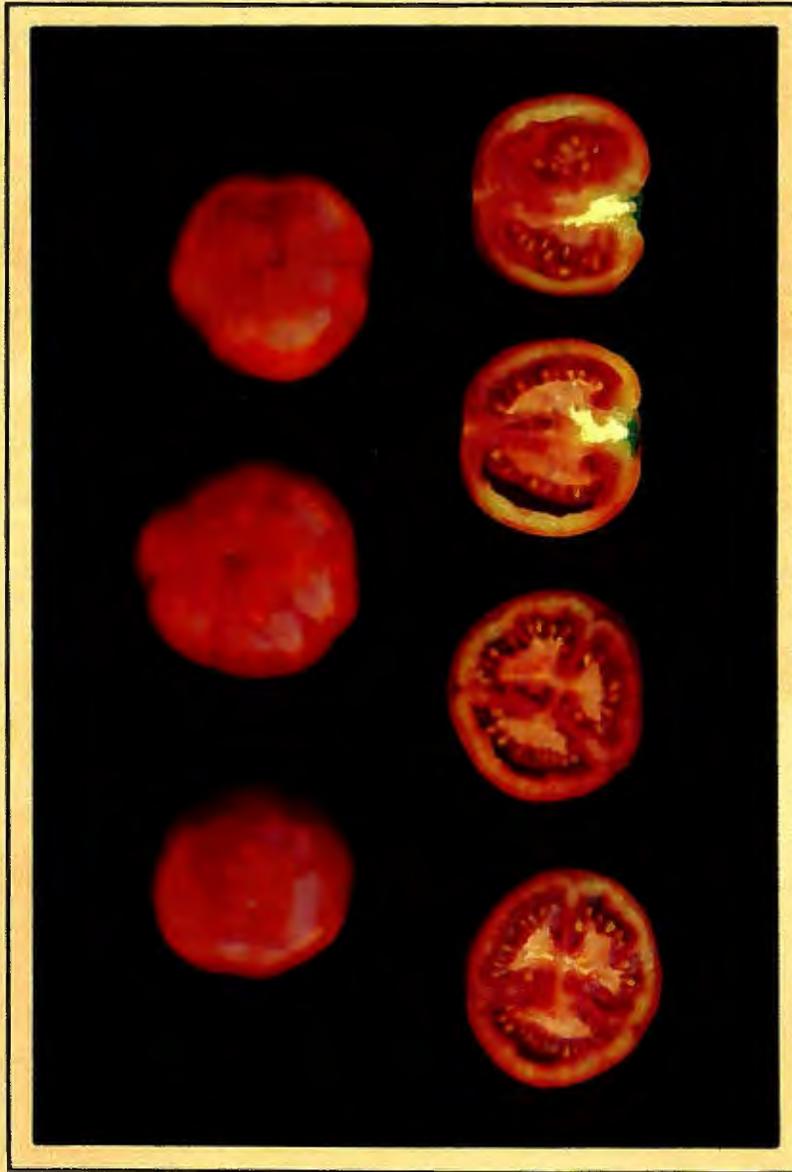


# AGRICULTURAL EXPERIMENT STATION

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**1991 ANNUAL REPORT**  
**College of Agriculture & Life Sciences**  
**University of Guam**

In 1991, two horticulturists were recruited to conduct research on vegetable and fruit crops. Having experimental farms at four different locations in Guam facilitated carrying out the field experiments. Plans have been made to set up automated weather stations in the experimental farms. Major research activities were focused on alley cropping, fertilization, automated irrigation system, varietal trials of vegetables, stress physiology of fruit crops, turf management and orchid production, crop protection, local feeds for chicken, and marketing.

Collaborative research programs with regional and international institutes were continued. A monthly workshop for science teachers was organized to increase the interaction between school teachers, recruitment of students for agriculture and exposure of research programs to the public.

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*Jose A. Cruz*

A fertilizer experiment was conducted in the Yigo Experiment Station during the dry season designed to observe the combined effects of applied nitrogen and potassium on the yield components of head cabbage grown on the Yigo clay soil. The Yigo soil is classified as clayey, gibbsitic, isohyperthermic Tropepic Entrustox. The initial soil test results indicated pH 7.65 and nutrient levels of 5.39 ppm P, 55 ppm K and 5.98 percent organic matter.

The experimental design was a randomized complete block with split plot arrangement of treatments. All treatments were replicated four times.

Both nitrogen and potassium fertilizers were applied at 0, 60, 120, and 180 Kg ha<sup>-1</sup>. The four nitrogen and four potassium rates were factorially arranged with nitrogen treatments as main plots and potassium treatment as sub-plots. Nitrogen fertilizer was applied as ammonium sulfate and K as potassium sulfate. Phosphorous fertilizer as phosphoric acid was added to all plots. All three fertilizers N, P and K were applied through the irrigation system. The results are being analyzed.

### Alley Cropping

J.L. Demeterio

Alley cropping is the growing of field crops between rows or hedges of trees or shrubs. One objective of this long term study is to evaluate alley cropping using *Leucaena leucocephala* (Lam) de Wit and its effects on the intercropped vegetable. Another objective is to determine the difference in performance of the intercropped vegetable during the dry and rainy seasons on Guam.

The unavailability of *Leucaena* and head cabbage seeds precluded laying out the alley cropping experiment during Guams dry season (January to May). However, enough *Leucaena* seeds were collected (from trees damaged by Typhoon Yuri in December 1991) and seeded in rows 1-meter apart in May 1991. In lieu of head cabbage, we opted to use okra (Clemson spineless) as the vegetable test crop. A split-plot experiment was laid out on a 30 x 36 meter field (Saipan soils - fine, oxidic, isohyperthermic, oxic Paleustalfs) at the Agricultural Experiment Station in Inarajan. The main plots were five nitrogen levels (0, 25, 50, 100 and 200 kgm N/ha using ammonium sulfate applied within the furrow prior to planting). Phosphorous and potassium were blanket applied at 300 kgm P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O/ha. *Leucaena* leaves and green stems were green manured on the companion crop when *Leucaena* tended to shade the companion crop. The sub-plots were alley cropping and open field cropping. Okra seeds were planted between vigorously growing *Leucaena* rows and in the open field plots in late July in time for the onset of Guam's rainy season.

The first twelve days of okra growth was uneventful with only 1.22 cm of rainfall. Water was supplemented with a drip irrigation system. Then the rains came with 52.53, 29.74, 34.29, and 32.49 cm in August, September, October and November respectively. The open field portion of the experiment had stunted and generally smaller plants. The okra growing in between *Leucaena* alleys had more vigorous and taller plants. It was also observed

that weeding was less of a problem in the alley cropping rows.

Okra fruits were harvested every other day during the course of the growing season. Total yield is shown in Table 1. Although the nitrogen additions had no significant effect on yields, a typical nitrogen response was exhibited by the open field cropping. A tremendous difference was noted when comparing total yields of the open field cropping and the alley cropping.

Alley cropping yielded 300% more than the open field cropping. The results indicate that vegetable growing could be possible during the rainy season when plants are grown in between alleys of *Leucaena*. This experiment will be repeated during the dry season using the plots.

**Table 1. Yield of Okra in Tons per Hectare**

Treatment	Open Field	Alley Cropping
0 kgm N/ha	4.166	16.503
25	5.142	16.035
50	5.865	17.273
100	7.225	16.483
200	<u>6.008</u>	<u>18.095</u>
	Mean 5.681*	16.894*

\* Yield difference between cropping systems, highly significant at the 1.0% level

c.v.=14.74%

**Fruits Crops: Drought Stress of Papaya**

*Thomas E. Marler*

Papaya plants are irrigated during the dry season on Guam, however we have no information to determine how papaya plants respond to drought or to develop optimal irrigation management decisions. As a result, container-grown papaya (*Carica papaya* L.) plants were placed under drying cycles to determine responses to drought.

Net photosynthesis began to decline when the medium matric potential fell below about -20 to -30 cb. At a matric potential of -50 cb, net photosynthesis averaged about 20% of the plants that were well-watered. Drought stress of papaya plants reduced dark respiration and the efficiency of using light for photosynthesis. Drought also reduced the level of light at which photosynthesis became saturated.

Papaya plants responded to the drought in several ways. The closing of stomata lead to decreased water loss, and resulted in a constant relative leaf water content throughout the study. Many species respond to drought by adjustment of osmotic potential, thus allowing greater ability to draw water from the drying soil. These papaya plants did not, however, respond to these rapid cycles of drying by osmotic adjustment. Chlorophyll fluorescence characteristics of the papaya leaves indicated that drought stress may cause the plants to be more susceptible to high light damage by the sun.

