



COLLEGE OF NATURAL & APPLIED SCIENCES

WESTERN PACIFIC TROPICAL RESEARCH CENTER

2022 IMPACT REPORT

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MESSAGES FROM THE DIRECTORS

Håfa Adai!

For the past 14 years the College of Natural & Applied Sciences, through its research unit known as the Western Pacific Tropical Research Center, has produced this annual report highlighting newfound scientific knowledge of benefit to the environment and people of Guam and this region.

This year our faculty and graduate student researchers have new findings to share in agriculture and aquaculture, the nutritional value of a locally abundant fruit, the conservation of ecologically and economically important plants and trees, as well as capacity building in the use of drone technology for research. One study brings a topic of national interest to the local level: the top stressors affecting farmers and the areas where farmers need more support. Another study shows the potential of raising marine shrimp and freshwater prawns together as a way to improve food security and productivity. These are just some of the ways our research is working to impact lives.



Most of you are aware this is my last academic year with CNAS and the University of Guam. It has been a great pleasure to have been both the dean of the college and director of the WPTRC and contribute to the legacy of these impact reports. It is my sincere belief they showcase who we are as a center of excellence. I want to thank all the faculty, staff, and students who have contributed to the success of these impact reports, especially to my wonderful media staff, who work hard each year to ensure these important projects reach the public. My hope is that the next dean/director will continue to support and inspire our faculty to make new discoveries and will carry on UOG's land-grant mission of bringing these findings to the people of the region.

Lee S. Yudin, Ph.D.

Dean, College of Natural & Applied Sciences
Director, Western Pacific Tropical Research Center

Håfa Adai!

In 2022, the Western Pacific Tropical Research Center continued the steady progress it has experienced in recent years. New research faculty have brought renewed energy, broader diversity, and novel ideas contributing to the expansion of our research portfolio. The profiles of the two highly qualified faculty who recently joined WPTRC under the College of Natural & Applied Sciences are presented on page 4 of this report.

WPTRC faculty hold expertise in agriculture economics, animal science, aquaculture, endangered plant species, horticulture, natural products, plant health, restoration ecology, soil science, and spatial science. I find this impressive for a small research center on a tiny island. Our personnel launch drones, conduct surveys, sample soils, raise virus-free shrimp, track the food sources of bees, examine the properties of underutilized natural foods, venture to the hills to describe a new orchid species for Guam, select improved varieties of eggplant and hot peppers, and perform other activities to generate knowledge and benefit stakeholders in the Western Pacific. Whereas the main role of WPTRC faculty is research, they are happy to share applied aspects of study findings with farmers and other community members.



The resources available to our research personnel have increased in quantity and quality through the acquisition of laboratory equipment, vehicles, software, computers, and other items. WPTRC administrative personnel do a superb job through the procurement process. Preventive measures to cover eventual equipment service and maintenance are being taken to reduce interruptions in research activities. The restoration of an aquapark, which is walking distance from the Agriculture & Life Sciences building, is close to being completed. This facility, in alignment with the renewed interest for aquaculture in Guam, will contribute to the extension, instruction, and research activities of UOG as a land-grant university. Many more tasks lie ahead. On the wish list are, among other projects, an upgrade to the Ija Research & Education Center and a revamp of the Triton Farm infrastructure. We are committed to finding the best technical alternatives and pursuing the resources to make these wishes reality.

As always, on behalf of WPTRC, I would like to express deepest gratitude to a wide array of collaborators and the U.S. Department of Agriculture and other donors for their generous support.

Adrian Ares, Ph.D.

Interim Associate Director

Western Pacific Tropical Research Center

NEW WPTRC FACULTY



Sahena Ferdosh, Ph.D.
*Assistant Professor of
Natural Product Chemistry*

Sahena Ferdosh joined the Western Pacific Tropical Research Center in September 2022 as an assistant professor of natural product chemistry. She comes to the University of Guam from the International Islamic University Malaysia,

where she was an assistant professor in the Department of Plant Science from 2014 to 2022.

As an expert in the field of natural product chemistry, Ferdosh's research at UOG will begin with the development of novel extraction methods for use on sea cucumbers, fish, and medicinal plants in Guam. She has expertise in supercritical fluid technology for the processing of omega-3 fish oil from marine by-products and of bioactive compounds from medicinal plants. She has also developed methods to separate saturated and unsaturated fatty acids from fish by-products by enriching omega-3 polyunsaturated fatty acid in fish oil, which is also cholesterol-free. Ferdosh's methods utilize low temperatures and yield large quantities of enhanced food, nutraceutical, and bioactive compounds without incorporating harmful substances.

Ferdosh holds a doctorate in natural product chemistry from the University of Science, Malaysia, and a master's in fisheries management and bachelor's in fisheries from Bangladesh Agricultural University.



Romina King, Ph.D.
Associate Professor of Geography

Romina King is an associate professor of geography. She has been faculty at the University of Guam since 2014 – initially with the College of Liberal Arts & Social Sciences under the Geography Program, then transferring to the Micronesian Area Research Center as research faculty. She transferred to the Western Pacific Tropical Research Center in 2022.

Her research interests include natural resource management, coastal zone management, coral reefs, GIS, remote sensing, and climate change adaptation and vulnerability, particularly in Guam, Micronesia, and Oceania.

King was a NOAA Coral Reef Management Fellow and created a successful program called "Guardians of the Reef," where local high school students educated third graders about Guam's reefs. More recently, King was part of a team that was awarded the NASA Group Achievement Award, recognizing her contribution to the NASA NeMO-Net app and its inclusion of Guam's reefs. She has also co-lead the development of the UOG Drone Corps, a program that provides students with the opportunity to become certified drone pilots.

She serves as vice chair of the Guam Climate Change Resiliency Commission, the UOG lead for the Pacific Islands Climate Adaptation Science Center, and the associate director of NASA Guam Space Grant and NASA Guam EPSCoR.

King holds a doctorate in geography from University College Cork (Ireland); a master's in geographic information systems/science from University Southampton (England); a master's in Micronesian studies from the University of Guam; and a bachelor's in economics from Boston College.



