students to assist us in finding answers. We place great importance in accountability to ourselves and to stakeholders in fulfilling our research mission.

Greg Wiecko, Ph.D.
University of Guam, CNAS
Associate Dean/Director
Western Pacific Tropical Research Center

Greg Wiecko, Ph.D.

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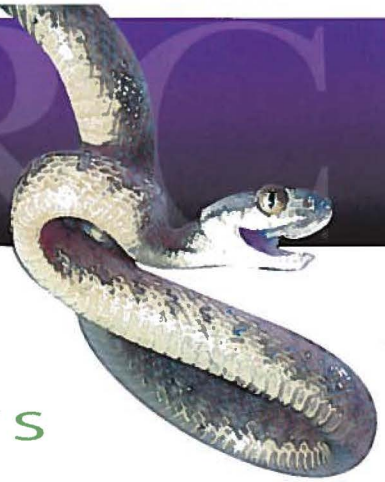

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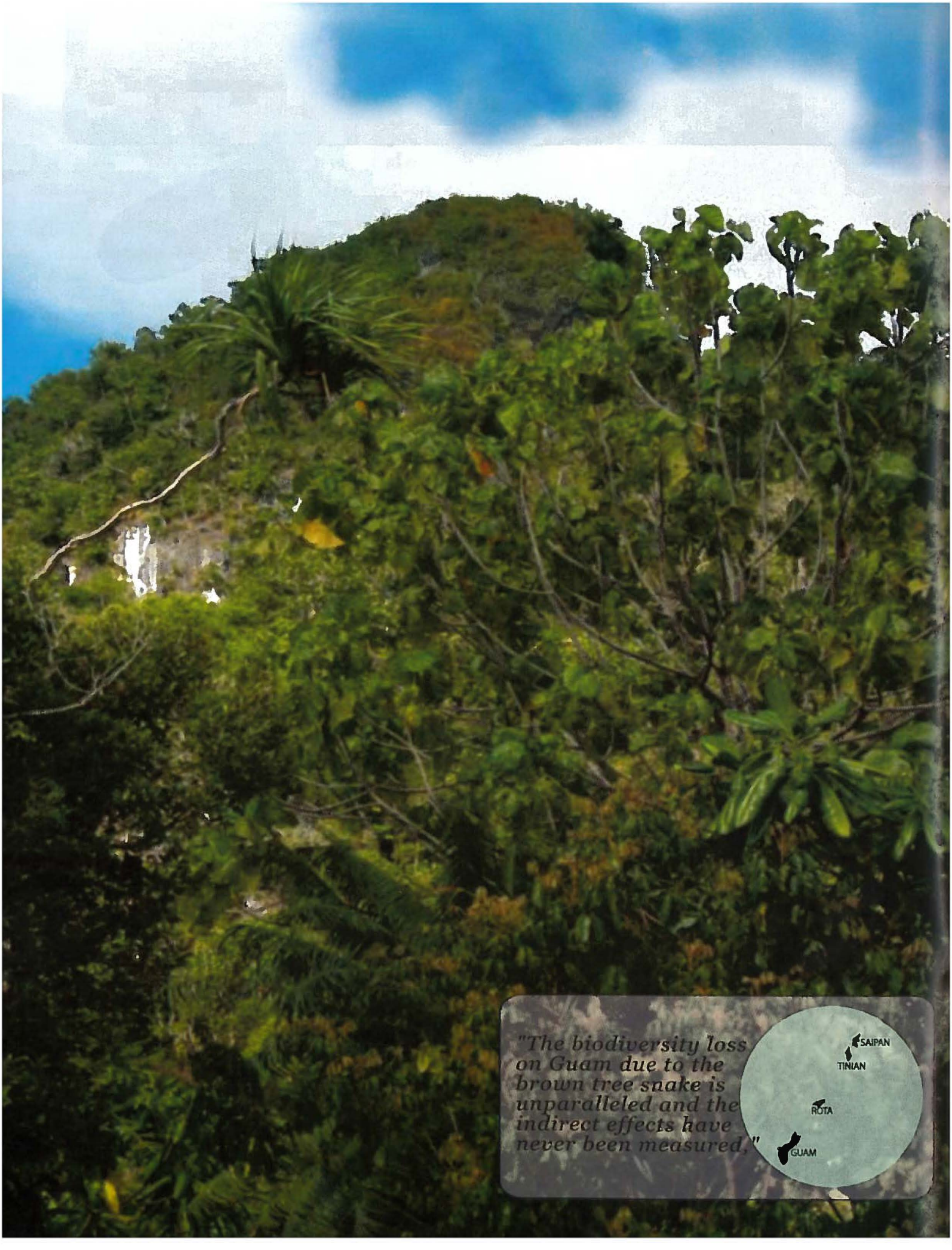

"The biodiversity loss on Guam due to the brown tree snake is unparalleled and the indirect effects have never been measured."
SAIPAN
TINIAN
ROTA
GUAM

The Birds and Trees

With the disappearance of Guam's forest birds, the limestone forests themselves may be in danger of vanishing. WPTRC entomologists Drs. Ross Miller and Aubrey Moore are collaborating with University of Washington ecologists to study the indirect effects of one of the world's worst invasive species, the brown tree snake, on island ecosystems. "The biodiversity loss on Guam due to the brown tree snake is unparalleled and the indirect effects have never been measured," said Ross Miller.

This research, funded by a National Science Foundation grant written by Haldre Rogers, a former Guam DAWR employee currently pursuing a doctorate in ecology at UW, examines the ecological effects of the loss of native birds on plant and insect communities on Guam. Due to the unfortunate circumstance of losing much of its native bird population to the brown tree snake, Guam is an ideal laboratory to increase the scientific understanding of how birds contribute to the health of plant communities through seed dispersal and insect control. "Studies on avian seed dispersal and avian control of insect herbivores have focused primarily on single species bird-plant pairs. By examining a system where virtually all bird dispersers and bird insectivores have been lost, we can provide critical insights into the importance of birds for forest community structure," said Rogers.

The brown tree snake has not invaded the neighboring islands of Rota, Tinian or Saipan and their bird populations are still relatively intact.

Field experiments are being conducted on all four islands and comparisons made between the forests on Guam and forests on the islands where birds continue to thrive.

These studies will inform conservation and management efforts on Guam and permit generalization of the results to ecosystems experiencing bird loss. Rogers said, "The magnitude of difference between seed dispersal on Guam and Saipan is alarming because of its implications for Guam's forests, and for forests worldwide experiencing a decline or complete loss of birds."

The UOG role in this project includes the growing and monitoring of local plants for field studies as well as the identification of insects. For help in identifying insects researchers are utilizing an optical sensor and digital signal analysis system invented by Aubrey Moore.

The research activities for this three-year grant will culminate in the creation and delivery an advanced graduate level ecology class at UOG. The course will involve students from both UW and UOG and be taught primarily by Ross Miller and Josh Tewksbury of UW. Haldre Rogers and other UOG and UW professors will also participate. "This should be a great class for ecologists from the US and Micronesia, and will emphasize island issues such as invasive species, development impacts and the structure and function of insular ecosystems. This is a wonderful opportunity for UOG students and researchers to study the impact of the brown tree snake on insular environments, and to collaborate with University of Washington scientists who are at the forefront of their fields," said Dr. Ross Miller.

Dr. Mankin, an entomologist with the USDA Agricultural Research Service in Gainesville, Florida, is a recognized world-class expert on acoustic detection of insect pests.

Listening for Rhinos

The Guam Coconut Rhinoceros Beetle Eradication Project is a cooperative project being run by the Guam Department of Agriculture, the United States Department of Agriculture, and the University of Guam. The project was organized in 2007 when an infestation of the coconut rhinoceros beetle was detected in Tumon. This large scarab beetle is a major pest of coconut and other palms. It is a new pest for Guam. Adult beetles bore into the crowns of palm trees to feed on sap and once a beetle bores through the growing tip, the tree will die. Several young coconut palms have already been killed by CRB and many mature trees have been mortally wounded throughout Tumon. The objective of the eradication project is to kill all rhino beetles on Guam. Adult beetles are being removed by catching them in large bucket traps, which use a pheromone lure. Immature beetles, called grubs, are hard to find because they feed deep inside rotting coconut material. When breeding sites are discovered, all rotting coconut material is removed and treated to kill all the grubs. UOG has used grant funds provided by the US Department of Agriculture and the US Forest Service to hire ten people to check traps and remove breeding sites. This crew is lead by Roland Quitugua, who is the operations chief for the eradication project.