## Vegetable Crops

M. Marutani

### Improvement of Plant Development and Yield of Solanaceous Crops in Guam.

In October 1991, a Hatch project entitled "Improvement of Plant Development and Yield of Solanaceous Crops in Guam" was initiated. Objectives of the project are:

1. Evaluate recently developed cultivars, hybrids and breeding lines of solanaceous crops obtained from public and private breeders for adaptation to the hot and humid environment of Guam.
2. Evaluate current and new production practices to maximize yield and improve quality of solanaceous crops, particularly emphasizing cultural practices to prolong the production period during the wet season. Examine influence of plant growth regulators on yield and plant development of tomatoes grown under cover.
3. Evaluate available rootstock of tomato and eggplant to produce crops at areas where soil-borne diseases such as bacterial wilt and root knot nematodes are presently prevalent.

For Objective 1, seeds of twenty two cultivars, hybrids, and breeding lines of heat tolerant tomato (*Lycopersicon esculentum*) were obtained from Asian Vegetable Research and Development Center (AVRDC) in Taiwan, University of Hawaii, University of Florida, and commercial seed companies. Currently, seedlings of these plants are being evaluated in the field of Yigo Experimental Farm in soil characterized as clayey, gibbsitic, nonacid, isohyperthermic, Lithic Ustorthents, having pH of around 7.5 during dry season in a randomized complete block design with three replications. Similarly, seeds of 30 accessions of pepper (*Capsicum annum*) were sent from AVRDC for a field evaluation in

Guam. For Objective 3, rootstocks for a grafting experiment of tomato and eggplant were obtained. They are eggplant cultivars 'Akanasu', 'Caravan', 'Meet', and 'Torubamu Vigor', and tomato cultivars 'LS-89', 'BF Okitsu No.101', and 'Healthy'.

### Evaluation of Legumes as Green Manures at Three Different Sites in Guam

A preliminary trial evaluating four leguminous species was conducted in three different locations of the island from October to November, 1991. All four crops, *Crotalaria juncea*, *Vigna radiata*, *V. unguiculata* and *Lablab purpureus* produced the largest amount of biomass in soil of Udic Haplustalfs with pH 7.3 in Radio Barrigada, the central part of Guam. Crops grown in limed soil of Oxidic Haplustalfs with pH 7.4 in Ija of the south gave the second largest amount of biomass. Plants in soil of Oxidic Haplustalfs without liming (pH 5.8) and soil classified as Lithic Ustorthents with pH of 7.6 in Yigo of the north performed very poorly. This study indicated that the plant development of these legumes was apparently affected by soil pH, the composition of nutrient elements and soil structure at each locality. There is a need for the identification of some other species suitable for extreme conditions in Yigo and Ija in future research activities. Also, low input soil amendments and application of phosphorus should be considered to improve the production of biomass and nitrogen fixation.

## **Ornamentals**

*J. McConnell*

### **Orchid Culture/Orchid Fertilization**

Orchid cut flower production has been one of the key research area for the past few years. Crushed limestone aggregate (3/4") was previously found to be a suitable growing medium for growing dendrobiums. Research is now being conducted to determine the optimum level of fertilizer to use. Five levels of fertilizer were applied to plants of *Dendrobium* Jaquelyn Thomas 'Uniwai Supreme'. The orchids were planted in either 2 or six inch pots. This dendrobium is a prolific producer of white and lavender flowers. Water soluble fertilizer (20-20-20) was applied at 2 week intervals.

Plants growing in the 6 inch pots produced twice as many flowers as plants growing in two inch pots. The plants in 6 inch pots also had more growths. The results indicate that it may be useful to fertilize at a higher rate for 1 year to produce more growths and then reduce the fertilizer rate. Further fertilizer studies are being conducted.

### **Seasonal Flowering**

Dendrobiums and vandas have been monitored for flowering behavior to obtain information on how the climate in Guam affects flowering. Various characteristics were measured over time. This included where flowers were harvested and when new growth appears. Along with recording data on the plants behavior, weather data was recorded. By comparing the data it was found that the total amount of light affected flowering in the following months. When the weather is rainy and overcast for several days, flowering is reduced in the following months. Propagating orchids

In addition to research on the culture of orchids, selected orchid cultivars are being propagated by tissue culture. This method of propagation produces thousands of plants from a small piece of tissue from the shoot tip. All of the plants produced by this method will be genetically similar.

### **Turf grass Fertilization**

Turf grass has become a significant crop in Guam. Due to the large acreage of turf grass being planted in Guam, a fertilizer experiment was initiated to compare different forms of nitrogen fertilizer. Seven types of fertilizer, including slow release and water soluble formulations, were applied to hybrid Bermuda grass. Leachate of irrigation water is collected and analyzed for nitrate content. The leachate is monitored to see how much of the fertilizer is used by the grass and how much is lost in leachate. The quality of the grass is also being evaluated with the different fertilizers. The color and rate of growth are among the characteristics being compared. This study will help identify the best fertilizers to use in Guam. The follow-up studies will look at the optimum rate of application to allow a sufficient rate of fertilizer for the grass without allowing it to leach into the ground.

### **Mist Propagation of Cuttings**

Intermittent mist systems are used widely to improve the rooting of softwood, semi-hardwood, hardwood and herbaceous cuttings. These systems produce a fine mist that provides a fine film of water over the cuttings and media. The water film controls water loss from cuttings by reducing both leaf and surrounding air temperature by evaporative cooling and raising the humidity. The mist greatly lessens the damage to leaves by not allowing them to dry for very long. Even 10 minutes on a hot day will kill leaves.

Two of the components of a mist system are a controller and solenoid which control the frequency of misting. Most systems use controllers that are powered by connection to a 120 volt power line. A difficulty in Guam is that power outages disrupt the operation of the control system. A solar powered mist system was developed to allow the continuous operation of the system. The system utilizes a controller with a balanced screen. It is placed in the mist with cuttings. When the water on the screen dries it turns on the solenoid which mists the area.

## **Automation of Micro-irrigation Scheduling**

*Prem Singh*

One of the decisions that vegetable growers must make on a continual basis from planting until final harvest is when to irrigate and how much water to apply. There are three major categories of factors that influence this decision: 1) Crop factors, 2) Soil factors, and 3) Climatic factors. These factors also determine which of the various methods of irrigation scheduling is more suitable under a given set of soil and climatic conditions. An evaluation of these factors and the choice of the automatic micro-irrigation scheduling method was presented in the 1990 annual report. In order to develop and test the operational procedures for this scheduling method experiments were continued during 1991.

Experiments focused on determining the optimum soil moisture tension in the root zone for scheduling irrigation using tensiometers equipped with switching capability. These tensiometers were installed 15 cm deep and 15 cm away from the crop row against a plant hill. The hill consisted of one or two actively growing plants. The crop selected was cucumbers (*Cucumis sativus L.*) variety Fountain. There are a number of cucumber varieties being grown on Guam for a variety of reasons. Attempt was made to choose a more common variety. No single variety was dominantly grown. The crop was grown on Guam clay soil at Inarajan Experiment station. The soil depth in the experimental plot ranged 25-45 cm.

The switching tensiometers were connected to an irrigation controller via solenoid actuated hydraulic valves. The controller was programmed to continually monitor the tensiometers. Tensiometers were set to a value of 5, 10, 25, 45 or 75 Centi-Bar (CB) for the five irrigation treatments that were tested in this experiment. In this set up, the tensiometer switch will turn on whenever the soil moisture near the vicinity of a tensiometer cup reached its preset value. This initiates an irrigation event. When water reaches the tensiometer cup and lowers its value, the switch will turn off and stop the irrigation event. The results of this experiment are presented in table 1. Cucumber yield is unaffected by scheduling irrigation between 5 and 45 CB. The yield is significantly reduced when irrigation is scheduled at 75 CB. However, cucumber yield was depressed at 5 CB during 1990 trial. It is expected that irrigating at 5 CB is likely to result in aeration problems and associated nutrient uptake complications. This experiment will be repeated to ascertain this aspect and to test the repeatability of our results.

**Fertigation versus Manual Fertilizer Application:**

*P. Singh and J. L. Demeterio*

Fertigation, applying fertilizer through micro-irrigation system, saves time and labor. Split fertilizer application has better crop response under many soil and climatic conditions. Split applications reduce amount of fertilizer loss to deep seepage during a rainy season, particularly in shallow soils like those in northern Guam. An experiment was designed to test this concept under shallow soil conditions at Yigo Experiment Station.