Malojloj resident Andrew Manglona checks on his adult tilapia.
Photo by John I. Borja

NURTURING AN INTEREST IN BACKYARD FISH FARMING

What started off as a favorite pastime is now a long-term investment for Malojloj resident Andrew Manglona, who has turned to farming tilapia as a source of sustenance. Manglona is among more than a dozen backyard aquaculture farmers who have purchased tilapia from the Guam Aquaculture Development & Training Center under the UOG Western Pacific Tropical Research Center.

“I give them to family and neighbors to eat. It’s just part of our culture to share with others,” Manglona said.

Some of these farmers have, in turn, sold fry to other farmers as well, contributing to the now 30 tilapia farmers estimated in Guam.

The GADTC, also known as the Fadian Hatchery, raises tilapia and shrimp for research, export, and local consumption under a public-private partnership with CoreSeed Aquaculture (Guam) Corp. that began in 2020.



Healthy adult tilapia peer above water in search of food at Andrew Manglona's backyard tilapia farm.



Tilapia fry purchased from the Guam Aquaculture Development & Training Center now being raised at Andrew Manglona's backyard tilapia farm.

Becoming a tilapia farmer

Manglona's journey as a tilapia farmer began in 2008, when he bought his first batch of tilapia from UOG's hatchery. He spent many years dabbling in it as a hobby until the COVID-19 pandemic came to Guam in 2020 and he decided to make a more permanent and productive setup for tilapia farming. He attended workshops hosted by the university to learn the basic setup and maintenance for tilapia tanks. He also researched systems online before merging designs to craft one of his own.

Tapping on familial resources and his experience in engineering, Manglona created a home for his tilapia in a repurposed 4,000-gallon fuel storage tank that was previously used to catch rainwater for irrigation. The tank has an aerator and filtration system to collect waste. To conserve water, he put together a recycling component that filters water from the main tank and channels it back in.

Altogether, Manglona has three stations that separate his tilapia stock by their growth rate. Each station is full of life. His most recent purchase from the Fadian Hatchery included 60 tilapia fry, 30 medium-sized fish that measured four to six inches long, and 10 that were eight to 12 inches long.

"I'm grateful with what I receive from [the hatchery]. Everything that they give me is healthy, and they also sell feed [...]. So far, I haven't had any problems with keeping the tilapia healthy," Manglona said.

Manglona said he looks forward to seeing tilapia farming bloom across the island with the increasing opportunities for aquaculture training.

"I'm grateful with what I receive from [the hatchery]. Everything that they give me is healthy."

– Andrew Manglona, Malojloj tilapia farmer



Donghuo Jiang, managing director of CoreSeed Aquaculture (Guam) Corp., which operates UOG's aquaculture facility under the Western Pacific Tropical Research Center. Photo by Eugene Herrera

Fruitful partnership

Generally, tilapia is an ideal fish to raise via aquaculture as it can thrive year-round in Guam's climate. Donghuo Jiang, managing director of CoreSeed, said the hatchery raises more than 30,000 tilapia annually, which it sells to farmers as well as regular large-scale customers.

"In the last two and a half years, we have sold to hotels and restaurants and to about 12 to 15 backyard farmers. The farmers purchase anywhere from 50 to 200 tilapia of varying sizes per visit," Jiang said.

Locally sourced tilapia have an edge over imported ones, Jiang said, as they can be purchased without the risk of pathogens or harmful chemicals from preservatives. The hatchery maintains a high level of biosecurity to ensure none of its livestock are unhealthy or have diseases.

Jiang said the partnership between UOG and CoreSeed has been a

"win-win" scenario. "UOG provided CoreSeed with a space to work, so, in turn, we have revitalized the facilities and also provided opportunities for students, scientists, and visiting scholars to visit, learn, and train with us," he said.

With continued partnerships among private businesses and farmers and a space for research, Jiang said he is hopeful the hatchery can grow to a larger capacity. More awareness of aquaculture techniques in the local market may also pique interest in the community of the untapped potential of this industry, he added.

For more information:

Donghuo Jiang
Managing Director, CoreSeed Aquaculture (Guam) Corp.
dhjiang101@outlook.com

SUNN HEMP IMPROVES NUTRIENT-POOR SOILS AND CROP YIELD

With a porous limestone base, soil and farmland in the northern half of Guam are persistently drained of nutrients. The soils lack nitrogen, available iron, and other important nutrients for crop growth, and they are high in calcium, which binds to phosphates and limits the amount of phosphorous plants can absorb.

These soil conditions present a costly challenge for farmers, who must amend their fields with fertilizers and use pesticides and herbicides to fend off pests and weeds that become more prevalent in unhealthy crops. That, then, presents a risk to the underlying aquifer, which supplies 80% of the island's drinking water.

In December 2020, Dr. Mohammad Golabi, along with research associate Ferdinand Galsim and field technician Karl Nelson, began a three-year project to evaluate the agronomic value of different soil amendments in northern Guam, including biochar, fertilizer, and compost. In between plantings of a desired crop, they also experimented with sunn hemp (*Crotalaria juncea L.*) as a cover crop, which is used in other places to improve crop yield.

Sunn hemp is a legume similar to alfalfa but grows in warmer climates. It forms a symbiotic relationship with bacteria that convert nitrogen gas from the atmosphere into nitrate, one of the most important nutrients for crops. In addition, sunn hemp can suppress weeds and invertebrate pests, particularly plant-parasitic nematodes (roundworms), which consume energy and nutrients by affecting the roots.

Because sunn hemp grows rapidly with very fibrous stalks, it can produce more than 5,000 lbs. of biomass and up to 250 lbs. of nitrogen per acre when it is cut and incorporated into the soil. This brings more organic matter and, therefore, nitrogen and other nutrients to the soil, which then requires less water and fertilizer.

“The healthier the crop, the less susceptible it is to insects and diseases.”

– Mohammad Golabi, Ph.D.

The researchers planted corn in 2021 and 2022 at the WPTRC's Yigo Research & Education Center and planted sunn hemp in the same field prior to each cropping season. Results to date show improved soil quality, soil health, and overall crop productivity and no major plant diseases.