University of Guam entomologist, Dr. Aubrey Moore received funding from the USDA Western Integrated Pest Management Center to bring Dr. Richard Mankin to Guam to assist with the CRB eradication project. Dr. Mankin, an entomologist with the USDA Agricultural Research Service in Gainesville, Florida, is a recognized world-class expert on acoustic detection of insect pests.

He has developed hi-tech electronic equipment that can detect insects in their natural surroundings, like coconut trees, by the sounds they make.

Dr. Mankin arrived on Guam in early May and he and Dr. Moore spent much of his two-week stay in the field evaluating acoustic detection technology to see if they could locate the hard to find rhino beetles so that they can be killed.

Insect activity can be detected acoustically by attaching an accelerometer to the base of a tree or log suspected of CRB infestation. Accelerometers are commonly used for measuring vibrations. Since CRB are such large and active beetles, adults and grubs generate detectable feeding sounds. CRB also communicate by stridulation (rubbing together of body parts to produce sounds, like crickets). Once the accelerometer is attached to a coconut tree or log, Dr. Mankin monitors the situation using headphones and makes digital recordings for analysis. The assessment can be double-checked using signal-processing software developed by Dr. Mankin and his colleagues. This software discriminates insect sounds from background noise by analysis of their spectral and temporal patterns.

This method was helpful this past September when the rhinoceros beetle eradication team went up north to Urunao to see if there were any indications that the beetle had broadened its range. Unfortunately, feeding grubs were found, evidence that there is a breeding population in that area. As the range of the CRB infestation widens it may mean that total eradication of the beetle on Guam will be impossible. The good news is that Dr. Mankin's expertise and equipment allowed Roland and his team to locate the beetles faster and with fewer people than it would have taken without the hi-tech equipment.

UOG scientists take their research and the research of their colleagues into the field, making a positive impact on the ecosystems of Guam and the region.

New specimens collected by University of Guam scientists and by collaborators from Micronesia and worldwide are continually being added to the collection.

Insect Museum for the Region

WPTRC entomologists, Drs. Ross Miller and Aubrey Moore have attained a long-term goal with the official recognition of the Wilfred Leon Guerrero Insect Museum (WLGIM) by the University of Guam in 2008. The museum is poised to make an impact with several leading entomologists on its Board of Directors: Richard Zack, associate professor and director of the T. James Entomological Collection at the University of Washington; Robert Foottit, curator of the Canadian National Collection of Insects; Robert Sites, professor and director of Enns Entomology Museum, University of Missouri; Ross Miller, professor and curator of the WLGIM; Aubrey Moore, UOG extension entomologist, inventor and associate curator of the WLGIM.

Located in the Agriculture & Life Sciences Building, the Wilfred Leon Guerrero Insect Museum houses an extensive collection of approximately 25,000 pinned insect specimens sorted by order and family, with many identified to the species level. Some insects in the collection date to the liberation of Guam at the end of WWII, while most have been collected in the past 30 years. New specimens collected by University of Guam scientists and by collaborators from Micronesia and worldwide are continually being added to the collection.

In addition to the insect specimens the museum also maintains an insect database which contains information not only on the insects housed in the collection, but also contains information gleaned from the scientific literature regarding insects collected on Guam and throughout Micronesia. Housed on computers within the College of Natural and Applied Sciences, this database allows researchers to efficiently carry out queries on specific insect species or groups, with information on the taxonomy, collector and collection site, and literature citation for each species readily available.

WLGIM curator Ross Miller believes the mission of cataloguing insect biodiversity on Guam and in Micronesia in general is just one aspect of the fledgling institution. He states, "Specimens from the collection are provided on loan to qualified researchers and other research institutions upon request and we intend to expand outreach activities to specialized technical groups and the general public in the future as resources allow." Avenues for funding will now be available with the official recognition of the Wilfred Leon Guerrero Insect Museum by the university. "This allows us to compete for National Science Foundation funds which will allow us to expand the collection making it an even more useful research and teaching tool," says Dr. Miller.

WPTRC scientists are making a difference for the island, the region and the world.

Experiments using noni juice or extracts in vitro or in vivo show evidence of biological activities such as scavenging for free radicals, stimulating the immune system, and inhibiting LDL oxidation.

Modern Food Technology Improves Ancient Practice

Noni (*Morinda citrifolia, L.*) is a traditional Polynesian medicinal plant used in the Pacific Islands to treat topical and internal diseases for more than two thousand years. Noni fruit juice is marketed as a dietary supplement for consumers, often advertised as a cure-all product with many unsubstantiated health claims such as a menstrual cycle regulator, anti-cancer agent and blood cleanser. According to scientific literature, more than 150 phytochemicals have been identified from the noni plant. Experiments using noni juice or extracts in vitro or in vivo (conducted in a living cell or organism) show evidence of biological activities such as scavenging for free radicals, stimulating the immune system, and inhibiting LDL oxidation.

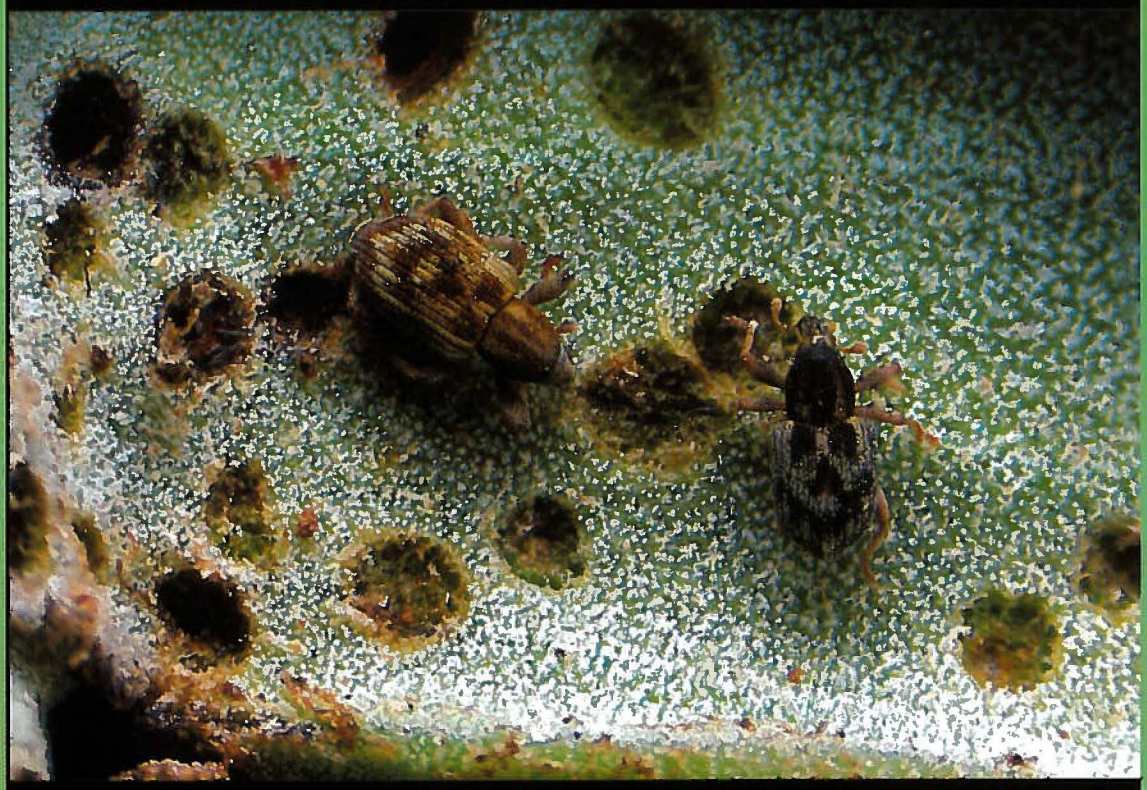
Noni fruit juice is traditionally made by fermentation, in which noni fruits are placed in jars outdoors and left in the sun for weeks to allow the juice to separate from the pulp. In commercial processing and home preparation of noni juice fruits are in packed in sealed containers at ambient temperature and allowed to ferment for a period of time from 10 to 60 days.

The overall moisture content of noni fruit is 89% but the traditional fermentation process only produces a juice yield of 40-50%. Not only is this method inefficient, the juice obtained from the fermentation process is dark in color with an unpleasant smell and taste. "We observed in our experiments that using the traditional method with a one month fermentation period resulted in a loss of 100% of the initial ascorbic acid, 90% of its antioxidant capacity and 40% of the total phenols of the noni juice when compared to freshly squeezed juice," says Dr. Yang.