The experiment was conducted during the transition from dry to rainy season to evaluate the effect of fertilizer application method and nitrogen levels on yield of Head Cabbage (*Brassica oleracea L.*) variety KK Cross. This experiment was conducted during May through July, 1991. There were: three irrigation treatments (10, 25 and 45 CB irrigation); two fertilizer application methods (Manual application at planting and Split Fertigation), and four nitrogen levels (0, 40, 80 and 120 Kg/ha N). The experimental design was split-split plot design. Irrigation treatments were assigned to main plots, fertilizer application method to sub plots and nitrogen levels to sub-sub plots. The experiment was replicated three times. The crop was transplanted on May 21, 1991 in rows 120 cm apart. Plants were 45 cm apart. Potassium and phosphorous at the rate of 150 Kg/ha were banded before transplanting the seedlings. All nitrogen of Manual Fertigation treatment was also applied at this time. Nitrogen by fertigation was applied in four split applications about two weeks apart. Combination of pesticide application and trap cropping was used to control insects and pests. The crop was harvested on July 29, 1991.

Irrigation was applied uniformly during the seedling establishment stage. Data analysis showed that irrigation levels and fertigation methods were not significantly different. Irrigation levels were not significant because plenty of rainfall occurred after seedling establishment stage. Nitrogen treatment effect was highly significant at 0.01 probability level. Average head weight for 0, 40, 80 and 120 Kg/ha N levels were 0.81, 0.94, 1.02 and 1.04 Kg per plant. It was a bit surprising that no effect was detected due to the fertilizer application methods. Normally it is expected that split fertigation would result in better fertilizer use efficiency. One of the problem with this experiment was that one of the insect could not be controlled effectively for some period of time. This resulted in a large error variance thus reducing the efficiency of the statistical tests. This experiment will be repeated during the dry season.

Table 1. Pan Evaporation, Rainfall, Amount of Irrigation Water Applied in each treatment and cucumber harvested yield per plant.

WEEK	PAN EVAPO	RAIN (cm)	AMOUNT OF WATER APPLIED IN EACH TREATMENT (cm)				
	(cm)		5 CB	10CB	25CB	45CB	75CB
3	7.4	0	1	0.9	0.9	0.8	1
4	4.1	0.2	1.2	1.3	1.3	1.1	1.2
5	4.3	0	0.9	1.3	1.3	0.8	0.9
6	4.6	0.3	1.5	1.6	1.6	1	1.3
7	5.5	1.1	2.3	2.4	2.8	1.9	1.9
8	3.9	2.6	1.5	1.7	1.1	0.9	0.6
9	3.9	1.1	1.6	1.8	1.2	1.1	0.8
10	3.3	0.5	1.8	2.3	2.6	1.5	0.2
11	2.8	2.4	1.4	1.8	1.6	0.6	0.1
TOTAL	39.8	8.2	13.2	15.1	14.4	9.7	8
HARVEST YIELD (Gms/plant)	-	-	1996 <sub>a</sub> ++	1722* <sub>b</sub>	1982 <sub>a</sub>	1965 <sub>a</sub>	1608 <sub>b</sub>

++ Treatment yield followed by the same letter are not statistically different using Duncan's test.

\* This value is spurious and probably due to faulty solenoid valves that prevented watering in some plots where watermeters were not installed.

### Control of Cabbage Insects

R. Muniappan, M. Marutani and Promila Singh

Cruciferous crops on Guam are attacked by diamond back moth, *Plutella xylostella* (L.), imported cabbage webworm, *Hellula undalis*, F., cabbage cluster caterpillar, *Crociodomia pavonana* Zeller, cut worm *Spodoptera litura* (F.), flea hopper, *Halticus tibialis* (Reuter), corn earworm, *Helicoverpa armigera* (Hubner), leaf miner, *Liriomyza* spp., fireant, *Solenopsis geminata* (F.), and garden looper, *Chrysodeixis chalcitens* (Esper) and mustard aphid, *Lipaphis erysimi* (Davis).

*H. undalis* infests the crop throughout the season and especially it becomes a serious pest on young seedlings before and after transplanting in the field. It damages terminal shoots of seedlings resulting in the production of multiple axillary shoots and unmarketable heads. It bores into the midribs of the outer leaves in the older plants and occasionally boring into the head. *P. xylostella* and *C. pavonana* mostly infest the transplanted crop. *P. xylostella* and *L. erysimi* infest during the dry season and *C. pavonana* occurs sporadically on Guam. *S. geminata* is a problem only during the dry season. It damages newly transplanted seedlings. Other pests listed above are polyphagous and opportunistic invaders.

Trap cropping with radish, mustard and Chinese cabbage cv. Tempest in the head cabbage field attracted *H. undalis*, *C. pavonana*, *H. tibialis* and *L. erysimi*.

Trap cropping was found to increase predators such as spiders, lady beetles and muddaber wasps in the field. Other parasites observed in the field were *Telenomus* sp on eggs and *Cotesia variventris* on larvae of *S. litura*. Investigations on standardization of the trap cropping procedures, biological control and chemical control are in progress.

### Biological Control of *Lantana camara*

R. Muniappan, T.S. Lali and M. Marutani

Surveys conducted in Micronesia revealed the absence of lantana in Rota and Kosrae. A legislation has been introduced in the Commonwealth of the Northern Marianas Legislature to ban introduction of lantana into Rota. A similar legislation has been recommended for Kosrae.

Our surveys indicated absence of *Uroplata girardi* in Tinian. Hence, this natural enemy was introduced to Tinian. Similarly, *U. girardi* and *Teleonomia scrupulosa* were introduced to Yap. Surveys were continued on Guam and other Micronesian islands to assess the damage done to lantana by the natural enemies. Seasonal fluctuations and population density were also determined. The population dynamics of natural enemies of lantana on Guam is being studied. A request for permit to introduce *Calcomyza lantanae* from Australia to Guam has been made.

*T. scrupulosa*, *U. girardi* and *Hypena strigata* were the three predominant leaf-damaging insects. Incidence of *T. scrupulosa* activity was high in Mangilao and Dededo sites with considerable foliar damage. *T. scrupulosa* activity combined with warm sunny weather results in severe damage. *U. girardi* the leaf-mining beetle, spread rapidly during rainy days, and caused damage at all sites except Mangilao. Increasing activity of *H. strigata* was an important development noticed at Inarajan and Mangilao. Occasional appearance of *Adoxophyes melia* at the Mangilao site played only a minor role in control lantana.

In the case of flower damage the caterpillars of *Lantanophaga pusillidactyla* and *Epinotia lantana* are the major natural enemies, and they infest more than 50% of the flowers. Seed production is also severely affected by the activity of the pod fly, *Ophiomyia lantane*, which is prevalent on Guam.

**Interaction Between Siam Weed and its Natural Enemy**

*R. Muniappan, J. McConnell and M. Marutani*

Siam weed (*Chromolaena odorata*) in Chamorro known as masiksik is an introduced weed. It occupied pastures, roadsides, and vacant lands in Rota, Tinian, Saipan and Guam in early 1980's. However, introduction and establishment of the natural enemy, *Pareuchaetes pseudoinsulata* in these islands in mid 1980's has effectively suppressed this weed.

Currently this weed is a problem in the Philippines, Indonesia, Southern China, Vietnam, Laos, Cambodia, Malaysia, Thailand, Burma, India, Sri Lanka, Bangladesh, Bhutan, Nigeria, Ghana, Cameroon, Rwanda, Ivory Coast, Benin, Zaire and South Africa.

Based on the successful control of this weed achieved in the Marianas, the natural enemy *P. pseudoinsulata* has been shipped to Yap, Palau, Pohnpei, Kosrae, Thailand and Ghana. It was also shipped to Germany for research purpose. Requests have been received for shipments to Indonesia and Ivory Coast.

Recently it has been determined that this natural enemy has been established in Pohnpei and Yap.

Siam weed no longer is a serious threat on Guam. However, in the current situation of sparse distribution, it exhibits insect induced change. *C. odorata* turns yellow upon feeding of *P. pseudoinsulata*. Yellow leaves are not palatable to larvae of *P. pseudoinsulata*. Chemical analysis of yellow leaves showed eight times higher nitrate nitrogen over the green leaves. First instar larvae of *P. pseudoinsulata* kept on yellow leaves did not feed and eventually died.

In normal conditions, *P. pseudoinsulata* larvae feed on *C. odorata* bushes at night and hide in the ground during the day time. However, when *C. odorata* leaves turn yellow, they remain on the foliage both day and night.

Studies on physical and chemical changes in the leaves during the process of yellowing and the reversion back to green are being studied.