While they have not yet quantified the yield improvement on the northern experiment, a similar experiment in southern Guam soil resulted in an approximately 20% higher yield on corn plots that were rotated with sunn hemp. The crops are being monitored to determine the longer term impacts of sunn hemp as a rotational cover crop.

Sunn hemp seeds have to be ordered from off island, and they are relatively expensive, Golabi says; however, if crop rotation with sunn hemp is practiced regularly, it will have long-term economic benefit to farmers and crop producers and promote agricultural sustainability.

Project: “Evaluating potential benefits of sunn hemp to improve crop’s health and disease resistance”

Researchers: Mohammad Golabi | mgolabi@triton.uog.edu
Ferdinand Galsim | galsimf@triton.uog.edu
Karl Nelson | nelsonk@triton.uog.edu

Timeframe: 2020-2023

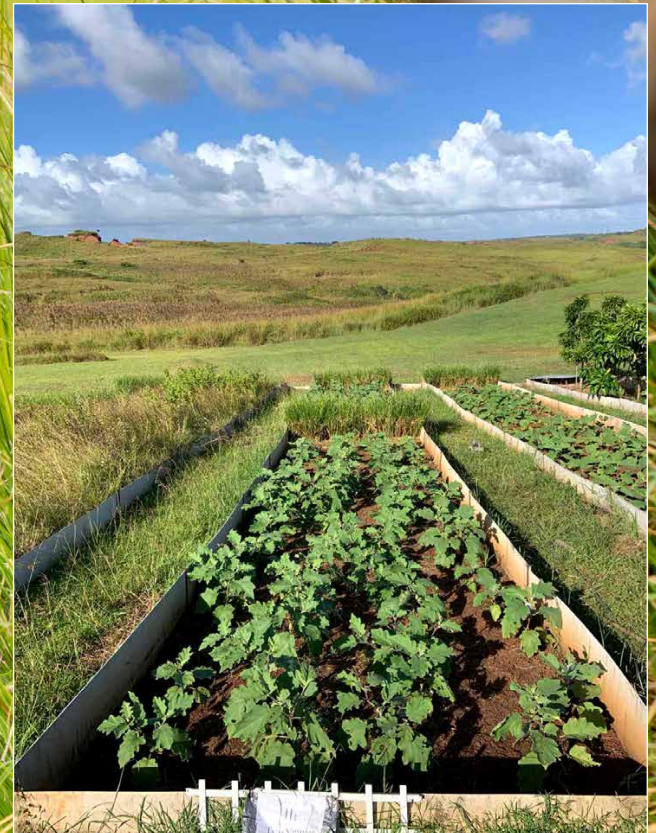
Funded by: Hatch Research Fund, National Institute of Food & Agriculture, U.S. Department of Agriculture



Sunn hemp, with its fibrous stalks, produces a significant amount of nitrogen when it is cut and incorporated into the soil. *Photo by Ferdinand Galsim*

An aerial photo of sunn hemp growing at the Yigo Research & Education Center as a rotational crop to add nutrients to the soil before corn is planted. *Photo by Chieriel Desamito*

Daniel Encio examines crops planted above vetiver hedges. In the background is a barren section of red clay, characteristic of the erosion-prone hills of southern Guam. Photo by Luke Fernandez



Vetiver planted at the bottom of a sloping plot holds the soil and its nutrients in place to allow for a vibrant crop of eggplant.

VETIVER HEDGES REDUCE FARM EROSION ON SLOPING SOUTHERN HILLS

At the Ija Research & Education Center in the southern village of Inalåhan, a 360-degree view reveals a panorama of rolling grasslands, large swatches of red clay, and no development in sight aside from the farm itself. A former dean of UOG's agriculture college, Dr. Wilfred Leon Guerrero, envisioned a research station there that could help turn the area into highly productive farmland.

The steep slopes and the barren soil patches make the land prone to severe erosion, which is not conducive for retaining the nutrients – or the soil itself – to grow healthy crops. Farmers in southern Guam struggle to produce abundant commercial crops, and the soil is often washed into rivers and streams nearby, ultimately damaging the coral reefs – which are of ecological, cultural, and economic importance.

Dr. Mohammad Golabi has been mentoring graduate student Daniel Encio in a project to reduce the runoff on sloping agricultural plots by planting hedges of vetiver to act as a natural terrace and silt screen. Vetiver is a low-maintenance grass native to tropical Asia that looks similar to sword grass. It naturally repels animals and bugs, is fire-resistant with its deep roots allowing it to stay green through the dry season, and absorbs trace metals from the soil.

The researchers created 12 plots, each measuring 72 x 8 feet, that run downhill at an average slope of 9 degrees. The plots have plantings of different crops and fruit trees. One plot contains only red clay soil, and another plot includes wild vegetation. They planted wall-to-wall grass hedges horizontally at several points and have been measuring the amount of runoff and sediment that runs into collection tanks at the base of each plot on a weekly basis. Each plot has a different number of hedges to determine the best number and placement for trapping sediments and retaining the soil.

“Any land in this area — with this type of slope — is basically unusable farmland.”

– Daniel Encio

The data collection is continuing; however, the researchers have concluded so far that vetiver grass is effective in controlling erosion, with the hedged plots containing up to 80% of the sediment that was washed away in the non-hedged plots over a year's time. Additionally, they found that having multiple hedges within a plot slows down the rainwater and reduces the formation of gullies.

If farmers in southern Guam make use of vetiver grass hedges in steep-slope land areas, they can put even more land to productive use while also improving the health of the environment and protecting the coral reefs.

Farmers can obtain vetiver grass by contacting Dr. Golabi at the email below.

Project: “Developing innovative mitigation techniques for soil erosion in Southern Guam”
Researchers: Mohammad Golabi | mgolabi@triton.uog.edu
Daniel Encio | enciod@triton.uog.edu
Timeframe: 2018-2022, extended to 2023
Funded by: McIntire Stennis Capacity Grant, National Institute of Food & Agriculture, U.S. Department of Agriculture

CALAMANSI PEEL: AN UNDERUTILIZED SUPERFOOD

Citrus fruits are abundant and readily accessible in Guam, and many residents have calamansi – a unique type of citrus fruit – growing in their yards. Citrus is known to be a rich source of vitamins, minerals, and phytochemicals with properties proven to combat cancer, bacteria, viruses, inflammation, and diabetes – all of which are common diseases or causes of illness among Guam’s population.