Dr Yang and his research team experimented with enzymes to improve the yield and quality of noni juice. Enzyme technology is widely used in fruit juice processing to improve juice yield and quality because enzymes such as cellulases, hemicellulases and pectinase can breakdown cell walls and disintegrate fruit tissues to promote juicing and increase soluble solid content. Using enzymes in noni juice processing also cuts the fermentation time from weeks to hours.

Noni juice processed with enzymes possessed the same antioxidant capacity and total phenols as freshly squeezed noni juice. In addition, the noni juice processed with enzymes exhibited improved sensory quality having a lighter color and more desirable taste and flavor than traditionally fermented noni juice. "Instead of needing weeks of fermentation to produce juice, applying pectolytic and cellulolytic enzymes can successfully make noni juice within several hours with an improvement of juice yield and quality," says Dr. Yang.

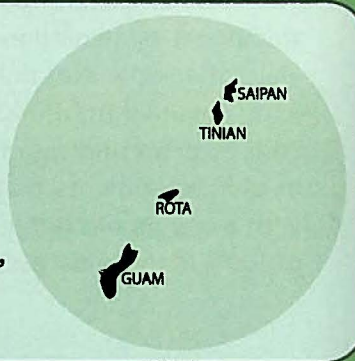
Biological Control of Tropical Weeds using Arthropods



EDITED BY
Rangaswamy Muniappan,
Gadi V. P. Reddy, *and*
Anantanarayanan Raman

CAMBRIDGE

"This is the first book on the topic particularly dealing with biological control and sustainability of tropical weeds."



Bio-Control: Insects vs. Plants

One man's weed is another man's wonder and University of Guam research scientist Dr. Gadi V. P. Reddy has spent much of his career finding environmentally safe methods to control invasive plants. A chemical ecologist and entomologist, Dr. Reddy is the coeditor and coauthor of the book *Biological Control of Tropical Weeds using Arthropods*, which is to be published by the Cambridge University Press and available to the public in March 2009.

Dr. Reddy coauthored four chapters of the book, two of which discuss his work at the Western Pacific Tropical Research Center with the invasive weeds *Chromolaena odorata* (Siam weed) and *Coccinia grandis* (ivy gourd vine). His research has been an immense help to farmers on the island of Guam and the Micronesian region. Dr. Reddy says, "This is the first book on the topic particularly dealing with biological control and sustainability of tropical weeds. It is a privilege to have a book published by CUP as they continue garner top honors in the publishing of scientific research."

The book discusses the use of insects for the control of twenty invasive weeds, which is often more cost-effective than using chemical means and safer for the environment. Providing ecologically sound management practices for controlling invasive plants in the tropics is one of the main purposes of this book, as well as serving as a tool in the assessment of dangers for native plants. Policy makers and scientists working with the environmental impacts of invasive plant species will find *Biological Control of Tropical Weeds using Arthropods* a very useful resource.

Lantana *camara* has the dubious honor of being the first weed ever targeted for bio-control. Twenty-three insect species were shipped to Hawaii from Mexico in 1902 to control *L. camara*. Over 100 years later scientists around the world are still looking for an effective means to control this invasive weed. It is regarded as one of the most serious weeds of plantation crops such as coffee, oil palm, and coconuts. It invades pastureland in Australia, Africa, Fiji, India, the Philippines, Hawaii and other Pacific island groups.

Dr. G. V. P. Reddy and his research assistants conduct on-going surveys designed to examine the current situation of *L. camara* and its natural enemies in Guam. In the most recent survey, the population of *L. camara* was assessed in different niches in Guam. Nine field sites, each with well-established stands of *L. camara*, were selected for the survey from villages in northern, central and southern Guam. *L. camara* has been kept in check by successful natural enemies, which were deliberately and fortuitously introduced to Guam over the last three decades. However, this recent survey indicates the existing natural enemies are not sufficient to completely eradicate the weed. To keep this highly invasive weed under control, Dr. Reddy's recommendations include rearing effective biological control agents, particularly Uroplata girardi, Epinotia lantana and Ophiomyia lantanae in the laboratory and carrying out further field releases.

Left: Uroplata girardi *is a recommended bio-control agent.*
Above right: The highly invasive weed, Lantana camara.

Bio-Control: Insects vs. Plants Cont.

Mimosa *(invisa) diplotricha*, the creeping sensitive plant, is a native of Brazil and is a serious weed in the Philippines, Southeast Asia and the Pacific Islands. Dr. Reddy and his bio-control team have released the psyllid insect *Heteropsylla spinulosa* as a bio-control measure to curtail the spread of this thorny pest. The insects were collected in Pohnpei, where they have been successfully used to control the invasive mimosa weed on that island. The plant has sharp, hooked prickles and thickets of the tangled stems can injure humans and prevent animals from grazing. H. *spinulosa* is a sap-feeding bug, which stunts the growth of the plant and prevents the production of flowers.

Collaborating with Dr. Jack Tenorio of Northern Marianas College nymphs, adults and immature stages of the insect were released by placing infested plant parts on to plants growing in targeted areas of Guam and Saipan. The establishment of H. *spinulosa* has been observed in Yigo on Guam and Kagman in Saipan. The remainder of the H. *spinulosa* population collected is being used to develop and maintain the laboratory cultures at the Western Pacific Bio-control Quarantine Laboratory on Guam and Northern Marianas College on Saipan. Drs. Reddy and Tenorio have also collected H. *spinulosa* in Palau for releases on Guam and Saipan. The bio-control teams continue to monitor the establishment of H. *spinulosa* biweekly.

Above left: Sap-feeding psyllid on leaf.
Above right: Bore holes in vine made by larvae of bio-control moth.

Ivy Gourd Vine: The bio-control agent released in August 2007 to control *Coccinia grandis*, commonly called ivy gourd vine, has established in Guam and Saipan. The bio-control agent, the insect *Melittia oedipus* (Lepidoptera: Sesiidae) has been successful in controlling the ivy gourd in Hawaii and Dr. Reddy has spent years getting permits and rearing young moths in the lab prior to releasing them in the region.

Dr. Reddy and his research assistants have observed numerous bore holes in the vines on Guam and Saipan, evidence that the larvae of this small moth are boring into the stem to feed. Larvae begin feeding in young shoots, boring down through the larger stems and into the root, eventually killing the vine. This is good news for Saipan where the vine has taken over an estimated 1500 acres and Guam where 500 acres are covered by this highly invasive plant. The ivy gourd vine is a host for most of the pests of cucurbitaceous crops such as cucumber worm, pumpkin beetle, melon fly, melon aphid, whiteflies and others. "Although the release has been a success, it will still take another year or two to see concrete results of the moth controlling the invasive vine island wide," says Dr. Reddy.

Bio-Control: Plants vs. Insects

In addition to his work on invasive weeds, Dr. Reddy is assisting local farmers in developing an integrated pest management (IPM) system for managing insect pests on cabbage and other cruciferous crops in an effort to eliminate the application of toxic insecticides to control the pests. IPM approaches to insect control seek to minimize environmental impact and optimize benefits to farmers.

Dr. Reddy and his research team are conducting comparative experiments at the UOG Agricultural Experiment Stations in Inarajan and Yigo using an insecticide that has been developed from a chemical extracted from the Neem tree (Neem Azal). According to Dr. Reddy, "In addition to being environmentally friendly, the advantage of using the neem-based insecticide is that it is relatively non-toxic to beneficial insects as well as insect pollinators."

The results of Dr. Reddy's research will be shared with farmers in the Micronesia/Pacific region and practical IPM training will be given to local farmers on demonstration plots at the Agricultural Experiment Station in Yigo.

University of Guam scientists continue to make important contributions to the island's farmers through their work in the field, in laboratories and on experiment station farms.