### Fruit Piercing Moths

C.A. Kimmons, T.S. Lali and R. Muniappan

Fruit-piercing moths are responsible for severe damage to ripe fruits on Guam, CNMI, and the FSM. The adult moth has an extremely powerful proboscis, with which it is able to pierce holes through the skins of many fruits, including guava, banana, tangerine, pomegranate and papaya. The moth then moves its proboscis around inside the fruit, sucking out juices. In fruits suffering severe attacks, a dry shell may be all that remains. Even one pierce can cause post-harvest rotting resulting in non-marketable produce. Four species of moths on Guam are known to inflict this type of damage. A number of other species are considered secondary fruit-piercers, and attack fruit which has been damaged sufficiently to allow them to insert their weaker proboscis.

*Othreis fullonia* is the most important of the fruit piercers. The caterpillar of this species feeds only on the foliage of the tree *Erythrina variegata*. Numbers of this insect are kept under control by three species of egg parasites. An U.S. Department of Agriculture permit has been obtained to import a fourth species of parasite from Papua New Guinea via Australia. The first shipment is expected in 1992. We have also completed a test to determine if there is a sexual difference in fruit preference of the adult moth.

*Pericyma cruegeri* is well known on Guam in its larval form, the flame tree looper, which is responsible for severe periodic defoliation of our flame trees. The adult moth has a very strong barbed proboscis, and is quite capable of piercing the toughest fruits. We have recently completed several studies of fruit preferences of *P. cruegeri*, using local bananas, papaya, avocado, kiwi fruit, pomegranate, eggplant, and tangerines. Banana was most preferred, followed by papaya and pomegranate. The moths were able to pierce even through the tough skins of avocados, although this was the least popular of the fruits tested.

*Platyja umminia* and *Ercheia dubia* are frequently captured on fruit trees at night and in traps hung near ripe fruit. There is no information available concerning their host plants. We are currently surveying the different habitats of Guam in our search for the caterpillars. Until we locate them and determine their food plants, we are unable to develop control methods. Areas surveyed include the following: Naval Magazine, Pagat Cave cliff and coastal area, Tanguisson Beach-Shark's Hole cliff and coastal area, Nimitz Hill, Sigua Falls, Ritidian Point cliff top, and coastal areas of Piti.

A survey trip was made to Saipan to determine the status of fruit piercing moths and egg parasites. Populations of *O. fullonia* appeared to be much higher than on Guam. About 10 *E. variegata* trees at the Last Command Post were completely defoliated by the caterpillars. We observed both green and ripe guavas sucked almost dry by the moths. We also observed a large heavily fruiting tangerine tree with hundreds of feeding moths and many dropped and damaged fruits.

In August 1991 field experiments conducted by exposing known numbers of 12 hours, 24 hours, 36 hours old, and 48 hours old *O. fullonia* eggs at 1-m, 3-m and 6-m heights proved that the parasite, *Telenomus* sp., was the most effective one on Guam.

**Effects of fertilizer, weeding and desuckering on yield and pest populations of taro**

*I. Schreiner and D. Nafus*

An experiment to test the effects of fertilizing or not, weeding or not and removing suckers or not in all possible combinations taro yield and taro insect populations was performed. A field was planted 9 July 1990, using the common local variety, 'Sunin agaga'. The field was planted at the Yigo experiment station in Yigo soil. This is thin soil over limestone. Soil depth varied considerably in the field, with numerous rocks present in some plots and few in others. Fertilizer was applied twice, at planting and six weeks after planting, at the rate of 300 lbs/acre of 16-16-16 each time. All plots were weeded on August 1, 1990. Plots receiving the weeded treatment were weeded on August 1, 1990. Plots receiving the weeded treatment were weeded two more times, in September and again in October. Suckers were removed October 4 and November 1. Typhoon Russ hit the island on Dec. 20, 1990 and stripped most of the leaves off the plants. The plants were harvested Jan. 15, 1991.

Fertilizer application increased yield substantially, but the two extra weedings and sucker removal had no significant effect on total marketable yield or on total biomass (minus rootlets) production. Yield for this experiment was very low. All plants showed symptoms of iron deficiency. In some of the plots, particularly in two plots where many limestone cobbles were visible on the surface, plants became entirely white and eventually died out. This occurred even in fertilized plots in the parts of the field that were most severely affected. In other parts of the field, the plants were green, but with some yellow mottling typical of iron deficiency in taro. Marketable yield ranged from 0-4305 kg/ha in highest yielding plot. Total corn yield ranged from 6-5564 kg/ha. Multiple regression of marketable weight versus various soil minerals showed that only iron content of the soil was close to significantly correlated with yield.

The insect populations were low, in no case approaching what might be expected to be economic injury levels (although these have not been determined for taro insects). Taro hornworm and melon aphids numbers were not affected by the various experimental treatments. There were significantly more taro planthoppers on the fertilized plants, probably because the planthoppers preferred bigger plants. Sucker removal and weediness had no effect on planthopper numbers per plant. Webs of the dryinid parasite of the taro planthopper most abundant on plants with more planthoppers and also on the larger plants. Although most of the insects were severely affected by the typhoon with the consequent loss of leaves, taro planthoppers apparently found shelter between the plant petioles, and were about as abundant immediately after typhoon as they had been in the previous sample.

**Effect of soil insecticides, plastic mulch and adult control on the larval stages of orange pumpkin beetle in cantaloupe**

*I. Schreiner and D. Nafus*

The larvae of the orange pumpkin beetle, *Aulacophora similis*, are serious pests of cantaloupes, feeding on the roots, sometimes to the extent of causing plant death, and also damaging the undersides of melons where the contact the soil, penetrating the rind and allowing rot organisms entry into the fruits. Two experiments were performed to determine possible methods of controlling these larvae in cantaloupes.

In the first experiment, three soil insecticides were tested in combination with black plastic mulch. The insecticides tested were diazinon and carbofuran, which are legal to use on cucurbit fields as well as chlorpyrifos which is not, but is often used against the somewhat similar corn rootworm. Insecticides were applied preplant as required by the label. Numbers of larvae were monitored by soil samples. Cantaloupes, cv. 'Burpee Hybrid' were planted 10 January 1991.

In a sample taken sixty days after planting, the

number of larvae in the carbofuran treated plots was 1/6 to 1/9 of that in the other plots, although statistically the difference was not significant. However, in a sample taken 80 days after planting, the overall number of larvae was very much greater, and there was no difference in the plots treated with carbofuran and the other plots. In contrast to 1990 results from the wet season, in this dry season planting, larvae were significantly more abundant around the plants grown on black plastic mulch than around the plants with no mulch. We believe that this indicates that it is not the plastic mulch by itself that influences the distribution of larvae, but the effect that the plastic has on soil moisture levels. The first experiment terminated with the death of all the plants before the melons were mature due to a combination of severe powdery mildew which occurred despite fungicide treatment and damage to the roots by the large numbers of beetle larvae.

The second experiment was planted April 15, 1991 using a cultivar resistant to powdery mildew, Premier hybrid. The two soil insecticides with no obvious effect were dropped and only carbofuran was tested. The field was split into two separate sites. At one site, adult beetles were treated with insecticide every time the number exceeded 1 per 10 plants. At the other site beetles were not treated. In this experiment larvae were sampled both by taking soil samples, and by turning over melons and counting the number of larvae under them.

Controlling the adult beetles did seem to result in a reduced number of larvae in the field, as there were significantly fewer larvae under the melons in the treated field. There were also half as many larvae in the soil sample, but this difference was not significant, due to variance between samples.

Overall, the number of larvae under the melons in the plots mulched with plastic was significantly lower. About half of the fruit were growing on the plastic mulch. The half that were on the soil between the mulched rows, however, had a similar number of larvae under them as did the melons in the

unmulched plots. No difference in the number of larvae could be observed between plots that were treated or not treated with carbofuran.

Unfortunately, the rainy season began two weeks before the melons were ready to harvest, and southern blight wiped out much of the yield. However, it was clear that the number of larvae observed even in the treated field was damaging. For cantaloupes, an action threshold of 1 adult beetle per 10 plants, checked once a week, was too high, and significant damage from the larvae resulted. Soil insecticides applied preplant were ineffective in protecting the melons as harvest time approached, though carbofuran may have reduced beetle larval populations early in the season. Plastic mulch was not effective in reducing beetle larvae populations in the field, but did provide an effective barrier between the larvae in the soil and the melons.

#### **Influence of various types of mulch on insect pests of cucumbers**

*D. Nafus and I. Schreiner*

Mulches of different colors are known to affect the response of aphids and certain other small insects to plants. Less is known about how they may affect some of the other pests of cucumbers. An experiment that had been performed in 1990 was repeated in 1991. Three types of mulch, black plastic, silver plastic and cardboard, were compared with bare ground on insects feeding on trellised cucumbers. The cucumbers, cv. Sweet Slice, were planted in Barrigada on Jan 4, 1991. Adult orange pumpkin beetles, and melon worms were sampled on several occasions throughout the season. Orange pumpkin beetle larvae were sampled once by taking a soil sample around the cucumber plant roots. Cucumbers were harvested and weighed.