While the fruit is used to prepare many food items, including lemonade, jams and marmalades, sauces, marinades, and the CHamoru dish kelaguen, it is primarily the juice that is used, and the peel is discarded. However, the peel contains the bulk of the benefits – for both disease prevention as well as food safety.

Food scientist Dr. Jian Yang’s research group set out to find the bioactive components and properties specific to the calamansi peel and to make it into a functional food ingredient that people enjoy and can incorporate into popular local recipes.

The researchers analyzed the phenolic content and antioxidant activity of calamansi peel, finding that yellow-green calamansi peels contained the highest phenolic content, while orange calamansi peels exhibited the highest antioxidant activity.

They then turned the peel into a powder that they used in recipes for rosketti cookies and sausages. The powder increased the phenolic

content of rosketti cookies by three times and of sausages by 20% to 36%. The cookies and sausages measured 3.4 times and 140% higher in antioxidant activity, respectively. Both products, with powder amounts up to 5%, were well-received in a sensory evaluation panel. Green calamansi peels showed the least amount of beneficial nutrients and a lower taste acceptance, so the researchers recommend using orange or yellow-green peels for creating a powder.

Knowing the health value of local calamansi may benefit the community in agriculture production, value-added food processing, local economy development, and improvement in human health on the island of Guam. In the next step, the researchers will test the dietary fibers, antimicrobial activity, and prevention of lipid oxidation of calamansi peels.

Project: “Valorization of calamansi (*Citrus microcarpa*) for improving food quality, safety, and functional properties”

Researchers: Jian Yang | jyang@triton.uog.edu
Bulan Wu | wubulan@triton.uog.edu
Kristi Hammond
Victoria Lee Mapa

Timeframe: December 2020 – November 2023

Funded by: Hatch Multistate Research Fund, National Institute of Food & Agriculture, U.S. Department of Agriculture

“Calamansi is an underutilized fruit, and its peels have not yet been explored and applied for the health benefits of people.”

– Dr. Jian Yang



Food scientist Dr. Jian Yang collects calamansi, a citrus fruit prominently grown in Guam but underutilized for its properties for fighting disease and illness.
Photo by Jackie Hanson



Dehydrated calamansi powder.



Dehydrated calamansi halves.



Dr. Kuan-ju Chen, assistant professor of agricultural economics at UOG, hands out agricultural stress surveys to local farmers in 2021.



Guam farmer Ernie Wusstig with his corn crop in Dededo.
Photos by Luke Fernandez

SURVEY PINPOINTS TOP STRESSORS AFFECTING REGIONAL FARMERS

Farmers and agricultural producers have one of the highest suicide rates of any industry in the nation, according to a 2016 study in Morbidity & Mortality Weekly Report. The rates vary significantly by region, with the Western region posting the highest rates.

As part of the Western Region Agricultural Stress Assistance Program – a collaborative effort led by Montana State University and Washington State University to better support the mental health needs of farmers in Western states and territories – the University of Guam led a baseline survey of Guam agricultural producers to better understand the types of stressors they are facing and the support services they would find helpful.

Dr. Kuan-ju Chen, assistant professor of agricultural economics at UOG, led a team in disseminating the survey from May to October 2021 through phone calls, agriculture organization members and channels, and farm visits.

Of the respondents, 61% reported experiencing a medium level of stress, while 4% reported high stress, and 35% reported low stress.

The top stressors indicated by Guam farmers were pests, production costs, increased labor costs, lack of time, and crop and plant diseases. Lowest on the list of stressors were international

trade policies, wildfires, and social isolation.

The top topics they expressed wanting to know more about were finances (70% of respondents), succession planning (30%), relationship support (34%), and retirement planning (33%). Topics of least interest were mental health, tobacco cessation, and drugs and alcohol. Their top preferences for receiving this information are through face-to-face counseling and individual consultations.

This better understanding of stressors in the local agriculture community may impact the availability of needed resources for farmers. The Cooperative Extension & Outreach service at the University of Guam will be working to inform local health organizations and nonprofit agriculture channels on the survey results.

Project: “Agricultural Producer Stress: Guam Territory Report”

Researchers: Kuan-ju Chen, Ph.D. | chenk@triton.uog.edu
Mary Catherine Wiley | wileym@triton.uog.edu

Timeframe: 2021

Funded by: Farm & Ranch Stress Assistance Network, U.S. Department of Agriculture - National Institute of Food & Agriculture

“It can be easily forgotten that we do have wellness problems that stem from the theft of our crops, lack of pest control, and other factors.”

– Angelita “Angie” Mendiola, retired Guam farmer

UOG DRONE CORPS: MEETING DEMAND IN A RISING INDUSTRY

The demand for drones – or unmanned aerial vehicles (UAVs) – continues to soar as sectors locally and globally begin to heavily implement the technology to perform industry-specific tasks. In Guam, numerous local drone companies have emerged, specializing in fields such as marketing, construction, and real estate. The 2022 Drone Technology & Global Markets Report shows the demand for drone usage is expected to grow another 51% over the next five years with sales reaching more than \$16 billion by 2030.

As the need for this service continues to grow in both academic and recreational capacities, so, too, will the number of certified commercial drone pilots. To meet the demands of this rising industry, the University of Guam launched the Drone Corps program in April 2021 – a collaborative effort between NASA Guam Space Grant and the NASA Guam EPSCoR grant – to create a cadre of FAA-licensed, informed, and responsible pilots. It is the University's first drone certification and training program, and it's open to all students, faculty, and staff.

In addition to teaching the regulations and safety protocols of proper flying operations through the FAA Part 107b examination preparatory knowledge course, the program also provides members with stipends and hands-on experience flying UAVs. Students experience the full process of a drone mission: pre-flight safety checks, equipment inspections, flight protocols, data interpretation, and product renderings. Through these practicum sessions, members engage with a variety of high-end drone equipment, including UAVs like the DJI Matrice 210 and Phantom 4, LiDAR cameras, and ArcGIS mapping software.