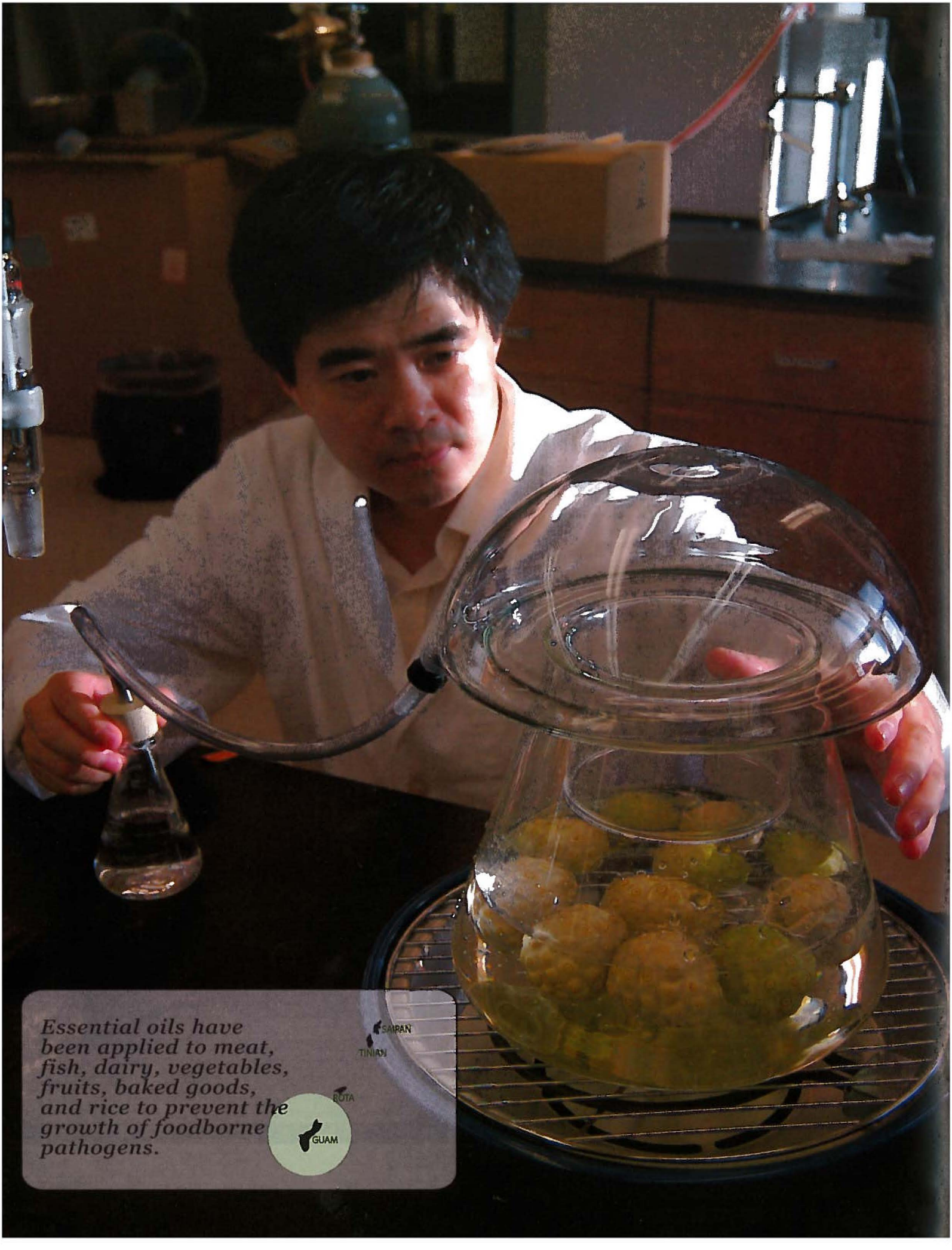
Dr. Reddy and his research team.

WPTRC Inventor

UOG entomologist Dr. Aubrey Moore has invented a photosensor that records signals made by flying insects. The sensor uses a miniature solar cell to capture waveforms consisting of patterns made by small flashes of light reflected from the insects' wings. Moore's research has shown that the waveforms can be used as signatures for identifying different species of insects. Dr. Ross Miller, another UOG entomologist, used Moore's equipment to automatically identify five species of aphids commonly found on Guam. The sensor has also been used in Kenya to count malaria mosquitoes flying in and out of native huts.

Moore has teamed up with Dr. Eric Wan, an engineer at the Oregon Health and Sciences University, and Philipp Kirsch of APTIV Inc., a small research and development company that specializes in insect traps and monitoring devices. This team is working under a $600,000 National Science Foundation grant to develop an instrumentation package which uses the photosensor for automated monitoring of insect populations. Their goal is to perfect a device that can be used like a remote weather station. Except in this case, insects are monitored instead of weather. If they are successful, networks of Moore's sensors could be used to detect and count changes in the numbers of flying insects in different habitats, whether they are crop pests, malaria mosquitoes, honeybees, or newly arrived invasive species.

An early prototype of Moore's photosensor connected to a solid state digital recorder. This set up is used for field recordings of flying insects.



Essential oils have been applied to meat, fish, dairy, vegetables, fruits, baked goods, and rice to prevent the growth of foodborne pathogens.

Noni Essential Oils Fight Foodborne Pathogens

Kelaguen is a Guam delicacy found on fiesta tables around the island. Unfortunately, kelaguen has been identified by the Guam Department of Public Health and Social Services as one of leading vehicles associated with foodborne illness on the island. Dr. Jian Yang and his team of researchers conducted a kelaguen survey in the community which indicated that 74% of the respondents like to eat kelaguen prepared with raw beef, fish, or shrimp; and 19-28% use raw or partially cooked beef, chicken, shrimp, and fish when preparing kelaguen. Utilizing raw or partially cooked meat and allowing the dish to sit out on fiesta tables without temperature control are the main causes of foodborne illnesses.

Although lemon juice is a major ingredient for kelaguen, lemon does not effectively kill harmful bacteria. To reduce the risk of foodborne illness, it is necessary to seek alternatives to ensure that pathogens will not proliferate when kelaguen is prepared with meats that have not been thoroughly cooked. Natural essential oils, volatile compounds extracted from plants and herbals, have been used as embalming agents, perfumes, food preservatives, and anti-inflammatory remedies. Essential oils from rosemary, oregano, lemongrass, clove, and thyme show antimicrobial activity against foodborne pathogens such as *Escherichia coli, Salmonella typhimurium, Bacillus cereus, Staphylococcus aureus,* and *Listeria monocytogenes*. Essential oils have been applied to meat, fish, dairy, vegetables, fruits, baked goods, and rice to prevent the growth of foodborne pathogens.

Noni (*Morinda citrifolia*, L.) is a traditional Polynesian medicinal plant and noni fruit juice is marketed as a dietary supplement.

Dr. Yang and his research assistants extracted noni essential oil from ripe noni fruits with a yield of 5% using steam distillation. Using Tryptic Soy Agar as a growth medium, they observed that noni essential oil at a concentration of 0.4 ml cm-1 completely inhibited the growth of *Salmonella enteritidis* and *Escherichia coli* O157: H7. In a Tryptic Soy Broth medium, noni essential oil exhibited a minimum inhibitory concentration and a minimum bactericidal concentration at 0.4% against *S. enteritidis* and *E. coli* O157:H7.

Using Gas Chromatography and Mass Spectrometry (GC/MS) analysis, Dr. Yang identified the volatile compounds of the extracted noni essential oil as octanoic acid (82%), 2-Heptanone (8.6%), a-pinene (4.3%), camphene (2.3%), and methyl ester (2.3%). Octanoic acid is a compound that has been reported to effectively reduce *Listeria monocytogenes* bacteria in ready-to-eat meat and poultry products. In addition, octanoic acid also exhibits a minimum inhibitory concentration 4-5 times lower than that of acetic, benzoic, butyric, and lactic acid against *Bacillus cereus*. "It appears that octanoic acid is the component responsible for the antimicrobial activity of noni fruit essential oil," says Dr. Yang.

Noni essential oil exhibits potential for use as an antimicrobial agent against foodborne pathogens. Further studies are needed to evaluate the effectiveness of applying essential oils to reduce the risk of foodborne illness for foods like keleguen that are prepared with raw or partially cooked meat.

Meeting the needs of local consumers with research on native plants and foods is a driving force for Dr. Yang and his lab team.

Michael Calonje supported the team's conservation efforts with one month of independent work in Guam and Rota.

Cycad Studies

WPTRC Attracts International Experts

Two cycad-specific alien insect pests invaded Guam several years ago, and they have combined to reduce Guam's cycad population so heavily that it is now listed as endangered. WPTRC scientists Thomas Marler and Irene Terry have been deeply involved in the conservation and research efforts of Guam's cycad population, known locally as fadang. But with ongoing epidemic plant mortality, their progress was not keeping pace with the mortality.