As in the previous experiment, beetle larvae were most abundant under the black and silver plastic mulches, and less abundant under cardboard mulch and bare soil. The difference was not statistically significant in this test, however. Adult beetle num-

bers were also not significantly affected by the type of mulch the plant was growing on. Melonworms were most abundant on plants grown on black plastic and least abundant on plants on bare ground. This corresponds to earlier trials where melonworms were also found to be more common on mulched plants.

The yield of the cucumber plants was about twice as high for plants grown on silver plastic as for ones grown on bare ground. Black plastic and cardboard were intermediate. The percentage of cucumbers that were scarred or damaged in some way was also lowest for those cucumbers grown on silver mulch. The benefits of growing cucumbers on plastic mulch greatly outweighed the small increase in leaf loss caused by the increased melonworm population.

#### Effects of biological control on nontarget organisms

##### *D. Nafus*

Since 1945, five of Guam's 20 species of butterflies have become extremely rare or extinct. Probable extinctions include the endemic butterflies, *Euploea eleutho* (Danaiidae) and *Vagrans egistina* (Nymphalidae) and the widespread species *Appias paulina* and *Papilio xuthus* (Papilionidae).

Recently, Howarth has criticized the safety of biological control, citing numerous possible species extinctions. Since 1911, 27 biocontrol agents were released on Guam to control seven lepidopterous pests including one butterfly and one skipper. To see if movements of biological control agents to nontarget butterflies was a possible problem, I monitored mortality factors affecting juvenile stages of the nymphalid butterflies *Hypolimnys anomala* and *H. bolina*.

Both species were attacked by the same species of native, accidentally introduced, or deliberately-introduced parasitoids and predators. Parasitoids killed 2.4% of the eggs of *H. anomala*, and ants removed about 25%. *H. bolina* had 40% of its eggs

parasitized and 35% eaten by ants. One species introduced for biological control, *Trichogramma chilonis*, was found parasitizing the eggs of both species, but it caused little mortality. Most parasitization was by the native species *Telenomus* sp. and *Ooencyrtus* sp.

Most larval mortality could not be determined. No larval parasites were reared for either species. *H. anomala* suffered heavy mortality from a disease, probably a virus. Both species were attacked by ants and two exotic, self-introduced predators, *Hierodula patellifera* (Mantidae) and *Eocanthecona furcellata* (Pentatomidae). *H. patellifera* and *E. furcellata* killed less than 3% of larvae. The toad *Bufo marinus*, which had been introduced as a biological control agent in 1937, ate a few larvae of *H. anomala*.

The major pupal parasite was *Brachymeria lasus* (Walker), a deliberate biological control introduction. *B. lasus* parasitized 19% of the pupae of *H. bolina* and 2.9% of *H. anomala*. Ants attacked a minimum of 17% of *H. anomala* pupae and 7% of *H. bolina*.

Two deliberately introduced arthropods attacked the nontarget butterflies. One, *T. chilonis*, was uncommon. The other, *B. lasus*, was present mainly during periods of the year when *H. bolina* was abundant. Neither biocontrol agent played a role in the possible extinctions of *A. paulina*, *P. xuthus*, or *E. eleutho*, as these species had already disappeared before the biocontrol agents were introduced. *V. egistina* could have been affected by *B. lasus*. *V. egistina* is still present on Rota, where it has coexisted with *T. chilonis* since the late 1930s.

Ants preyed on juvenile stages of both butterflies, and overall were the most important mortality factors. Ants killed all *H. bolina* eggs and larvae during certain parts of the year. All the ants were self-introduced tramp species, some of which were recent introductions. The role of exotic ants in the extinction of island species cannot be overempha-

sized. Ant predation takes place quickly leaving little evidence, and can be easily overlooked. Without detailed life history data, the role of ants, deliberately introduced biocontrol agents, or accidentally introduced generalists cannot be disentangled.

**Parasitization of leaf-footed bug *Leptoglossus australis* by *Gryon pennsylvanicum***  
*N. Dumaliang, I. Schreiner and D. Nafus*

The leaf-footed bug is relatively rare in Guam but a serious pest in other parts of Micronesia. To determine reasons for rarity on Guam, a preliminary survey of natural enemies was initiated in late 1990. It is expected to continue through 1992. Nymphs and adults were collected in the field and held or reared to determine if parasitoids were present. No parasitoids were found. Since leaf-footed bugs were rare in the field, eggs from laboratory reared bugs were set out to assess parasitization. Newly laid eggs were attached to the sticky side of masking tape. The tape was then coated with finely ground clay to create a non-sticky surface. Strips of tape were pinned to leaves of bittermelon, the most common host of the leaf-footed bug, left for four days, and brought back to the laboratory. Eggs were held until leaf-footed bugs or parasitoids emerged. Studies were done at six sites. The only parasitoid reared was *Gryon pennsylvanicum*. Parasitization rates varied with site and season. At sites where leaf-footed bugs were consistently found (Marine Laboratory, Ipan, and Merizo), parasitization rates averaged 30% or better.

Parasitization rates were high during the late wet season and early dry season. During this period,

vines were in good condition and had many fruit pods. By late April, many vines had dried up and fruit was rare or absent. Populations of the leaf-footed bug declined and reproduction was erratic. Parasitization rates of laboratory eggs by *Gryon* were erratic during this period, fluctuating between 0 and over 50%. At other times of the year, populations were more stable and parasitization rates were consistently near 50%. In areas where bugs were rare or not seen, few or no parasitoids were collected. Disappearance rates of eggs and numbers of dead eggs were similar in all areas. Ants were observed removing eggs and first and second instar nymphs.

**A Study of the diseases of beans on Guam, their importance and control**

*G.C. Wall and C.A. Kimmons*

The two most important diseases of yard-long beans on Guam are powdery mildew and a mosaic disease. The causal agent of the mosaic disease was shown, by serologic methods (ELISA) and host range studies, to be Black-eye Cowpea Mosaic Virus (BICMV), also known as Cowpea Aphidborne Mosaic Virus. We showed that it can be transmitted mechanically, also by the aphid *Aphis craccivora* in a non-persistent fashion, and most importantly by seed. Out of nine accessions tested in the field, one (Manibusan Green) was found to have tolerance to BICMV, consistently producing good yields in spite of high incidence levels. Of the varieties available from seed companies, Takii Red and Burpee Asparagus possessed a good deal of field resistance; their yields were moderate (Figs. 1 & 2). However, the latter produces purple-tipped pods, which may be undesirable commercially. The Known-You white-seeded variety also had good resistance, but its yield over two seasons were not stable; the same was true for the local red-seeded variety. BICMV was shown to reduce production by 43% when compared to healthy plants. It also was shown to affect plant growth, reducing stem diameter and leaf canopy area. Other plants that are also hosts for this virus include other Vignas, Phaseolus, and various other legumes. Wing beans and jicama or yam beans can become infected.

Control recommendations for BICMV include the following: Use of disease-free seed is essential. Additionally, aphid control and avoidance of mechanical transmission are necessary. The local variety 'Manibusan Green' is recommended, as it possesses a high degree of disease tolerance, and produces good yields. Also, the variety 'Takii Red' is recommended for having some field resistance. The variety 'Burpee Asparagus' is recommended for home gardening, but not for commercial production, as it has some field resistance, but produces purple-tipped pods.

No difference in powdery mildew reaction was found when 6 varieties were evaluated in a field experiment. Fungicide tests revealed that Super Six and Kolospray gave higher yields than Bravo, Kocide, and TriBasic, Super Six was superior in reducing powdery mildew severity by keeping disease progress farthest from vine tips. When compared to crude neem oil, neem oil extract from Grace & Co., and Sunspray, Super Six produced highest yields, and resulted in least defoliation from powdery mildew or otherwise.

Control recommendations that can be made for powdery mildew are to use Super Six or Kolospray according to label instructions. More powdery mildew can be expected to occur during the dry season, or when planting in the vicinity of older fields.