Now in its second year, the UOG Drone Corps has produced 24 FAA-licensed pilots. Upon receiving their licenses, students have put their drone-piloting skills to good use, helping UOG researchers, agencies, and organizations provide services such as aerial field surveys, orthomosaic maps, LiDAR scanning, search-and-rescue missions, and more.

“We are helping to build a generation of responsible drone pilots who can assist our local workforce, educational institutions, and research projects with an array of aerial services.”

– Dr. Romina King

Through the NASA Guam Space Grant Professional Internship, Drone Corps members work under the mentorship of local drone industry experts to expand their skillset into more specialized areas, such as construction or marketing. As of November 2022, nine Drone Corps members have interned with private drone companies, including 2cofly, Bella Wings Aviation, and Tech Center Guam.

A key mission of the Drone Corps program is safety: to avoid drone accidents, minimize potential conflicts, and increase awareness of drone technology through responsible use. To fulfill this mission, members have participated in outreach activities, educating different industries how to responsibly utilize drones in their work. Several Drone Corps members have taken on the mantle of instructor, leading courses for the Guam Fire Department and Guam Police Department about drone certification.

As drone technology continues to advance and become increasingly accessible, the UOG Drone Corps aims to continue providing a robust and engaging experience that nurtures students' interest in drone flying. Moving forward, the program hopes to expand both its membership and fields of specialty to include crop monitoring, drone assembly, aerial cinematography, and even first-person-view racing.

Learn more at url.uog.edu/drone-corps or email dronecorps@triton.uog.edu.



UOG student Jin Hee Choe holds a drone during a UOG Drone Corps practicum at the Guam International Raceway in Yigo.
Photo by Keanno Fausto

Project: UOG Drone Corps

Researchers: Romina King | roking@triton.uog.edu
Leslie Aquino | aquinol8112@triton.uog.edu

Timeframe: April 2021 - Present

Funded by: NASA Guam Space Grant and NASA Guam EPSCoR grant from the National Aeronautics & Space Administration



A magnified cross section of *Taeniophyllum mariannense* root showing mycorrhizal pelotons where it attaches to the host tree (bottom portion).



Michael Fernandez extracts the DNA of mycorrhizal fungi inhabiting a native epiphytic orchid's roots for genetic identification and phylogenetic analyses.



Taeniophyllum mariannense, the most common of Guam's native epiphytic orchids, grows on the invasive, non-native *Vitex parviflora*. This orchid was observed growing on 25 different native and invasive tree species, likening it to a symbiotic generalist. Photo by Michael Fernandez

TWO ECOLOGICAL RELATIONSHIPS FOUND TO BE IMPORTANT FOR NATIVE ORCHID SURVIVAL

Many native orchid species have been declining because of the loss of native forests. Epiphytic orchids are reliant on host trees as a habitat in the forest, and all orchids are dependent on mycorrhizae – a symbiotic fungi – for basic nutrient uptake. These two factors may, in fact, be shaping the distribution and survival of epiphytic orchids.

Though the host tree species and mycorrhizal relationships of orchids have been studied elsewhere, such basic knowledge in orchid ecology remains limited in remote tropical Pacific Islands, including Guam, where native epiphytic orchids are ecologically and culturally important plants.

Under the mentorship of Dr. Mari Marutani, integrative biology major Michael Fernandez investigated the distribution of native epiphytic orchids in Guam, their host tree species, and the mycorrhizae associated with them. He documented the host tree species of 185 individual orchids at 10 different sites. The sites encompassed the island's three most prevalent vegetation types: limestone forest, volcanic ravine forest, and urban/planted vegetation. He also collected root samples and extracted mycorrhizal DNA for genetic identification and phylogenetic comparison to other mycorrhizae documented around the world.

The findings revealed that host tree and mycorrhizal preference of a native epiphytic orchid may be related to how abundant it is in nature. The leafless worm orchid, *Taeniophyllum mariannense*, was the most common orchid found. This orchid was observed growing on 25 different native and invasive tree species across all three habitat types and with 38 mycorrhizal and non-mycorrhizal endophytic fungal groups – likening it to a symbiotic generalist.

Other, less common orchids, such as *Luisa teretifolia* and *Coelogyne guamensis* and the rare and threatened *Bulbophyllum guamense* and *Dendrobium guamense*, were observed growing mostly on native host

“Unraveling the intertwined relationship between host tree, mycorrhizae, and orchid is essential in understanding orchid ecology and ultimately their conservation.”

– Michael Fernandez

trees in native forests and with specific mycorrhizal fungi groups – likening them to symbiotic specialists. An exception was *Tuberolabium guamense*, which was found on the invasive tree *Vitex parviflora*.

This project will contribute important findings for the conservation and reforestation of island forest systems in Guam, which are facing numerous threats, including rapid urbanization and the spread of invasive species. Knowledge of these ecological interrelationships among host trees and symbiotic mycorrhizal fungi in orchid distribution is essential for the conservation of especially rare or threatened orchids endemic to Pacific Islands. Conservation efforts are already being undertaken in the micropropagation and outplanting of some of Guam's threatened orchids, and this new knowledge can further bolster these efforts.

Future studies should address 1) outplanting the orchids on preferred host trees to improve survival and growth and 2) using mycorrhizal inoculation to promote germination and hardening of orchid seedlings.

Project: “Interrelationship of forest trees, native orchids, and mycorrhiza in Guam”

Researchers: Mari Marutani | marutanim@triton.uog.edu
Michael Fernandez | fernandezm11781@triton.uog.edu

Timeframe: October 2018 – September 2022

Funded by: McIntire Stennis Capacity Grant, National Institute of Food & Agriculture, U.S. Department of Agriculture

SEED PRODUCTION SYSTEM EXPANDS PUBLIC ACCESS TO HEIRLOOM VEGETABLES

Heirloom eggplant (*Solanum melongena*) and chili peppers (*Capsicum sp.*) have been cultivated locally over many decades. Having grown well in Guam's climate for many years and having desirable qualities, the local varieties of these plants would be ideal for farmers, gardeners, and consumers, but they are only grown on a small number of self-sustaining family farms and the seeds have not been available to the broader public.