"I felt the best way to advance our efforts with respect to the continuing decline in survival of the population was to solicit help," said Marler. The approach resulted in productive visitations by three internationally respected scientists.

Michael Calonje supported the team's conservation efforts with one month of independent work in Guam and Rota. Calonje is the cycad biologist with the Montgomery Botanical Center in Miami, Florida. His role was to characterize the fadang population in 25 distinct locations throughout Guam and Rota. The information is critical for building an understanding of the population status before more of the plants are lost. The Center's mission is to advance science, education, conservation, and horticultural knowledge of cycads and other tropical plants.

Robert Roemer was on Guam for one month to support Dr. Terry's fadang pollination biology research efforts. Roemer is a professor and administrator with the College of Engineering, University of Utah. The mechanisms used by reproductive structures of cycad plants to secure pollination services of insects are intriguing. One of those mechanisms is to produce heat, and Roemer has characterized the daily pattern of the process and is pursuing an understanding of the energy relations underlying this unique plant attribute.

Eric Brenner supported various projects that Dr. Marler conducted in Guam, Rota, and Tinian. Brenner is Assistant Curator with the New York Botanical Garden, and is an expert in plant molecular genetics and genomics. His primary interest in the near future is to study the relationship among various cycads that are closely related to Guam's fadang, specifically looking at a unique seed structure that allows fadang seeds to float from island to island.

"That Marler and Terry have been able to attract the on-site support of these internationally respected experts is a testimony to the quality of the ongoing research within the WPTRC," says Associate Director Greg Wiecko.

US Navy Funds Cycad Collection

One approach to the conservation of an endangered plant species is to establish collections of the species in geographic sites outside of its native threatened range. The WPTRC has been overseeing the establishment of several collections of Guam's Cycas micronesica due to its recent endangered status.

"The goal is not just to stick plants in various locations and take care of them to ensure representatives of the species stay alive," said WPTRC scientist Thomas Marler. "The conservation value of off-site collections is actually most dependent on the initial step of selecting what to collect and propagate from the native habitat."

Marler's laboratory team spent several years collecting seeds throughout Guam's various habitats. Each seed harvest was recorded with data on micro-location, habitat information, and individual plant characteristics. Seeds and data were disseminated to the Montgomery Botanic Garden in Miami, Florida and the Nong Nooch Tropical Garden in Chonburi, Thailand. These institutions are committed to conservation of cycad species, and have agreed to house the valuable plants for Guam's future. A third collection has been established in a native limestone forest habitat on Tinian.

WPTRC Cycad Studies

"We have obtained emergency funding for various conservation efforts from several agencies," said Marler. "The funds from the U.S. Navy to establish a collection of Guam's cycad plants on Tinian revealed a commitment unlike that of the other funding agencies." Most of the initial grants were given to pay for various forms of protecting Guam's plants from the new alien threats that led to the endangered status. The long-term effectiveness of these temporary efforts was uncertain from the start, mainly because of the temporary status of emergency funding. In contrast, the success of conserving the genetic variation among Guam's cycad plants by establishing a living collection outside of Guam is guaranteed regardless of what continues to happen to the plants on Guam.

The value of the U.S. Navy's Tinian collection is magnified by the fact that the co-occurring plant species within the limestone forest site are appropriate neighbors for Guam's cycad plants. The underlying factors that lead to beneficial or facilitative relationships among co-occurring native plant species are not fully understood. Despite this limitation in our understanding, the site in Tinian should meet the needs of the transplanted Guam plants in a manner that cannot occur at the Florida and Thailand sites.

According to Marler, these off-site collections will be available for use in the future to repatriate Guam's forests if the species becomes extinct on the island. The WPTRC's detailed data that accompany each individual in these conservation collections will provide biologists with the ability to introduce the most appropriate individuals back to each of Guam's habitats in a highly successful manner.

High Construction Cost For Cycads

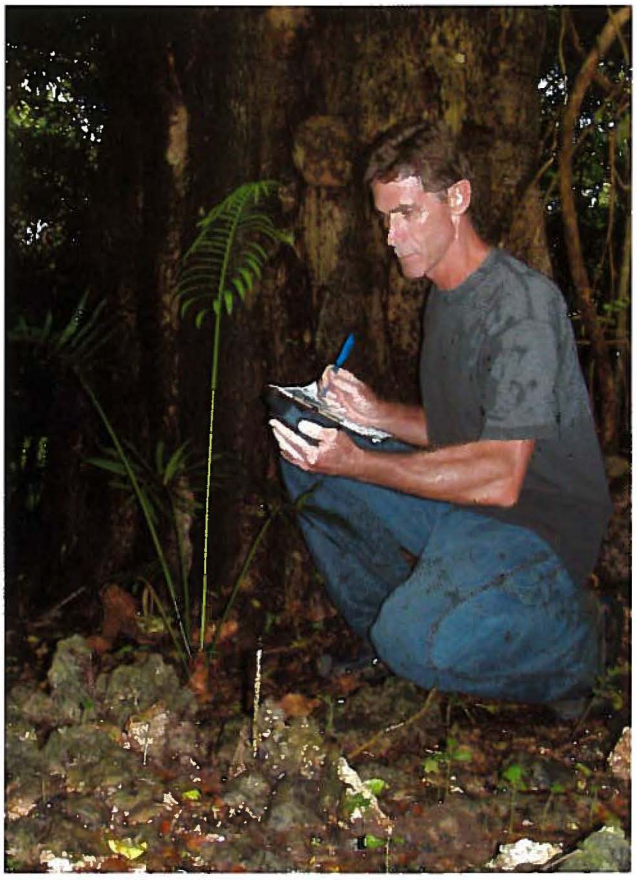
Self-sustaining organisms like plants possess the ability to synthesize their own food using inorganic materials. Plants use water and carbon dioxide to begin this process in their green tissues. The leaf is the organ most often used by plants for this food synthesis. The WPTRC is contributing to the general understanding of the strategies that plants employ to carry out this foundational step of the food web.

Thomas Marler recently published the results of his research that reveal some of the attributes of the long-lived leaves of Guam's *Cycas micronesica* plants. "These leaves are relatively large and are constructed of tough tissues," said Marler. "Both of these factors indicate the construction costs of this leaf form are substantial."

Green leaves must pay back their own construction costs, but each leaf is also required to supply the energy needed to maintain its live tissues throughout its lifespan. Additionally, large plants like Guam's *Cycas* have an abundance of non-green tissue that requires energy to maintain. Therefore, large plants with this leaf construction strategy must also possess a payback strategy that allows recovery of these costs coupled with an excess in food synthesis to support plant growth.

"These phenomena are understood using a financial analogy where borrowing a modest amount of money for one investment strategy is much easier to pay back and less risky than borrowing a substantial sum of money for a different investment strategy," said Marler. "The manufacture of food by the leaf is analogous to the income generated from the investments."

Cycad Studies



Results of the research indicate these plants approach the substantial leaf construction investments by delaying the decline in food synthesis capacity that accompanies the leaf aging process. Many fast-growing species, for example, constantly replace their leaves. For these species, food synthesis may be reduced to negligible levels in less than one month after leaf construction. In contrast, the decline in food synthesis for leaves of Guam's Cycas is minimal, with rates of two-year-old leaves sustained at 80% of the initial maximum. Marler indicates this sluggish pace of decline is 65-80 times slower than other species for which this trait has been determined.