**Development and evaluation of effective control techniques for the Papaya Ringspot disease on Guam**

*G.C. Wall, L.S. Yudin, and R.J. Quitugua*

Eleven papaya varieties were planted at Radio Barrigada Experiment Station in April. These included varieties collected locally, ordered from seed companies, and obtained from international institutions. The plot was for observation of these and evaluation of their reaction to natural Papaya Ringspot Virus (PRV) infection. Plants were already bearing fruit when Typhoon Yuri decimated the plot in November. Trunks were cut back and will be allowed to ratoon. In a preliminary test, the local strain of PRV was used to challenge-inoculate papaya seedlings previously inoculated with a mild PRV strain developed in Cornell University, resulting in adequate levels of cross-protection. That is, infection of the seedlings with the mild strain of the virus kept the seedlings from being infected by the severe strain of the virus (the wild strain). Papaya seedlings of cultivar Waimanalo Low-Bearing have been inoculated with the mild strain and will be exposed to our wild PRV strain to test for cross-protection in a larger scale. Control plants received no mild strain inoculation. Two such tests are

planned, one for Inarajan Experiment Station and another one for Yigo.

A papaya grower's field was monitored all through the growing season. All ringspot-infected plants were recorded as the disease progressed. Aphid numbers were also monitored with sticky traps. Data will be analyzed using a new software to study the patterns of how the disease progresses in the field, and to determine the importance of removing infected plants from a production field. Monitoring continues this year.

**Identification of economically important diseases on cucurbit crops on Guam, and development of strategies for their control**

*G.C. Wall*

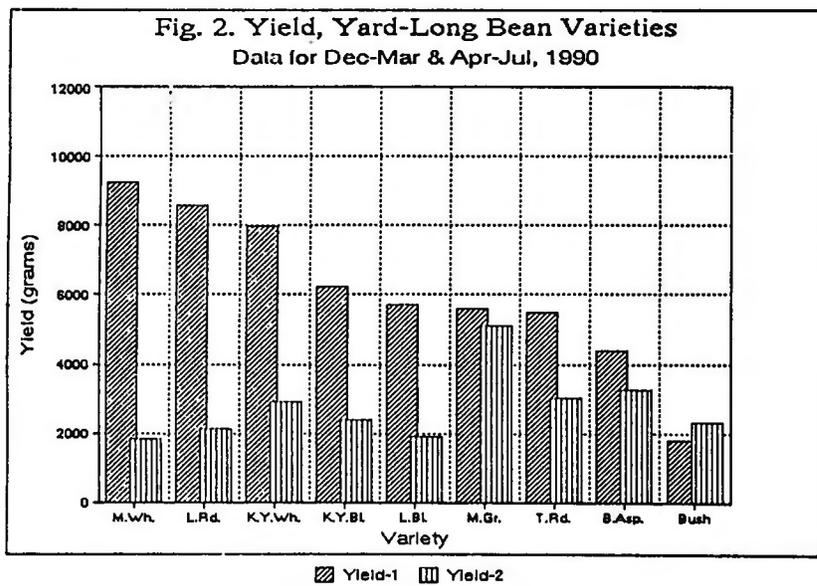
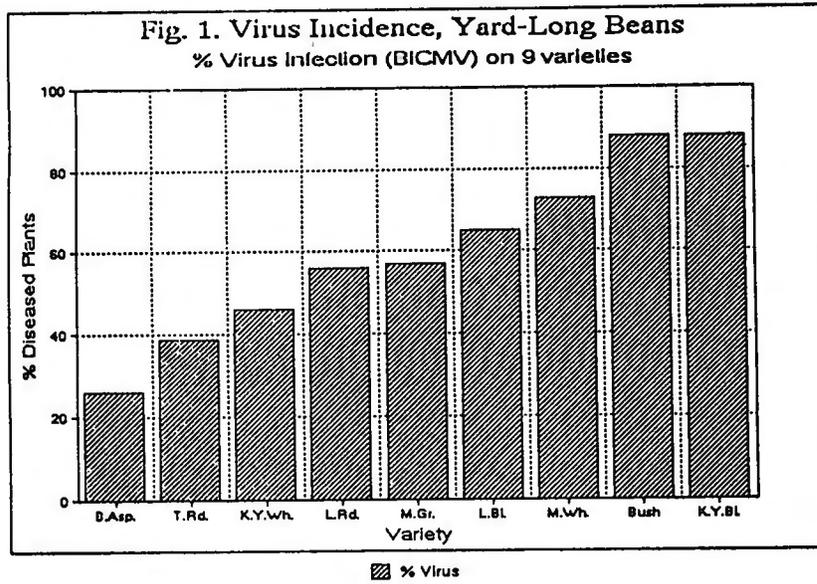
A field trial including 28 varieties of watermelons was carried out at Radio Barrigada Experiment Station during the dry season. Fruits were spray-inoculated with a suspension of *Pseudomonas pseudoalcaligenes* subsp. *citrulli*, the causal agent of fruit blotch disease. The inoculations, which had worked well in the previous rainy season, failed in the dry season; natural occurrence of fruit blotch also is absent in the dry season. Twenty-six of these varieties were then tested at the seedling stage by immersing seed in a bacterial suspension of the above pathogen. As they germinated, their cotyledons would become infected. Disease incidence was recorded for all varieties, and data were subjected to statistical analysis. This technique worked well, and varietal differences in disease reaction were noticed. The experiment is being repeated. A rating of blotch resistance for these 26 watermelon varieties, according to the statistical analysis, is shown in Table 1 and Figure 3.

In collaboration with a separate (ADAP) project, cucurbit crops and weed plants were surveyed island-wide, and leaf tissue blots on nitrocellulose were sent to Hawaii for serology. Of five antisera tested (PRV-W, ZYMV, WMVII, CMV and SqMV), only PRV-W showed positive results; this is unlike previous years, when we have had positive reactions to ZYMV and CMV, indicating a shift in the prevalence of cucurbit viruses. This nitrocellulose technique for assaying plant virus diseases is working out well, and will save time and resources over the ELISA techniques we are currently using.

**Biological suppression of soilborne plant pathogens**

*G.C. Wall*

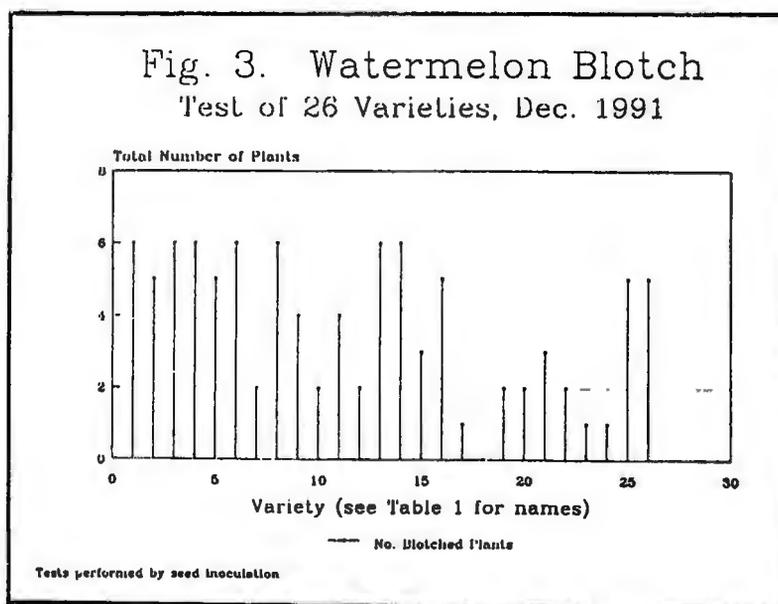
Soil from fields with a history of bacterial wilt of peppers and tomatoes (*Pseudomonas solanacearum*) was collected, along with soil from adjacent fields where bacterial wilt is not a problem. Soil samples were enriched by adding a broth suspension of the above bacterial pathogen isolated from tomato. The liquid suspensions of enriched soil were then filter-sterilized and added to bacterial cultures. Plaques (kill zones) were observed in samples of several uninfested fields, indicating the presence of bacteriophage (bacteria-killing viruses) attacking *P. solanacearum*. Fewer bacteriophage numbers were observed in samples from one infested field. These results indicate that the bacteriophage may be important in keeping the bacterial wilt pathogen under control in the soil. The experiment will be repeated to verify results.