Making seeds and other planting materials of heirloom vegetables readily available to all could improve island sustainability and food security. To promote the production of locally unique and successful crops for island agriculture, Dr. Mari Marutani, professor of horticulture, and research associates Chieriel Desamito and Shaylin

Salas have started to develop a public seed distribution system of selectively bred "local" lines with the collaboration with John C. Borja at the Guam Department of Agriculture's Agriculture Development Services Division.

The researchers collected more than 50 local accessions of hot pepper and eight accessions of eggplant from local farmers, vendors, and community members from 2020 to 2022. They grew the accessions at the University of Guam Horticulture Laboratory and the agricultural experiment station in Yigo and characterized them according



A packet of Guafi hot pepper seeds produced at the UOG Horticulture Lab.

“For island sustainability and food security, seeds and other planting materials should be readily available to farmers and home gardeners.”

– Dr. Mari Marutani

to their field performance. After conducting field trials, one eggplant and one hot pepper variety with the most desirable traits were selected to be released through the Guam Department of Agriculture as local cultivars.

Residents may now obtain seeds of the open-pollinated teardrop purple "Ideal" eggplant and open-pollinated "Guafi" – which means "fire" in Guam's native CHamoru language – hot peppers at the Department of Agriculture for \$10 for a 100-count seed flat or \$1.50 for six plants.

A fact sheet on the Ideal eggplant is available for download at www.uog.edu/wptrc/technical-reports, and a fact sheet on the Guafi pepper will be available there soon.

Project: "Improvement of seed distribution system of heirloom eggplants and chili peppers for sustainable agriculture of Guam"

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Timeframe: September 2018 - September 2022

Funded by: Agricultural Marketing Service, U.S. Department of Agriculture (awarded to the Guam Department of Agriculture, sub-awarded to the University of Guam)



Research Associate Chieriel Desamito shows some eggplants growing at the UOG Horticulture Laboratory. Seeds will be collected from eggplant accessions to be studied in future research at the University of Guam. *Photo by Jackie Hanson*



The *Bulbophyllum raulersoniae* orchid, known only to be in Guam and Rota, is considered a diminutive epiphyte, meaning it is smaller and grows on host plants.

BULBOPHYLLUM RAULERSONIAE: THE NEWEST MARIANAS ORCHID SPECIES

An estimated 86% of land-dwelling species on Earth are yet to be described, according to a study in PLOS Biology, but following a formal description published in Orchideen Journal by Western Pacific Tropical Research Center researchers, an orchid endemic to Guam and Rota is no longer one of them.

The orchid, which has been known to local botanists for decades but never formally described, is now known as *Bulbophyllum raulersoniae*. The species is named posthumously in honor of Lynn Raulerson, the longtime curator of the University of Guam Herbarium, who first reported the taxon as unique. The description was authored by Benjamin E. Deloso, '20 Master of Environmental Science alumnus from UOG and now a horticulturist at the Missouri Botanical Garden along with UOG environmental science graduate student Charles A. "CJ" Paulino and noted Australian taxonomist Jim Cootes. Cootes has an orchid named for him, *Bulbophyllum cootesii*, or Cootes' Bulbophyllum, according to the Smithsonian Gardens.

The researchers examined dried and living specimens and determined it was distinct from the other species of *Bulbophyllum* in the Mariana islands. It is considered a "diminutive epiphyte," meaning it is smaller and that it grows on host plants, such as pandanus. The plants produce a solitary flower of about one centimeter in size.

Their paper notes that the orchid is only known to be on the islands of Guam and Rota in limestone forests that are at least 500 feet above sea level. Additionally, its historic geographical range may be greatly reduced today because of habitat loss, with the Lamlam-

"The ecosystem along the Lamlam-Alifan ridge is truly a special place containing some of Guam's most interesting plants and animals."

– Charles Paulino

Alifan ridge in southern Guam being a refugium for the remaining individuals of the species in Guam.

For an organism to receive federal protection, it must be formally described according to the system of taxonomical nomenclature. Because of its limited range and estimated continual population decline, the authors made a recommendation to the International Union of the Conservation of Nature to assess the species as "endangered."

The Mariana Islands are home to 30 reported species of orchids, four of which are considered endemic to the archipelago and seven of which are endemic to Micronesia. *B. raulersoniae* adds to 2,200 known species globally in the *Bulbophyllum* genus.

Project: "A new species of *Bulbophyllum* (Orchidaceae) from the Mariana islands of Guam and Rota"

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Journal: Orchideen Journal

Issue: 2022 - 2nd Quarter

CULTIVATING THE NEXT GENERATION OF GUAM FARMERS

A first-time grant for the University of Guam is helping to support and give hands-on training to individuals in Guam who are just starting out in farming or related endeavors.

Through the Western Pacific Tropical Research Center at the College of Natural & Applied Sciences, UOG received a grant in September 2020 from the Beginning Farmer & Rancher Development Program under the U.S. Department of Agriculture – a program with an approximately 20% application acceptance rate.

The three-year, \$450,000 grant aligns with the University's land-grant mission of delivering practical knowledge to the community-at-large. Through various partnerships, the program has funded community agriculture workshops, internships, and other activities and provided beginning farmers with supplies and technical assistance.

The USDA program came about in response to an increasing number of people across the nation entering agricultural production for the first time – whether in traditional farming, aquaculture, beekeeping, or production of other agricultural commodities. The trend into agriculture among Guam residents seems to mirror that in the U.S. mainland, in particular with people who have inherited land or want to follow in their ancestor's footsteps and work the land.

"Guam residents looking to get into agriculture tend to be interested in niche markets, high-value products, and specialty goods, and they care about the environment," said Adrian Ares, interim associate director of research at WPTRC. "They have the enthusiasm and the commitment, but they need financial, legal, and technical assistance."