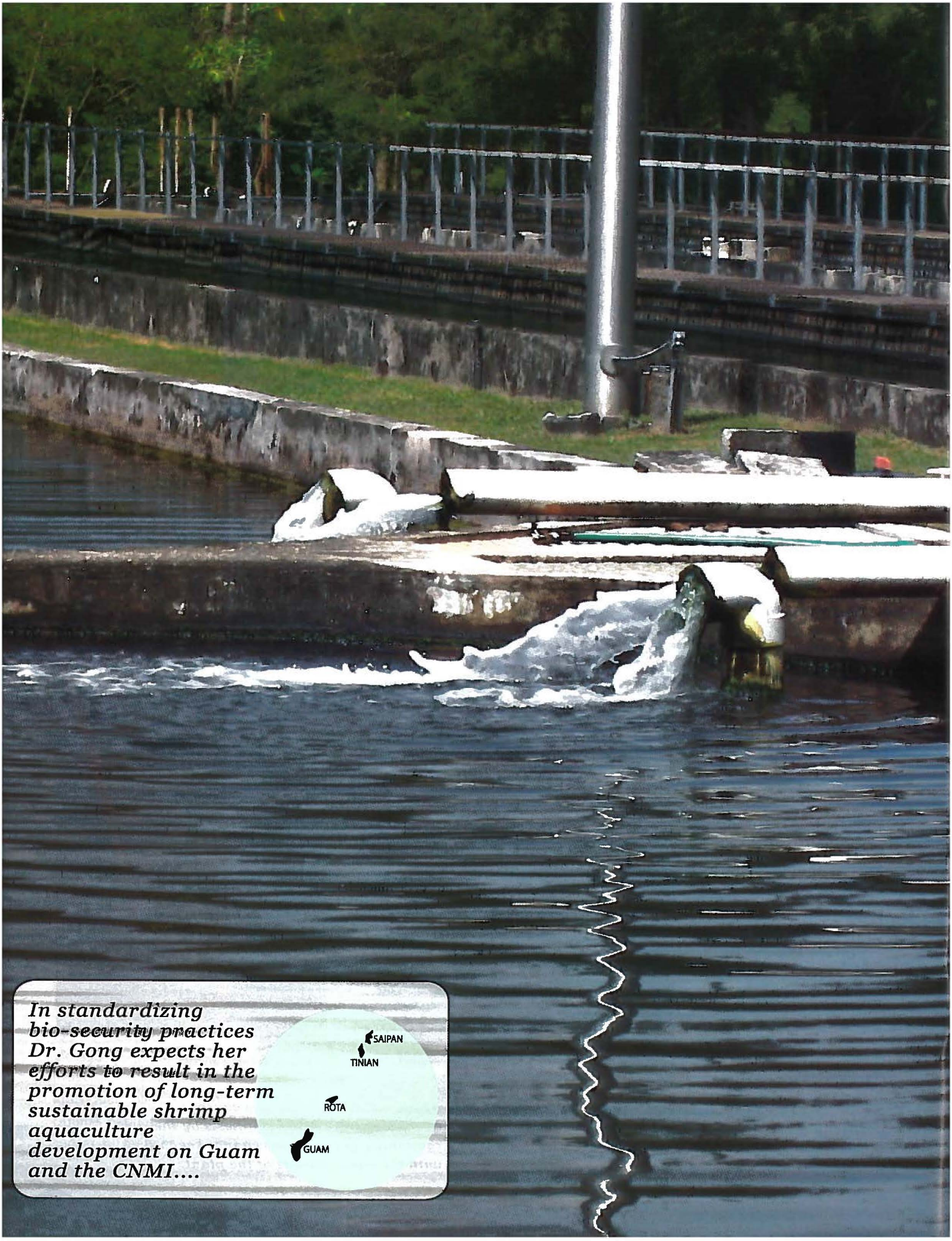
Above left: Thomas Marler uses global positioning technology to mark the location of a newly planted Cycas micronesica *seedling in Tinian.*

The financial risk analogy illuminates a critical environmental issue because Guam's Cycas population is being threatened by alien species that feed on its leaves. Guam's alien deer and several alien insects halt a leaf's payback process such that construction costs are not recovered before the leaves are eaten. As the process is repeated the plant effectively starves to death.

This work continues to propel forward the Cycas research that is based in Guam. The general lack of physiology research on Cycas species is a limitation to our understanding of this important plant group. Every comprehensive written text on Cycas makes a point of how little is known about how these plants function. The WPTRC is busy addressing this void in the literature.

For further reading: Memoirs of the New York Botanical Garden 97:193-203. 2007.

Above right: Leaf damage caused by alien insects. Food synthesis by the remaining green leaves cannot keep up with the energy needs of the plant.


In standardizing bio-security practices Dr. Gong expects her efforts to result in the promotion of long-term sustainable shrimp aquaculture development on Guam and the CNMI....
SAIPAN
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Bio-Security for Sustainable Shrimp Farming

Through the applied research of Dr. Hui Gong the Guam Aquaculture Development Training Center (GADTC) is poised to lead aquaculture farmers into a new awareness of the enormous potential of aquaculture in the region. As the principle investigator on a grant from the Center for Tropical and Subtropical Aquaculture (CTSA) Dr. Gong is responsible for establishing a comprehensive and strategic health management scheme to protect the entire region from the introduction of viral pathogens to shrimp operations.

Dr. Gong and her team began bio-security audits of all existing shrimp farms in September 2008 in order to identify the key risk factors for each operation. These audits have a three-fold objective:

1. Evaluate the current health status of shrimp farming in the region.
2. Increase awareness of the necessity for bio-secuity.
3. Assist farmers in understanding their individual bio-security risks and how to improve their operation's bio-security practices.

Scientists from the Oceanic Institute (Waimanalo, Hawaii) and GADTC will visit all farms in the region to assess the bio-security risks and conduct a visual inspection to evaluate the health status of shrimp stock. Samples will be collected, preserved and submitted to University of Arizona shrimp pathology lab for both PCR and histopathology tests.

Once the audits are completed a farm-specific bimonthly surveillance program will be implemented at one site in Guam and one in Saipan to be used as a model for other shrimp farming operations.

Health surveillance, consisting of visual inspections and lab testing, is an indispensable component in implementing any long-term bio-security program.

Because of the small scale of the shrimp industry and lack of knowledge of bio-security concepts in the region, limited effort has been put into bio-security practices in the past. In order to educate stakeholders and to promote bio-security practices a summarized report of the current status of bio-security in the region with practical suggestions for improvement will be distributed to farmers and relevant governmental entities.

Although the scale of shrimp farming in the region is small, the advantages for Guam and CNMI to expand in the development and export of specific pathogen free (SPF) broodstock include:

- The geographic proximity to the large broodstock markets in Asia
- Uncontaminated ocean as a water source
- Low density of shrimp farming activities
- Relatively "clean" shrimp disease history of the region

Shrimp farms in Asia need large numbers of healthy, SPF broodstock for their hatcheries and the current supply of broodstock from Hawaii and other areas in the U.S. (Florida) is well below market demand.

In standardizing bio-security practices Dr. Gong expects her efforts to result in the promotion of long-term sustainable shrimp aquaculture development on Guam and the CNMI, protection of the industry from major disease outbreaks and enhancement of the "clean zone" image of the region. Western Pacific Tropical Research Center scientists continue to play a major role in the ecology and economy of Guam.


The Inarajan wastewater treatment plant will be used as a pilot site for the experiment to evaluate the effectiveness of VGT before it is applied to other sewage treatment plants.
SAIPAN
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Vetiver Grass Technology: Alternative Wastewater Treatment

Soil scientist Dr. Mohammad Golabi is working with engineers at the Guam Waterworks Authority (GWA) to develop a low-cost method for cleaning up wastewater at sewage treatment plants in southern Guam. Dr. Golabi and his team will apply vetiver grass technology (VGT) to filter nutrients such as phosphorus and nitrogen as well as some heavy metals from the wastewater before the treated water is released into the ocean. Dr. Golabi has conducted extensive research using vetiver grass technology for mitigating sediment transport from Guam's southern watersheds, improving the water quality of the surrounding rivers and streams and allowing for the restoration of coral reefs. He is confident that VGT will also perform well in cleaning up wastewater and keeping the ocean surrounding Guam healthy.

The Inarajan wastewater treatment plant will be used as a pilot site for the experiment to evaluate the effectiveness of VGT before it is applied to other sewage treatment plants. Dr. Golabi and his team took baseline water samples before the application of VGT and continue to monitor water quality with the grass in place. Regular analyses of the wastewater lagoon will show the efficiency factor of using vetiver grass technology as a natural wastewater treatment technique when it is compared with wastewater in the control cell treated only with a floating mechanical surface aerator. The percentage of reduction in nitrates and ortho-phosphates as compared with the control lagoon over a twelve-month time period will also be evaluated.