**Table 1. Watermelon Varieties  
Varieties Screened for Blotch, Dec. 1991**

Number	Variety	Reaction
1	Big Top	Susceptible
2	Crimson Sweet	Susceptible
3	Royal Sweet	Susceptible
4	Sky Luck	Susceptible
5	New Dragon	Susceptible
6	Crimson Tide	Susceptible
7	Empire #2	Intermediate
8	Klondike II	Susceptible
9	Sweetmeat II	Susceptible
10	Farmers' Giant	Intermediate
11	Imperial (5005)	Susceptible
12	Top Yield	Intermediate
13	Regency	Susceptible
14	Super Top	Susceptible
15	Sweet Favorite	Intermediate
16	Early Jubilee	Susceptible
17	Calhoun Gray	Resistant
18	Sugarlee	Resistant
19	Summer Festival	Intermediate
20	Imperial (5006)	Intermediate
21	Carmen	Intermediate
22	Glory	Intermediate
23	Paladin	Resistant
24	Au-Producer	Resistant
25	Sugar Baby	Susceptible
26	Sweet Favorite	Susceptible

**Fig. 3. Watermelon Blotch  
Test of 26 Varieties, Dec. 1991**



**Small Landholders on Guam: Production Analysis and Risk-Avoiding Behaviors**

*J.W. Brown*

Agriculture on Guam is a high risk enterprise. The prevalence of insects, diseases, typhoons and droughts in the tropics all contribute to the production risks, while marketing risks are increased by the small size of the consumer population and the geographic isolation of the island from its main alternative sources of supply.

The production and marketing risks have never been quantified for Guam, nor has the basic data which would allow such quantification been collected. Estimates of agricultural production have been made by the University of Guam and the Department of Agriculture on an annual basis since 1965. Monthly prices and production estimates have been made on an irregular basis since 1979. With the exception of Thao Khamoui's Guam Agricultural and Related Statistics published in 1984, this information has never been assembled and synthesized in a single location.

No field survey of the risk of loss from insects, diseases, typhoons or droughts been undertaken for any crop on Guam. Without this information it will be impossible to evaluate any proposal for crop insurance or other schemes to aid the farmers in dealing with their production risks.

During the past year, the historic data on rainfall, typhoon winds, production and prices has been assembled. Khamoui's publication will be updated in the coming year. A farm-level survey of twelve crops on ten farms has been designed, and it has been implemented as of January, 1992. It is expected to take at least 15 months to complete. Once the survey is complete, evaluation of the primary risks to agricultural production and any plans to reduce this risk to the farmers will be on a much firmer scientific basis.

In late 1990 a cost analysis of hydroponic greenhouse production of tomatoes was completed and published in early 1991. The work on typhoon risks was extended to include an evaluation of droughts upon the size and costs of a cistern storage system

for rainwater. Such a system was found not to be economically feasible on Guam where there is access to public water supplies and where there is a significant risk of a severe dry-season drought. On Majuro, where the dry seasons are not normally as pronounced and where the public water supplies are not as readily available a rain water catchment could be a viable method of storage for a hydroponic operation.

**Guam Orchids as Carry-on Gifts: Targeting the Japanese Tourist Market**

*J. W. Brown and J. McConnell*

In 1990 a small grant was obtained through the Department of Agriculture from the USDA Agricultural Marketing Service. This grant is now in its second year. The purpose of this grant is to examine the potential for developing a carry-on market for orchids on Guam.

Tourism is now the largest sector of Guam's economy. Japan is the primary source of Guam's tourists. Currently, one of the locally grown gifts of choice for the Japanese tourists visiting Hawaii or Southeastern Asia is orchids. The Japanese love orchids. However, their preferences and gift-giving patterns do not necessarily coincide with the western aesthetic.

Three problems were identified in the development of a gift market for orchids on Guam. The first problem identified in marketing orchids to the Japanese tourists is simply that we do not know their tastes in cut flowers. A survey instrument intended to measure the Japanese preferences and the relative importance of the attributes of color, shape, form and decoration has been designed and pre-tested. Full scale exit surveys are scheduled to begin in February at the Antonio Won Pat Airport.

The second problem identified was marketing methods. An informal marketing survey was conducted in the major tourists areas of the Pacific basin that are also orchid producing areas. Hawaii, Thailand, Malaysia and Singapore were visited. Particular attention was paid to the retail sale of cut-orchids as carry-on gifts. In Hawaii, this industry was not

developed, although the management of the airport flower concession expressed a definite interest and was in the process of putting-up Japanese language displays. In Thailand and in Singapore there were well developed but small gift orientated markets. In Malaysia, the gift oriented industry was not well developed, primarily because Malaysia is not a departure point for most tourists visiting Southeast Asia.

The third problem identified was phytosanitary issues associated with the transport of orchids. Meetings were held with Japanese and Southeastern Asian plant quarantine officials. The result of these discussions was that there should be no problems in tourists importing small quantities of hand carried cut orchids into Japan, if proper plant sanitation precautions are taken.

**An Economic Analysis of Siganid Culture in Guam, the Commonwealth of the Northern Marianas and the Federated States of Micronesia**

*J. W. Brown and D. Crisostomo*

The rabbitfish are a traditional and highly valued food-fish in the western pacific. Once they metamorphize and move inshore, those species of rabbitfish which inhabit the esturine environment are highly tolerant of environmental stresses such as low salinity, changes in salinity and temperature, and low dissolved oxygen levels. This combination of high value and tolerance to the stresses of a fishpond environment has led to the investigation of various rabbitfish species as likely candidates for mariculture in many locations

The goal of this project is to provide a carefully crafted analysis of the feasibility of culturing rabbitfish on the Western Pacific Islands. In order to meet this goal, three principal objectives will have to be accomplished. The first objective is an analysis of the micronesian markets for rabbitfish. These would include Guam, the Commonwealth of the Northern Marianas, Pohnpei and Yap. The principal emphasis will be placed on the first two markets, because of the current premium prices for seafood in these markets, and because of their proximity to the proposed production areas.

The second objective is a production cost analysis. Production costs will be formulated for nursery production of fry and pond grow-out on Guam and for both cage and pond culture of wild-caught fry in the Federated States of Micronesia. Hatchery production of fry will be necessary on Guam if rabbitfish production is to be feasible here. It will not be politically possible to obtain wild-caught fry for maricultural purposes on Guam due to the popularity of both the fry and adult rabbitfish as traditional food sources. Since rabbitfish fry are not a popular food in the FSM, the feasibility of using wild fry is considered to be much better there than on Guam.

The third objective is an air transportation cost and availability analysis. Currently, air-transport from Guam to Japan is both limited and expensive because of the large quantities of tuna being transhipped by the Japanese long-liners to the sashimi markets in Tokyo, while air-freight is relatively inexpensive from the FSM to Guam and Hawaii.

The results from the marketing, production and transportation studies will allow conclusions to be drawn about the overall feasibility of rabbitfish culture in the western pacific.

*F. G. Abawi*

#### **Ground Coral as a Source of Calcium for Laying Hens**

An experiment was conducted to evaluate suitability of feeding local limestone (ground coral), primarily used on Guam for construction purposes only, as a source of calcium for poultry.

Laboratory analysis indicate that local limestone deposits on Guam contain an average of 33.75 percent calcium which is quite comparable to imported commercial calcium. However, the bio-availability or possible toxicity of local limestone as animal feed has not been determined.

One hundred and twenty eight layers of the commercial "Gold Links" cross were randomly assigned to 4 dietary treatment groups of 32 birds each. A treatment consisted of 8 replications of two consecutive pair caged layers. Treatment consisted of two levels each of commercial and local limestone (3.8%, 4.5%) in a completely random design experiment. Diets were isocaloric and isonitrogenous, providing 16 % crude protein and 2980 kcal/kg of metabolizable energy.

Preliminary results indicate that local limestone at a slightly higher inclusion rate is comparable to imported commercial limestone for laying hens with no apparent signs of toxicity. Statistical significance will be determined upon further data collection and termination of the study.

#### **A Comparison of Alfalfa and Leucaena in the Diet of Laying Hens**

One hundred and twenty eight layers of the commercial "Gold Links" cross were randomly assigned to 4 dietary treatment groups of 32 birds each. A treatment consisted of 8 replications of two consecutive pair caged layers in a completely random design. Treatment consisted of 3% alfalfa meal(AAM), 3% leucaena leaf meal(LLM), 0.1 mg/kg supplemental riboflavin, and control. Diets were isocaloric and isonitrogenous, providing 16 % crude protein and 2980 kcal/kg of metabolizable energy.

Preliminary results indicate that LLM at 3% inclusion without iron salts is comparable to imported AAM. Both LLM and AAM diets resulted in improved egg weight and percent hen-day production compared to the control diet. Statistical significance will be determined upon further data collection and termination of the study.

## **Rabbitfishes**

*S. G. Nelson*

The objective of this project is to develop techniques for the mass production of juvenile siganids, also known as rabbitfishes. These herbivorous fishes are associated with coral reefs and are popular throughout the Pacific Islands. Subsistence or commercial cultivation of rabbitfish has been considered within the U.S.-affiliated Pacific islands, including Guam, Pohnpei, Yap, American Samoa, the Northern Mariana Islands, and Belau. A major constraint to the development of siganid mariculture in this region is the lack of juveniles for stocking ponds. In some areas where siganids are cultured commercially, such as in the Philippines and in Taiwan, fry are collected from the wild and stocked in ponds. However, in Guam the wild stocks of juvenile siganids vary drastically from year to year and are not usually available in the large numbers that would be required for stocking ponds. The commercial production of siganids on Guam is dependent on either importing fry or developing techniques for the production of juveniles in the hatchery. Our work will allow the routine hatchery production of juvenile rabbitfish on Guam and enable the development of commercial siganid aquaculture in Guam and other Pacific Islands.