One of the first activities under the grant was an internal survey, with assistance from the Northern and Southern Guam Soil & Water Conservation Districts, of 110 farmers to get a better idea of their challenges, limitations, and expectations. This informed the specific services the program now provides. The Valley of the Latte, the Guam Beekeeping Association, and Farm to Table Guam Corp. are also partners in the project.

The program has supported a total of 13 community workshops on the topics of breadfruit, mango, and banana cultivation, raising baby chicks, and beekeeping and beehive assembly as well as soil testing, composting, plant propagation methods, and drip irrigation. Interest and participation in the workshops have been strong, with more than 200 individual participants.

The beekeeping workshops, in partnership with the Guam Beekeepers Association, have produced 18 beginner beekeepers, who are now managing their own hives with regular check-ins from the GBA and UOG. Honey is in large demand nationwide and is just one product beekeepers can harvest and sell – others being creamed honey, mead, infused honey, and beeswax.

The grant has also allowed 10 individuals to gain hands-on experience through six-month internships. The internships are intended for anyone of any age with an interest in farming and learning practical skills. The interns were placed at Triton Farm, the UOG Guam Aquaculture Training & Development Center, Valley of the Latte, and Farm to Table to gain experience in how to plant, weed, irrigate, and fertilize crops; manage poultry, fish, or shrimp; maintain aquaponics systems; identify and manage pests; create and utilize compost; and harvest, package, and market produce.

The grant has also funded supplies for beginner farmers, including compost, manure, seedlings, canopies and poles, as well as two screenhouses, one of which will be specifically used by farmers who are veterans.

Program: Beginning Farmer & Rancher Development Program
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Timeframe: 2020-2023
Funded by: U.S. Department of Agriculture



Beginner beekeeper Mike Aguon shows the honeycomb from his hive.



A jumbo Pacific white shrimp at the UOG Guam Aquaculture Development & Training Center.

POLY CULTURE POSSIBILITIES: CAN MARINE SHRIMP AND FRESHWATER PRAWNS COHABITATE?

Food security is a main concern for small islands. For Guam, with its stable temperature and availability of clean fresh and saltwater, one particularly viable method of food production is aquaculture. While aquaculture production is building momentum in Guam, land space and costly resources are limiting factors to producing greater quantities and more diversity of products.

The concept of polyculture – or the simultaneous production of two valuable species, such as a shrimp and a prawn – would allow Guam to produce more types of seafood for the public market while also providing economic benefits to farmers, who can produce more products with the same amount of water, land, labor, and feed.

Freshwater prawns (*Macrobrachium rosenbergii*) are commonly farmed in freshwater tanks and ponds, while marine shrimp (*Penaeus vannamei*) utilize full seawater. Given the shortage of information on co-culturing of marine shrimps and freshwater prawns in low-salinity water, UOG graduate student Steve Young-Uhk and his adviser, Dr. Hui Gong Jiang, designed a system to test if coculturing was viable. Their study assessed the shrimp-to-prawn ratio that would yield the highest growth and survival rates when prawns and shrimp are raised at the highest recommended density of 225 individuals per square meter.

The study was conducted over a period of 63 days at the Guam Aquaculture Development & Training Center under UOG’s Western Pacific Tropical Research Center with support from CoreSeed Aquaculture (Guam) Corp. Culture containers were stocked with 36 juveniles each at ratios of 5:1, 8:1, and 11:1 shrimp to prawns. The containers had a continuous flow of low-saline groundwater and water quality was monitored weekly.

Among the treatments, the stocking ratios of 8:1 and 5:1 had the highest survival of shrimps at 32.8% and 24.4% and prawns at 70.8% and

“In small-island environments, the concept of polyculture has potential applications for food and agriculture production, where land and resources are limited.”

– Steven Young-Uhk

52.8%, respectively. While the study did not find a higher survival and growth performance than shrimp monoculture – which has a survival rate of 75.9% and twice the yield – the project demonstrated successful acclimation of marine shrimps from full seawater to low-salinity water at high density over two months. This indicates that this marine shrimp species (*P. vannamei*) could be cultured using a wide range of water salinities.

Additionally, the tank culture system demonstrated feasibility of farming marine shrimps intensively and having a high output with an efficient use of space. The study also proved a degree of compatibility in co-culturing the two species. This could provide a basis for further trials into best stocking densities and growing conditions.

Project: “Effect of stocking ratios on the survival and growth of *Penaeus vannamei* and *Macrobrachium rosenbergii* in intensive co-culture tank system”

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Timeframe: January 2022 - December 2024

Funded By: Hatch Research Fund, National Institute of Food & Agriculture, U.S. Department of Agriculture

WPTRC ORCHARD READY TO FACILITATE MANGO RESEARCH

Despite the popularity of mango among Guam consumers and interest among local farmers to grow more of it, the last agricultural census for Guam reported mango production from only 700 of the more than 200,000 mango trees on island. Moreover, fruit yields are often low and erratic due to a lack of varieties on island that produce well in Guam's high rainfall and constant heat.

Another challenge is the type of mango seed most commonly found throughout Guam. This type of seed – called monoembryonic – does not necessarily produce the same fruit quality or have the same appearance as its mother tree. Polyembryonic seeds, which are less common in Guam, produce seedlings that are genetically identical to the mother tree, making them more desirable for propagation.

A 30-year-old mango tree orchard at the University of Guam's Ija Research & Education Center has 29 mango varieties from around the world – eight of which are polyembryonic – including some of the most commercially successful varieties in the world, such as Haden and Carabao. The orchard, recently trimmed to an accessible height and mapped in preparation for researchers to use, and a new guidebook that provides data on the orchard's varieties are setting the stage to revitalize mango cultivation in Guam.

The guidebook includes data for each variety of mango found at the station, including size and weight, seed type, sugar content, fibrousness, presence of seed weevil, and presence of flower damage. It also features the first aerial map of the orchard – a photo taken by drone by research assistant Kaya Taitano with each tree labelled according to its mango variety.

The Western Pacific Tropical Research Center will be making use of this data as researchers look to uncover new knowledge about mango varieties that are best adapted to Guam's conditions and are more resistant to fungal diseases, principally anthracnose, and pests, like seed weevils and the mango shoot looper. Their findings can

Mango yields in Guam are often low and erratic due to a lack of varieties on island that produce well in high rainfall and constant heat.

then be used to determine the trees that would be best sources of propagative materials for farmers and nurserymen.