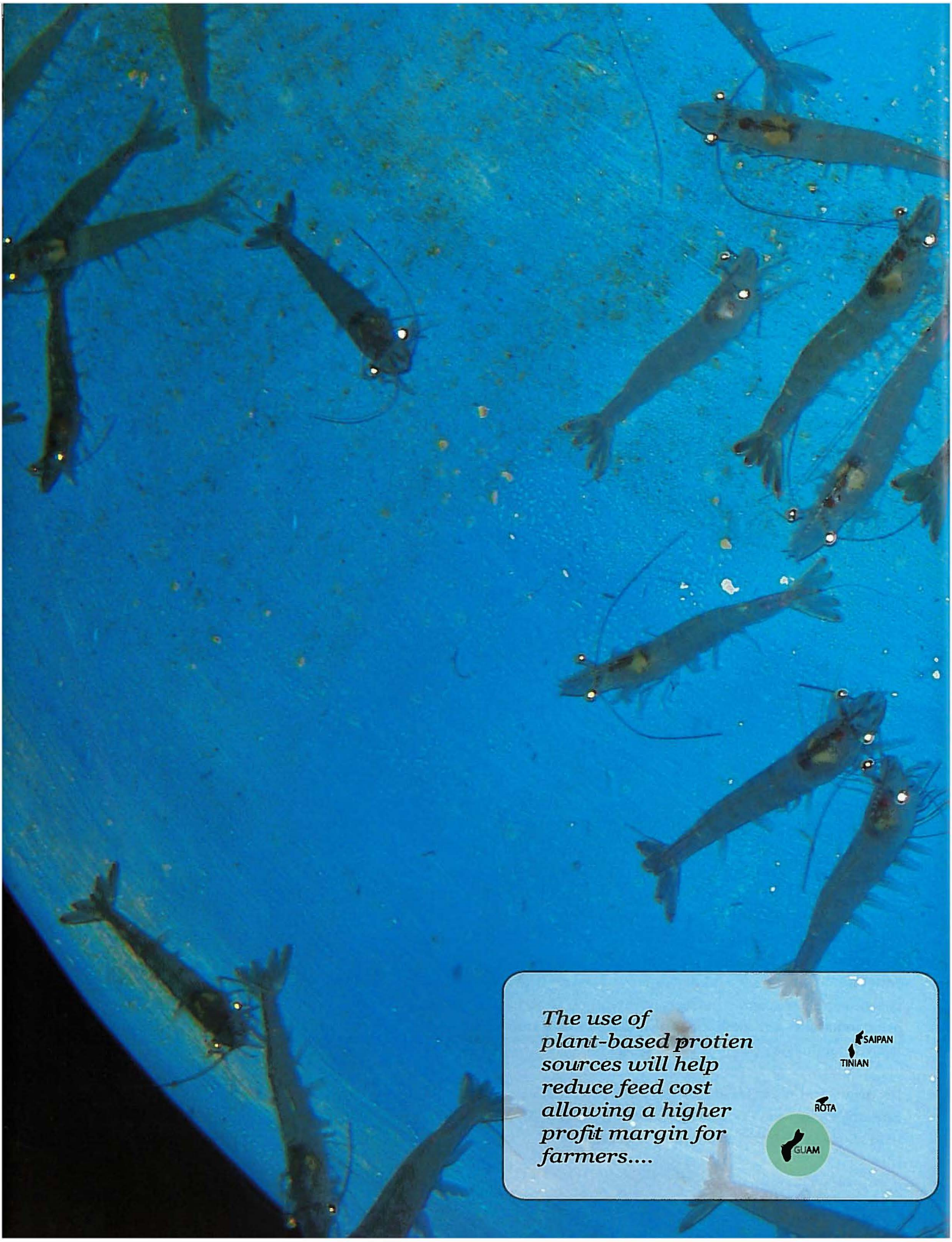
Dr. Golabi and his team at the Western Pacific Tropical Research Center and Cooperative Extension nurseries at UOG's College of Natural and Applied Sciences propagated hundreds of seedlings of Vetiveria zizanioides, commonly referred to as vetiver. These seedlings were then planted on "floating pontoons" and placed on the wastewater lagoon.

Veviter grass is exceptionally able to absorb and tolerate high concentrations of nutrients and agrochemicals and is tolerant of a wide range of soil types as well as water conditions," says Dr. Golabi. These attributes make vetiver grass highly suitable for treating polluted wastewater, making it an ideal plant for terrestrial and aquatic environmental applications.

The popularity of vetiver grass systems has increased in the last few decades partly due to the sharing of information about successful "bio-engineering" applications within the environmental science community and partly due to the low costs associated with its implementation in the long term. In contrast with conventional engineering structures, vetiver grass is virtually maintenance free and its efficiency improves with time as the vegetative cover matures.

At the completion of the experiment in September 2009, results will be shared with stakeholders in the region and with the scientific community. Dr. Golabi along with engineers at the Guam Waterworks Authority continue to keep the health of the ecosystems of our island at the forefront of their research.

Above center: Mohammad Golabi displaying vetiver grass.



The use of plant-based protien sources will help reduce feed cost allowing a higher profit margin for farmers....

Shrimp On A Diet

Researchers at the Guam Aquaculture Development and Training Center (GADTC) are getting shrimp to eat their vegetables: soybeans to be precise. Results of the first nutritional studies to be conducted at GADTC have shown that different dietary protein sources have a noticeable effect on the growth rate of Penaeus vannamei, the most popular species of shrimp currently cultured worldwide.

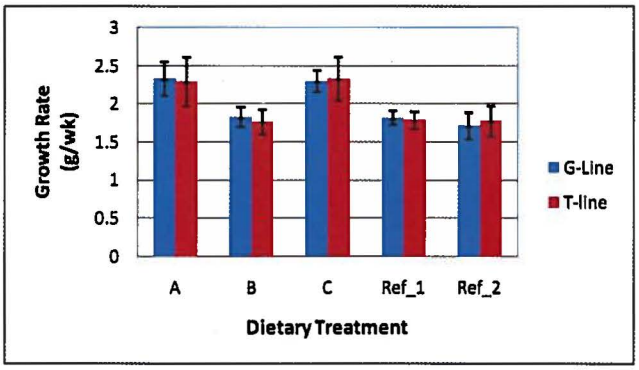
Ingredients	Diet A	Diet B	Diet C
010-Alginate	2.00	2.00	2.00
081-Ca Carbonate	2.00	1.61	2.08
105-Cellulose	2.50	2.76	2.73
106-Cholesterol	0.20	0.20	0.20
156-Chromic Oxide	1.00	1.00	1.00
179-Diatomaceous Eth	2.00	1.77	2.20
249-Fish,Menhaden	15.00	11.30	11.30
303-KCl	2.00	2.17	2.13
316-Krill Meal	10.00	5.70	5.70
370-MgO	1.50	1.55	1.54
421-NaCl	0.50	1.02	0.43
435-Oil,FishMenhaden		0.80	0.80
437-Oil,Soybean	0.30	0.52	0.35
462-Phospholipid,97%	4.00	4.00	4.00
470-PO4CaH,diCaPO4	3.00	4.38	3.72
480-NaHexaMetaPO4	1.00	1.00	1.00
518-PM Min/Vit LMCI	0.25	0.25	0.25
519-PM Min/Vit LMCI	0.21	0.21	0.21
698_Soybean-90%	7.90	0.00	16.65
706-Squid,Muscle	15.00	11.30	11.30
717-Vit C,Staple35%	0.04	0.04	0.04
940-Wheat Starch	29.60	46.42	30.37
TOTAL PERCENT	100.00	100.00	100.00

Shrimp feed is a significant production cost for farmers accounting for 60-80% of total cost, and marine protein (i.e. fishmeal) is an expensive component of shrimp feed, production of which is static or slightly declining due over fishing. The use of plant-based protein sources will help reduce feed cost allowing a higher profit margin for farmers in the industry, and alleviate the dependency on the marine resource for the sake of ocean conservation.

Dr. Hui Gong designed her preliminary study to explore the potential of genetic selection for efficient utilization of soy-based plant protein. With her team at GADTC she investigated the performance of two different shrimp lines under high-density conditions fed with semi-purified diets containing different protein levels and different ratios of marine protein and plant protein. Two distinct P. vannamei shrimp lines were selected from the same population: the G line was bred for fast growth and high production yield and the T line was bred for fast growth and resistance to a common virus (TSV). A total of five dietary treatments were used with 3 semi-purified diets and 2 commercial diets. The formulation of the 3 semi-purified diets is detailed in the chart above.

Diets A and C had higher percentages of soy protein which resulted in 25% faster growth than shrimp fed Diet B or the two commercial diets. This study suggests that soybean meal can serve as a good protein source partially replacing fish and/or squid meal in shrimp feed and that the experimental shrimp were efficiently utilizing soy-based protein.

The formulation of semi-purified base diets is worthy of additional nutritional studies. In conducting further studies Dr. Gong believes there are several factors to consider. "In this preliminary study the shrimp used were over 10 grams, it would be interesting to use younger shrimp," says Dr. Gong, "as well as families with more diversified genetic backgrounds using microsatellite genetic markers to identify the genetic distance between the families." Dr. Hui Gong is the first aquaculture research faculty to be employed by UOG and her research will have an important impact on island and regional shrimp aquaculture.