### **Major Achievements**

We have developed techniques for successfully spawning and collecting the eggs from several species of rabbitfishes, and fertile eggs can be obtained year-round on a routine basis without the use of hormone injections. Although we have had successful spawnings of three species of siganids, we have been most successful in rearing the larvae of one species in particular—*Siganus randalli*. This species is new to science and was only recently described. During the course of our investigation, the species was discovered to be present on Guam, and we have been able to rear the larvae of this species from hatching to juveniles and to rear the juveniles to sexual maturity. We have thus been able to suggest this fish as a new candidate for

aquaculture development on Guam and other Pacific Islands.

We have identified the period of transition from the yolk-sac stage to first feeding as a particularly critical period in rearing larval siganids. This stage has, therefore, been the focus of our most recent work. We now have detailed information on how age and environmental temperature affect the rates of metabolism and development of siganid embryos and larvae. We have also acquired relevant information on the behavior of the larvae and we know how prey density and previous experience affects the incidence of feeding and larval growth. This information will be used to improve our larval rearing procedures so that mortality is reduced and yield is increased.

### **Importance to Users**

The primary users of the information generated from our study are most likely to be hatchery technicians or hatchery managers. The information will allow these personnel to be more efficient and to achieve a higher rate of productivity per unit effort. Eventually commercial farmers will also benefit through the increased availability of siganid juveniles for stocking ponds or other grow-out enclosures. In addition, much of the information will be useful in developing hatchery techniques for production of other marine fishes that, like siganids, have small eggs and larvae.

Publications and technical reports of the results of this research will be available by the summer of this year. In addition, the work done in conjunction with this project will serve as the basis of two MS theses in Biology for students at the University of Guam and as the basis for a PhD dissertation for a doctoral student from the University of Washington, College of Fisheries.

### **Reproductive Biology of Three Commercially Valuable Sea Cucumbers**

*R.H. Richmond*

Work on the reproductive biology of three commercially valuable sea cucumber species, *Actinopyga mauritiana*, *Holothuria* (Micorthele) *nobilis*, and *Thelenota ananas* has continued, with concentrated efforts on fertilization processes and larval development.

During the past year, we had the first success in fertilizing eggs of *T. ananas* and raising larvae from dissected gonads. We had been unable to induce spawning in this species previously, and earlier efforts at excising gonads for in vitro fertilization were unsuccessful. In collaboration with Dr. Chango-Po Chen, Academia Sinica, Taiwan, Republic of China, we were able to use a "maturation inducing substance" (MIS) extracted from the female gonad, for initiating germinal vesicle breakdown (GVBD), which allowed subsequent fertilization of eggs.

As in previous years, we were able to determine maturity and reproductive readiness by measuring gonadal index and oocyte diameter. These values peaked during the months of June and July. Ripe females and males were collected, and maintained in a flow-through seawater table. Gonads were excised from a female, and the eggs were stripped by gently sliding forceps along the tubules. A section of emptied female gonadal tube was then macerated in filtered seawater, and the eggs were soaked in this solution for one hour. Sperm were then added to the solution at a concentration of approximately 10,000 cells per ml. Germinal vesicle breakdown, and subsequent fertilization were observed for the first time in this species. These experiments confirm earlier hypotheses regarding capacitation of eggs by chemical means. The larvae were raised through the doliolaria stage, but nutrition through metamorphosis to the pentacula stage has not been satisfactorily worked out, and we were only able to bring the larvae through the doliolaria stage.

Experiments on development and metamorphosis of *H. nobilis* and *A. mauritiana* larvae have advanced in the past year. We have been able to raise these larvae to the pentacula stage on four different occasions, and have been able to study the effects of several factors on growth, development and metamorphosis.

As determined from previous research, *H. nobilis* has several reproductive peaks each year. Experiments have shown nutrition during the auricularia stage is critical to the development of lipid storage. Auricularia with well-drained lipid deposits will successfully pass through a doliolaria stage to the pentacula stage. It appears that metamorphosing larvae are non-feeding, and that the lipid stores allow them to survive to the next stage. Here lies the difficulty in rearing sea cucumbers to the juvenile and adult stages. Auricularia fed monocultures of *Isochrysis galbana* at densities of 100,000 of 1,000,000 cells per ml increase in size from approximately 300 um to 700 um, but begin to shrink when metamorphosing to the doliolaria stage. This transition from a relatively flattened to a more three-dimensional form explains part of the size reduction. The rest is attributed to metabolic expenditure. As the larvae switch from a planktonic to a benthic existence, their feeding behavior must also change. Experiments with feeding advanced larval stages on benthic diatoms have been unsuccessful so far. This is the area of research focus at present.

Experiments have show temperature strongly affects development rate, which appears to be a key factor balancing growth, development and energetics. Larvae maintained at 24 to 25 degrees Celsius remained in the auricularia stage for four or five weeks, while those maintained at 29 degrees began to settle within seven to nine days. These differences in development rate appear to affect survival at later stages.

Larval density has also been found to affect growth rate and survivorship, with densities of one larva per 50-100 ml showing markedly higher rates of survival than cultures maintained at one larva per 1-10 ml.

The experiments during the past year have provided valuable results and have allowed us to focus on the variables of greatest importance, namely nutrition, temperature and density. Our knowledge of reproductive timing, and our success in being able to raise larvae to the pentacula stage reproducibly, give us confidence that we will be able to raise



#### HATCH PROJECTS

- GU0020      Improving the status of tropical fruit crops through selection, introduction and breeding - T. Marler
- GU0059      Reproductive biology of three sea cucumber species of potential commercial value - R. Richmond
- GU0063      Developing pest management systems for vegetables compatible with *Liriomyza* management - I. Schreiner
- GU0064      Identification of economically important diseases on cucurbit crops on Guam and development of strategies for their control - G. C. Wall
- GU0065      Development of cultural, chemical and biological control methods for pests of cruciferous crops on Guam - R. Muniappan
- GU0067      Nitrogen and potassium interaction on the production of selected vegetables - J.A. Cruz
- GU0068      Use of locally available feedstuffs and potential feed sources on Guam for poultry feeds - F. Abawi
- GU0072      Small landholders of Guam: Production analysis and risk avoiding behaviors - J. Brown
- GU0077      Evaluating alley cropping for a low input sustainable head cabbage production on Guam - J.L. Demeterio
- GU0078      Development of cultural methods for Vandas and Dendrobiums in Guam - J. McConnell
- GU0081      Improvement of plant development and yield of solanaceous crops in Guam - M. Marutani

#### REGIONAL RESEARCH PROJECTS

- GU0015      Establish, improve and evaluate biological control pest management systems of plants - D. Nafus
- GU0022      Water nutrient management of crops under microirrigation - P. Singh
- GU0026      Biological suppression of soilborne plant pathogens - G. Wall



## SECTION 406 PROJECTS

- GUOO57      Biology of biological control of the red coconut scale, *Furcaspis oceanica* Lindinger. - R. Muniappan & M. Marutani
- GUOO58      Environmental factors affecting flowering of Vanda and Dendrobium hybrids in the tropics - J. McConnell
- GUOO61      Biological control of *Lantana camara* in the Mariana Islands - R. Muniappan & M. Marutani
- GUOO62      A study of diseases of beans on Guam, their importance and control - G.C. Wall
- GUOO70      Development of techniques for the mass production of larval rabbitfishes (Siganidae) S.G. Nelson
- GUOO71      Biology and control of *Aulocophora similis* and *Diaphania indica* - D.M. Nafus and I. Schreiner
- GUOO74      Effect of insect induced changes in the Siam weed on three tropic levels - R. Muniappan, J. McConnell, & M. Marutani
- GUOO75      Evaluation of processing indigenous feeds as substitute for imported poultry feed - F.G. Abawi
- GUOO76      Development and evaluation of effective control techniques for the papaya ringspot - G.C. Wall, L.S. Yudin & S.A. Ferreria
- GUOO80      Turf grass fertilization in Guam - J. McConnell & F. Cruz

## SPECIAL GRANTS PROJECT

- GUOO79      Management of turf caterpillars with chlorpyrifos or *Bacillus thuringiensis* - D. Nafus, I. Schreiner & L. Yudin



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