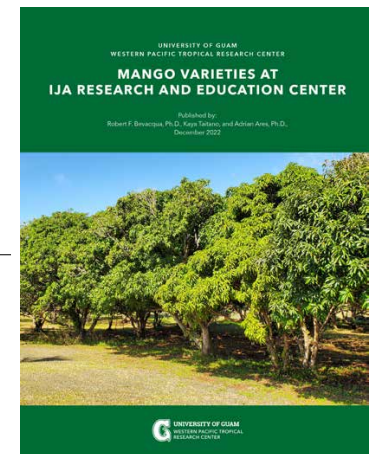
As imported mango materials commonly come with pests and diseases, they are on the Guam Department of Agriculture Biosecurity Division's radar for needing strict inspection, so the Ija orchard plays a particularly valuable role as a local source of propagative material. This includes polyembryonic seeds – for propagating by seed and for the production of rootstock – as well as budwood for grafting.

Grafting is another method of propagation that ensures the tree will bear the desired variety of mango, regardless of seed type. Anthony Yatar, a local farmer who is experienced in tree grafting, is assisting WPTRC in the first propagations from the orchard by grafting. His work is the start of getting more desirable varieties of mango growing throughout island.

Completed in December 2022, the "Mango Varieties at Ija Research & Education Center" booklet, authored by Robert Bevacqua, Kaya Taitano, and Adrian Ares, is available for download at www.uog.edu/wptrc/technical-reports.

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MANGO VARIETIES AT IJA RESEARCH & EDUCATION CENTER



BEVERLY



BOMBAY



BRAHM KAI MEU



CARABAO



CARRIE



COGSHALL



DOT



DUNCAN



EAST INDIAN



EDWARD



FAIRCHILD



GREEN KASTURI



HADEN



HATCHER



JAKARTA



KEITT



KHUN SEE



MANALAGI



NAM DOC MAI



OKRONG TONG



PALMER



SIMMONS



TOMMY ATKINS



VAN DYKE



ZILL



Ironwood is considered an integral member of the natural coastal landscape of Guam and the Northern Marianas, where it has likely grown for thousands of years.
Photos by Luke Fernandez

A survey by University of Guam researchers and supported by local forestry and agriculture professionals in 2022 has confirmed the disease commonly known as bacterial wilt and its pathogen are well-entrenched in ironwood trees in Micronesia and not likely to have originated from Guam.



An ironwood tree in Mangilao, Guam, shows signs of decline with its thinning foliage and progressive dieback of branches.

IRONWOOD TREES FROM AROUND THE WORLD ARE GIVING GUAM'S TREES A BRIGHTER FUTURE

Lush, towering 100-year-old-plus ironwood trees (*Casuarina equisetifolia*) were once common in Guam's landscape, but in 2002, trees of all ages began showing signs of decline. By 2008, many trees had died and an estimated 51% of the trees on the island were symptomatic. This condition, which continues today but at a slower rate, is referred to as ironwood tree decline, or IWTD.

Two pathogens are primarily responsible for IWTD: a bacterium that causes trees to lose their foliage (*Ralstonia solanacearum*) and a fungus that rots the trees' roots and trunks (*Ganoderma australe*). The percentage of cross-sectional area with bacterial wetwood has also been linked to IWTD.

Guam's ironwood trees – indigenous to Southeast Asia, Malaysia, Northern Australia, Oceania, and possibly Guam and the Northern Mariana Islands – are considered an integral member of Guam's natural landscape. They are propagated for windbreaks, erosion control, and urban landscaping.

After seeking the assistance of researchers from Australia, China, Guam, Hawaii, India, Louisiana, and the Northern Mariana Islands, UOG plant pathologist Robert Schlub decided that the impact of IWTD could be reduced by:

- 1) the natural incorporation of new genes into trees;
- 2) the identification of a non-destructive sampling method for estimating the percentage of wetwood;
- 3) determining the origin of Guam's *R. solanacearum* phylotype; and
- 4) conducting awareness programs.

This project resulted in the collection and planting of seeds from 10 mother trees on Guam. The origins of nine of the trees were Malaysia, Papua New Guinea, India, Kenya, Vietnam, Australia, China, Egypt, and Sri Lanka. The 10th source was a native Guam tree. More than 800 seedlings were either planted at the WPTRC experiment stations or given to people who showed an interest in planting ironwood trees, including golf course superintendents, farmers, students, faculty, and environmental professionals.

The conductivity of tree drill shavings was found to be the best variable for predicting the percentage of wetwood within a given tree. The wetwood percentage is useful in understanding the relationship between tree health and the colonization of tissue by wetwood bacteria.

In 2020, researchers at the University of Hawaii determined that Guam had two types of *Ralstonia* bacteria. *R. pseudosolanacearum*, phylotype I (of Asian and African origin), accounts for 95% of Guam's *Ralstonia*-positive trees, and *R. solanacearum*, phylotype II (of American origin), accounts for the remaining 5%. Based on this information, Guam would be advised to obtain resistant varieties from China for testing in Guam.

To inform and bring awareness to the public and scientific community about IWTD, the project investigator attended the 6th International Casuarina Workshop in Krabi, Thailand, and wrote an article for the published proceedings. In addition, the University of Guam conducted one workshop and two training events, which were attended by farmers, property owners, home gardeners, professionals, and students.

Schlub believes *R. solanacearum*, and not *Ganoderma*, is the primary agent impacting the health of ironwood trees in the region and will likely continue to do so into the foreseeable future. To reduce disease, the UOG team recommends reducing damage to trees from lawnmowers and weed trimmers, disinfecting pruning tools, removing trees in severe decline, and replanting with off-island cultivars if possible.

Project: "Strengthening ironwood tree populations on Guam through research and genetic diversification"

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Timeframe: 2018–2022

Funded by: McIntire Stennis Capacity Grant, National Institute of Food & Agriculture, U.S. Department of Agriculture

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