Above right: Diets A and C, high in soy protein, resulted in 25% faster growth.

Conservation practices, especially no-till farming, restore Soil Organic Carbon (SOC) and have the added benefit of controlling erosion. . .

Soil Management and Global Warming

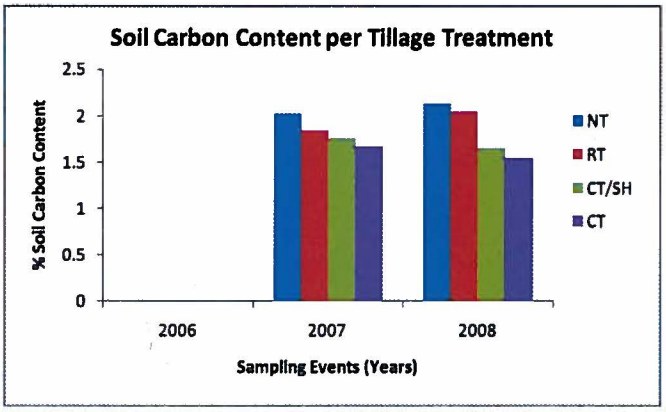
As the burning of fossil fuels continues to pump carbon dioxide into the atmosphere, scientists are investigating ways to support soil-plant ecosystems in carbon uptake and sequestration. The Kyoto Protocol on climate change has prompted great interest in conservation tillage as a management strategy to help sequester CO2 from the atmosphere into soil organic matter. Ongoing research on carbon sequestration is a priority for federal and state agencies and universities around the country. Dr. Mohammad Golabi and the Soil Science Laboratory began monitoring soil carbon content on Guam in 2007.

The carbon dioxide content of the soil is related to the overall soil microbial activity and plant uptake. However, once soil is disturbed by intensive tillage or other practices the carbon dioxide is released into the air. When combined with the added CO2 released from fossil fuels it exacerbates the problem of high rates of CO2 in the atmosphere, which the world community is working to mitigate.

"On the other hand, conservation practices, especially no-till farming, restore Soil Organic Carbon (SOC) and have the added benefit of controlling erosion," says Golabi.

Dr. Golabi's SOC research is twofold: developing practical strategies for agricultural productivity while restoring soil organic carbon in tropical agro-ecosystems and arresting ongoing water erosion in degraded areas of southern Guam. His research specifically examines the impact of long-term no-till and reduced-till based cropping systems on SOC sequestration within the tropical conditions of the Western Pacific.

Field experiments conducted used no tillage (NT), reduced tillage (RT), conventional tillage (CT) and conventional tillage with rotation to leguminous sunnhemp (CT/SH).



As predicted, the no-till and reduced-till treatments had the highest amount of soil organic carbon in this study. As shown in the chart above, the soils under conventional tillage, which received the highest level of disturbance registered the lowest level of carbon. This indicates that the soils under conventional tillage released carbon into the atmosphere as a result of the intensive treatment.

The results of Dr. Golabi's ongoing experiments will contribute to the overall scientific effort in understanding the role of agriculture in the sequestration of carbon in soils, and the ways in which this may reduce atmospheric carbon dioxide.

Left: Aerial view of small farm in southern Guam.

Plans for the near future are to offer disease-free Manila bananas through the Guam Department of Agriculture.

WPTRC Plant Pathology in the Tropics

Papaya

Local research on papaya is centered around finding practical control measures for the most important papaya diseases, like papaya ringspot virus (PRV). A breeding program implemented by Alicja Wiecko, Kenneth Paulino and headed by Dr. George C. Wall, plant pathologist, is under way to cross the most desirable varieties with those that possess some resistance to PRV and other diseases. Guam's local market prefers large papayas with red flesh, as compared with Hawaii where they prefer small fruit size and yellow flesh. Transgenic papayas (or GMO papayas, as they are mistakenly called) are available in Hawaii, which possess resistance to the Hawaii strain of PRV. Originally, researchers who developed these varieties reported that they were not resistant to the Guam strain of PRV. However, Dr. Wall and his research team have determined in field experiments that they are actually resistant to our local PRV strain. Yet, because of their transgenic nature, they are subject to patent laws and they are not approved for commercial use outside the state of Hawaii. Papaya varieties from Taiwan are large and red-fleshed, but they are susceptible to PRV and also to Erwinia, another important papaya disease. It should take this team of local researchers 5-7 years of breeding work with local varieties to develop improved, non-transgenic papaya varieties that have some resistance to the most important papaya diseases in the Mariana Islands and possess desirable market traits.

Banana

For the past 3 years, Dr. Wall and his plant pathology research team have been involved in a banana project, which is aimed at determining whether a silk-type banana variety grown on Kosrae (known as Kufwafwa there) is resistant to the dreaded Panama disease that affects our very popular silk banana, known locally as Manila.

After indexing for numerous banana diseases and finding the material to be disease-free, the Kosrae variety was introduced in tissue culture in order to test it on Guam. Simultaneously, Guam's saba-type local variety known as Palau, which is resistant to Panama disease, was established in tissue culture and also indexed for numerous banana diseases. After finding it disease-free, tissue culture plants of this variety were sent to Kosrae for testing there. Additionally, the lakatan-type variety Macau was also sent to Kosrae. Field testing on Guam for 3 years revealed finally that Kufwafwa is not resistant to Panama disease. However, tissue culture propagation can be used to make disease-free planting stock available to the public. Plans for the near future are to offer disease-free Manila bananas (propagated in tissue culture) through the Guam Department of Agriculture.

Coconut

It has been more than 10 years since the last survey of Tinangaja disease of coconut, a viroid disease that is, to date, only found on the island of Guam. Dr. Wall's plant pathology research team is gearing up to do another island-wide survey of this lethal coconut disease. Additionally, they plan to look for possible insect and pollen transmission of the viroid, and at the same time look for evidence of the similar Cadang-cadang disease, which occurs in the Philippine Islands and devastates vast coconut plantations there. The research team has been updating the molecular methods developed previously and used for the last survey.

Plant Pathology in the Tropics Cont.

Betel Palm

The bud rot epidemic of betel nut that started 4 years ago has slowed down to a crawl, thanks to climactic conditions. At that time, the disease killed more than 7,000 trees in southern Guam. In spite of this devastation, most growers did not follow recommendations to cut down and destroy infected trees. Many of the remaining tree stumps are still standing, and under the right weather conditions can easily spread the disease once again. Dr. Wall's research team determined that the disease was caused by a fungus, Phytophthora palmivora. Permission was obtained to recommend the use of Phosphite and Kocide on betel nut trees to prevent bud rot. Initially, Phosphite injections on the tree trunk were being recommended. However, after dissecting and analyzing several injected trees, the research team found wood discoloration, even tissue death, surrounding the injection site; so they stopped recommending the injection method of application. Instead, they found that one can immerse adventitious roots of the trees in a solution of Phosphite, and the chemical can be absorbed that way. Phosphite has been shown to prevent infection by the fungus Phytophthora.

Taro

Dr. Wall's research team maintains a taro collection at the experiment station, with some 70 varieties. For a number of years, they have been observing these taros and taking notes regarding their characteristics. They've had several taste tests throughout the years and documented their results. All this information, plus color photographs, is being compiled to produce a taro publication with descriptions of all these varieties. Furthermore, they have started testing the taro collection for virus diseases. Last year they developed a simple PCR technique to test for Taro Bacilliform Virus, after it was found to be present on Guam. Their technique is based on the use of commercial PCR kits.

Orchids

Trade in these beautiful flowering plants is worth a great deal of money on Guam. The Plant Inspection Facility and the Department of Customs & Quarantine routinely intercept shipments of orchids originating from foreign countries and the U.S.A. These shipments often include plants that are infected with orchid pathogens and are brought to the Plant Pathology lab for analysis and identification. Numerous orchid diseases have already been introduced to our island and threaten both commercial and private collections. The Plant Pathology lab tries to support the efforts of Customs agents and the Plant Inspection Facility to keep the threat of new disease introductions to a minimum, while at the same time allowing as much trade as possible to take place. This past year they have found a quick and reliable way to test for common orchid viruses.

WPTRC

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WPTRC 2008 IMPACT REPORT

Western Pacific Tropical Research Center
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